Modulhandbuch
Bachelor in Physik
PO von 2014

SS 2024

Juni 2024

Bachelor Physik

Rheinische Friedrich-Wilhelms-Universität Bonn

(gültig ab WS 2014/2015)

		Pflichtbereich					Wahlpflichtbereich		∑ pro Semester
1. Sem.	Okt Nov Dez Jan Feb März	**physik110: Physik I (Mechanik, Wärmelehre)** 4+2(SWS) Klausur (unbenotet) **7 LP**		**math140: Mathematik I für PhysikerInnen** 6+3(SWS) Klausur (unbenotet) **13 LP**		**physik130: EDV für PhysikerInnen** 3(SWS) schrifliche Ausarbeitung (unbenotet) **4 LP**	**physik120: Einführungs-veranstaltungen anderer Fächer: Astronomie / Chemie / Informatik / Meteorologie / BWL / VWL / Philosophie** Klausur (benotet) **8 LP**		**32 LP**
2. Sem.	Apr Mai Juni Juli Aug Sep	**physik210: Physik II (Elektromagnetismus)** 4+2(SWS) Klausur (unbenotet) **7 LP**	**physik260: Praktikum Mechanik, Wärmelehre** 3(SWS) mündliche Prüfung (benotet) **3 LP**	**math240: Mathematik II für PhysikerInnen** 4+3(SWS) Klausur (benotet) **11 LP**	**physik220: Theoretische Physik I (Mechanik)** 4+3(SWS) Klausur (unbenotet) **9 LP**				**30 LP**
3. Sem.	Okt Nov Dez Jan Feb März	**physik310: Physik III (Optik, Wellenmechanik)** 4+2(SWS) Klausur (unbenotet) **7 LP** **physik470: mündl. Übers.prüf. physik110, -210,-310** (benotet) **3 LP**	**physik360: Praktikum Elektromagnetismus / Optik** 6(SWS); mündliche Prüfung (benotet) **6 LP**	**math340: Mathematik III für PhysikerInnen** 4+3(SWS) Klausur (benotet) **11 LP**	**physik320: Theoretische Physik II (Elektrodynamik)** 4+3(SWS) Klausur (benotet) **9 LP**				**33 LP**
4. Sem.	Apr Mai Juni Juli Aug Sep	**physik410: Physik IV (Atome, Moleküle, Kondensierte Materie)** 4+2(SWS) Klausur (unbenotet) **7 LP**	**physik460: Elektronikpraktikum** 4(SWS) Klausur (benotet) **4 LP**	**physik440: Computerphysik** 3+2(SWS) schriftliche Ausarbeitung (benotet) **6 LP**	**physik420: Theoretische Physik III (Quantenmechanik)** 4+3(SWS) Klausur (benotet) **9 LP**	**physik540: Präsentation:** physik 541: Proseminar Präsentationstechnik Präsentation (benotet); physik542: Seminar zur Bachelorarbeit Präsentation (benotet) **5 LP**			**29 LP**
5. Sem.	Okt Nov Dez Jan Feb März	**physik510: Physik V (Kerne und Teilchen)** 4+2(SWS) Klausur (unbenotet) **7 LP**	**physik560: Praktikum Atome, Moleküle, Kondensierte Materie** 5(SWS) schriftliche Ausarbeitung(benotet) **5 LP**		**physik520: Theoretische Physik IV (Statistische Physik)** 4+3(SWS) Klausur (unbenotet) **9 LP**		**physik450: Vertiefung Physik / Astrophysik** Klausur (benotet) oder **Betriebs-praktikum** schriftliche Ausarbeitung (benotet) **6 LP**		**27 LP**
6. Sem.	Apr Mai Juni Juli Aug Sep	**physik670: mündliche Übersichtprüfung physik410,-510** (benotet) **3 LP**	**physik660: Praktikum Kern- und Teilchenphysik,** 5(SWS) schriftliche Ausarbeitung (benotet) **5 LP**		**physik680: mündliche Übersichtsprüfung physik220,-320, -420,-520** (benotet) **4 LP**			**physik690: Bachelorarbeit** (benotet) **12 LP**	**29 LP**
									180 LP

Inhaltsverzeichnis: B.Sc. in Physik (PO von 2014)

physik110 Physik I (Mechanik, Wärmelehre) ... 1
- physik111 Physik I (Mechanik, Wärmelehre) ... 2

physik120 Einführungsveranstaltungen anderer Fächer ... 3
- Liste der Einführungsveranstaltungen anderer Fächer ... 4
- astro121 Einführung in die Astronomie ... 5
- astro122 Einführung in die extragalaktische Astronomie ... 6
- astro123 Einführung in die Radioastronomie ... 7

physik130 EDV ... 8
- physik131 EDV (4 LP) ... 9
- physik132 EDV (6 LP) ... 10

math140 Mathematik I für Physiker und Physikerinnen ... 11
- math141 Mathematik I (für Physiker und Physikerinnen) ... 12

physik210 Physik II (Elektromagnetismus) ... 13
- physik211 Physik II (Elektromagnetismus) ... 14

physik220 Theoretische Physik I (Mechanik) ... 15
- physik221 Theoretische Physik I (Mechanik) ... 16

math240 Mathematik II für Physiker und Physikerinnen ... 17
- math241 Mathematik II (für Physiker und Physikerinnen) ... 18

physik260 Praktikum Mechanik, Wärmelehre ... 19
- physik261 Praktikum Mechanik, Wärmelehre ... 20

physik310 Physik III (Optik und Wellenmechanik) ... 21
- physik311 Physik III (Optik und Wellenmechanik) ... 22

physik320 Theoretische Physik II (Elektrodynamik) ... 23
- physik321 Theoretische Physik II (Elektrodynamik) ... 24

math340 Mathematik III für Physiker und Physikerinnen ... 25
- math341 Mathematik III (für Physiker und Physikerinnen) ... 26

physik360 Praktikum Elektromagnetismus/Optik ... 27
- physik361 Praktikum Elektromagnetismus ... 28
- physik362 Praktikum Optik, Wellenmechanik ... 29

physik410 Physik IV (Atome, Moleküle, Kondensierte Materie) ... 30
- physik411 Physik IV (Atome, Moleküle, Kondensierte Materie) ... 31

physik420 Theoretische Physik III (Quantenmechanik) ... 32
- physik421 Theoretische Physik III (Quantenmechanik) ... 33

physik440 Computerphysik ... 34
- physik441 Computerphysik ... 35

physik450 Fachgebundenes Wahlpflichtmodul ... 36
- Veranstaltungen aus Master Physik und Master Astrophysik ... 37
- physik458 Projektpraktikum Physik ... 38
- physik459 Betriebspraktikum ... 39

physik460 Elektronikpraktikum ... 40
- physik461 Elektronikpraktikum ... 41

physik470 Mündliche Übersichtsprüfung Experimentalphysik Teil I ... 42
- physik471 Übersichtsprüfung Experimentalphysik Teil I ... 43

physik510 Physik V (Kerne und Teilchen) ... 44
- physik511 Physik V (Kern- und Teilchenphysik) ... 45

physik520 Theoretische Physik IV (Statistische Physik) ... 46
- physik521 Theoretische Physik IV (Statistische Physik) ... 47

physik540 Präsentation ... 48

physik541 Proseminar Präsentationstechnik ... 49
physik542 Seminar zur Bachelorarbeit ... 50
physik560 Praktikum Atome, Moleküle, Kondensierte Materie ... 51
physik561 Praktikum Atome, Moleküle, Kondensierte Materie ... 52
physik660 Praktikum Kerne und Teilchen ... 53
physik661 Praktikum Kern- und Teilchenphysik ... 54
physik670 Mündliche Übersichtsprüfung Experimentalphysik Teil II ... 55
physik671 Übersichtsprüfung Experimentalphysik Teil II ... 56
physik680 Mündliche Übersichtsprüfung Theoretische Physik ... 57
physik681 Übersichtsprüfung Theoretische Physik ... 58
physik690 Bachelorarbeit ... 59
Lehrveranstaltungen Variante "FV" ... 60
physik691 Bachelorarbeit ... 61
zus.Angebote Zusätzliche Angebote ... 63
PhysPrivSec Physics in the Private Sector ... 64

Studiengang: B.Sc. in Physik (PO von 2014)

Modul-Nr.: physik110
Leistungspunkte: 7
Kategorie: Pflicht
vorgesehenes Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik I (Mechanik, Wärmelehre)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik I (Mechanik, Wärmelehre)	physik111	7	Vorl. + Üb.	210 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Grundlagen der Mechanik und Wärmelehre: Phänomene und Messverfahren

Qualifikationsziel:
Einarbeitung in die Mechanik und die Wärmelehre; Erarbeitung der Phänomenologie in Vorbereitung auf den theoretischen Unterbau

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Physik I (Mechanik, Wärmelehre)

Modul-Nr.: physik110

Lehrveranstaltung: Physik I (Mechanik, Wärmelehre)

LV-Nr.: physik111

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Erlernung und Verständnis der Physik der klassischen Mechanik und der Wärmelehre; Erarbeitung der Phänomene, der Experimente und der theoretischen Ansätze zur Beschreibung

Inhalte der LV:
Grundlagen (Größen, Einheiten; Mathematik zur Beschreibung)
Mechanik des Massenpunktes (Kinematik, Dynamik, Relativbewegung, Kreisbewegung, beschleunigte Bezugssysteme, Impuls, Kraft, Drehmoment, Drehimpuls, Arbeit, Energie, Newtonsche Gesetze)
Relativistische Kinematik (Lorentz-Transformationen, Längenkontraktion, Zeitdilatation)
Gravitation und Keplerbewegung
Mechanik des starren Körpers (Statik, Dynamik, Starrer Rotator, freie Achsen, Trägheitsmoment, Kreiselbewegung, Festkörperwellen)
Mechanische Schwingungen
Mechanik deformierbarer Medien (Aggregatzustände, Verformungseigenschaften fester Körper, ruhende Medien, statischer Auftrieb, Oberflächenspannung, bewegte Medien, Wellen und Akustik, dynamischer Auftrieb)
Mechanik der Vielteilchensysteme und Wärmelehre (Gaskinetik, Temperatur, Zustandsgrößen, Hauptsätze der Wärmelehre, Wärmekraftmaschinen, Entropie und Wahrscheinlichkeit, Diffusion, Transportphänomene)

Literaturhinweise:
W. Demtröder; Experimentalphysik 1 (Springer, Heidelberg 5. Aufl. 2008)
D. Meschede; Gerthsen Physik (Springer, Heidelberg 24. Aufl. 2010)
Alonso Finn, Physics, Addison Wesley
Feynman, Vorlesungen über Physik, Bd. I (Oldenbourg)
W. Otten, Repetitorium der Experimentalphysik (Springer Verlag, Heidelberg)
P. Tipler, Physik (Spektrum Akad. Verlag, Heidelberg)

Modul-Nr.: physik120
Leistungspunkte: 8*
Kategorie: Wahlpflicht
vorgesehenes Semester: 1.-4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Einführungsveranstaltungen anderer Fächer

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Veranstaltungen in Astronomie	astro121-123	4+4	s. Katalog	240 Std.	WS+SS
2.	Veranstaltungen in Informatik	siehe Liste	8	s. Liste	240 Std.	WS
3.	Veranstaltungen in Meteorologie	siehe Liste	6+2	s. Liste	240 Std.	WS+SS
4.	Veranstaltungen in Chemie	siehe Liste	8	s. Liste	240 Std.	WS
5.	Veranstaltungen in VWL/BWL	siehe Liste	7,5 **	s. Liste	240 Std.	WS/SS
6.	Veranstaltungen in Philosophie	siehe Liste	8	s. Liste	240 Std.	WS

Teilnahmevoraussetzungen:
gemäß gewähltem Modul

Prüfungsform:
gemäß gewähltem Modul

Inhalt:
Einführende Lehrveranstaltungen aus anderen Fächern ermöglichen es den Studierenden, Grundlagenwissen in anderen wissenschaftlichen Bereichen zu erwerben. Inhalt und Umfang des Moduls werden durch das jeweilige Fach definiert

Qualifikationsziel:
Die Studierenden sollen elementare Grundlagen aus anderen Wissensbereichen erarbeiten, um Verständnis für interdisziplinäre Fragestellungen zu erwerben. Sie sollen mit Sachverstand über die Bereiche berichten können

Studienleistung/Kriterien zur Vergabe von LP:
gemäß gewähltem Modul

Dauer: 1 oder 2 Semester

Max. Teilnehmerzahl:

Gewichtung:
8/163

* Die Leistungspunkte müssen in einem Fach erworben werden
** Wird für B.Sc. als 8 LP angerechnet

Liste der „Einführungslehrveranstaltungen anderer Fächer“:

Astronomie:
(1) Einführung in die Astronomie, (Vorlesung, Übung)
(2) Einführung in die extragalaktische Astronomie, (Vorlesung, Übung)
(3) Einführung in die Radioastronomie, (Vorlesung, Übung, Praktikum)

Informatik:
(1) Informationssysteme, (Vorlesung, Übung)
(2) Technische Informatik, (Vorlesung, Übung)
(3) Algorithmen und Programmierung, (Vorlesung, Übung)

Meteorologie:
(1) Einführung in die Meteorologie 1, (Vorlesung, Übung)
(2) Einführung in die Meteorologie 2, (Vorlesung, Übung)

Chemie:
(1) Experimentelle Einführung in die Anorganische und Allgemeine Chemie, (Vorlesung, Seminar)

Volkswirtschaftslehre/ Betriebswirtschaftslehre:
(1) Grundzüge der Volkswirtschaftslehre (Vorlesung, Übung, 7,5 LP)
(2) Grundzüge der BWL: Einführung in die Theorie der Unternehmung, (Vorlesung, Übung, 7,5 LP)
(3) Grundzüge der BWL: Investition und Finanzierung, (Vorlesung, Übung, 7,5 LP)
(4) Finanzmärkte und -institutionen, (Vorlesung, Übung, 7,5 LP)

Philosophie:
(1) Logik und Grundlagen ZF, (eine Vorlesung, ein Tutorium, Klausur, 8 LP)
(2) Erkenntnistheorie ZF, (eine Vorlesung, ein Tutorium, Klausur, 8 LP)
(3) Wissenschaftsphilosophie ZF, (eine Vorlesung, ein Tutorium, Klausur, 8 LP)

Modul: Einführungsveranstaltungen anderer Fächer

Modul-Nr.: physik120

Lehrveranstaltung: Einführung in die Astronomie

LV-Nr.: astro121

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Vorlesung mit Übungen	deutsch	2+1	4	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden werden an die stellare Astronomie herangeführt. Sie lernen die Probleme der Entfernungsbestimmung in der Astronomie kennen und erwerben Kenntnisse über Sterne und Sternentwicklung, einschließlich Phänomene in den Endphasen, wie Planetarische Nebel, Supernovaexplosionen und Schwarze Löcher. Man wird in die Lage versetzt, die Grundlagen der stellaren Astronomie einem Laien zu erklären

Inhalte der LV:
Teleskope, Instrumente, Detektoren; Himmelsmechanik; Himmel, Planetensystem, Kometen, Meteore; Sonne und Erdklima; Planck-Funktion, Photometrie, Sterne, Entfernungsbestimmung der Sterne, Hertzsprung-Russell-Diagramm; Sternatmosphäre; Sternaufbau und Sternentwicklung, Kernfusionsprozesse; Variable Sterne; Doppelsterne; Sternhaufen und Altersbestimmung; Endstadien der Sterne; Messgeräte der anderen Wellenlängenbereiche; Interstellares Medium, ionisiertes Gas, neutrales Gas und Molekülwolken mit Sternentstehung, heiße Phase

Literaturhinweise:
Skriptum zur Vorlesung; Astronomie (PAETEC Verlag, ISBN 3-89517-798-9)

Modul: Einführungsveranstaltungen anderer Fächer

Modul-Nr.: physik120

Lehrveranstaltung: Einführung in die extragalaktische Astronomie

LV-Nr.: astro122

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Vorlesung mit Übungen	deutsch	2+1	4	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Einführung in die Astronomie

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Studierende sollen die extragalaktische Astronomie in ihrer Breite kennen lernen, werden an die Schwerpunkte der aktuellen Forschung herangeführt und sollen in die Lage versetzt werden, astrophysikalische Zusammenhänge auch für Laien verständlich darzustellen. Durch die Diskussion der Dunklen Materie und der Dunklen Energie werden auch zentrale Fragen der fundamentalen Physik angesprochen

Inhalte der LV:
Struktur der Galaxis: Scheibe, Bulge, Halo; Rotation der Galaxis, Entfernung zum Zentrum; Dunkle Materie; Spiralgalaxien und ihre Strukturen; Elliptische Galaxien und ihre stellare Populationen; Aktive Galaxien; Quasare; Galaxienhaufen, großskalige Strukturen im Universum; Gravitationslinsen; Bestimmung des Anteils an Dunkler Materie; Kosmologie, Expansion des Universums, Bestimmung der Entfernungen weit entfernter Objekte; Urknall, Kosmische Hintergrundstrahlung, kosmologische Parameter

Literaturhinweise:
Skriptum zur Vorlesung
P. Schneider, Einführung in die Extragalaktische Astronomie und Kosmologie (Springer Verlag, Heidelberg 2005)

Modul: Einführungsveranstaltungen anderer Fächer

Modul-Nr.: physik120

Lehrveranstaltung: Einführung in die Radioastronomie

LV-Nr.: astro123

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Vorlesung mit Übungen und Praktikum	deutsch	2+1	4	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Einführung in die Astronomie I + II (astro121, 122), Physik I-III (Physik 110, 210, 310)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (mündliche Prüfung oder Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis der Grundlagen der radioastronomischen Beobachtungstechnik und der wesentlichen astrophysikalischen Prozesse

Inhalte der LV:
Vorlesung:
Radioastronomische Empfangstechnik (Teleskope, Empfänger und Detektoren), atmosphärische Fenster, Strahlungstransport, Radiometergleichung, statistische Prozesse in der Signalerkennung, interstellares Medium, HI 21-cm Linienstrahlung, Sternentstehung in Molekülwolken, kontinuierliche Strahlungsprozesse, Maser, Radiogalaxien, Entwicklung der Galaxien im Universum, Pulsare, Physik in starken Gravitationsfeldern, Epoche der Re-Ionisation, frühes Universum, Zukunftsprojekte der Radioastronomie

Ergänzendes, optionales Praktikum (1 bis 2 tägig am Observatorium):
Eichung eines radioastronomischen Empfängers, Messung der HI 21-cm Linienstrahlung, Ableitung der Spiralstruktur der Milchstraße, Messung der kontinuierlichen Strahlung der Milchstraße, Messung und Analyse eines Pulsarsignals

Literaturhinweise:
Folien der Vorlesung werden zur Verfügung gestellt.

On-line material: http://www.cv.nrao.edu/course/astr534/ERA.shtml

Dieses Modul kann anstelle von astro122 anerkannt werden.

Modul-Nr.: physik130
Leistungspunkte: 4
Kategorie: Pflicht
vorgesehenes Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: EDV

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	EDV (4 LP)	physik131	4	Vorl. + Üb.	120 Std.	WS
2.	EDV (6 LP)	physik132	6	Vorl. + Üb.	180 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Schriftliche Ausarbeitung

Inhalt:
Grundlagen der EDV in der Physik

Qualifikationsziel:
Die Studierenden sollen grundlegende Konzepte einer modernen Programmiersprache (z. B. C oder C++) erlernen und anwenden; Erstellen einfacher Dokumente mit Hilfe von LaTeX

Studienleistung/Kriterien zur Vergabe von LP:
Eine schriftliche Ausarbeitung

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: EDV

Modul-Nr.: physik130

Lehrveranstaltung: EDV (4 LP)

LV-Nr.: physik131

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	1+2	4	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Das Modul bleibt unbenotet

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen grundlegende Konzepte der Datenanalyse und der elektronischen Datenverarbeitung kennenlernen.

Hierzu gehören Einführungen in das Betriebssystem Linux und in die statistische Datenauswertung. Weiteres Lernziel ist das computergestützte Problemlösen mit Hilfe der modernen Programmiersprache Python. Python wird ebenfalls verwendet, um die erworbenen Kenntnisse der Statistik zu vertiefen und wissenschaftliche Daten zu visualisieren.

Inhalte der LV:
Betriebssystem Linux, Programmiersprache Python, statistische Datenauswertung, Visualisierung wissenschaftlicher Daten

Literaturhinweise:
Alle erforderlichen Lehrmaterialien werden online zur Verfügung gestellt.

Modul: EDV

Modul-Nr.: physik130

Lehrveranstaltung: EDV (6 LP)

LV-Nr.: physik132

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	1+3	6	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Das Modul bleibt unbenotet

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden lernen, wissenschaftliche Texte mit Hilfe des Textsatzsystems LaTeX zu erstellen.
Zusätzlich werden die Lernziele der Veranstaltung physik131 verfolgt.

Inhalte der LV:
Textsatzsystem LaTeX, Betriebssystem Linux, Programmiersprache Python, statistische Datenauswertung, Visualisierung wissenschaftlicher Daten

Literaturhinweise:
Alle erforderlichen Lehrmaterialien werden online zur Verfügung gestellt.

Modul-Nr.: math140
Leistungspunkte: 13
Kategorie: Pflicht
vorgesehenes Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mathematik I für Physiker und Physikerinnen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Mathematik I (für Physiker und Physikerinnen)	math141	13	Vorl. + Üb.	390 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Lineare Algebra, Analysis I

Qualifikationsziel:
Vermittlung der mathematischen Grundbegriffe und Methoden

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Mathematik I für Physiker und Physikerinnen

Modul-Nr.: math140

Lehrveranstaltung: Mathematik I (für Physiker und Physikerinnen)

LV-Nr.: math141

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	6+3 *	13	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Vermittlung der mathematischen Grundbegriffe und Methoden; erforderlich für die Vorlesungen nach dem 1. Semester

Inhalte der LV:
Lineare Algebra:
reelle und komplexe Zahlen, elementare Gruppentheorie, Vektorräume, Skalarprodukt, lineare Gleichungssysteme, Matrizen, Determinante, Eigenwerte, Diagonalisierung symmetrischer Matrizen (Hauptachsentransformation), geometrische Interpretation
Analysis:
Folgen und Reihen, Differentiation und Integration von Funktionen einer Veränderlichen. Gewöhnliche Differentialgleichungen, lineare Differentialgleichungssysteme und deren allgemeine Lösung, einige spezielle Lösungen. Differentiation von Funktionen mehrerer Veränderlichen.

Literaturhinweise:
G.B. Arfken, H.J. Weber; Mathematical Methods for Phycisists (Academic Press 6. Aufl. 2005)
S. Hassani; Mathematical Physics (Springer; New York 1999)
G. Fischer; Lineare Algebra, Eine Einführung für Studienanfänger (Vieweg Wiesbaden, 15. Aufl. 2005)
O. Forster; Analysis I (Vieweg Wiesbaden 2004)

* Diese Lehrveranstaltung kann auch als 4-stündige Vorlesung mit 3-stündigen Übungen angeboten werden und einer 2-stündigen Ergänzung durch einen anderen Dozenten der Mathematik oder der theoretischen Physik.

Modul-Nr.: physik210
Leistungspunkte: 7
Kategorie: Pflicht
vorgesehenes Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik II (Elektromagnetismus)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik II (Elektromagnetismus)	physik211	7	Vorl. + Üb.	210 Std.	SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Elektromagnetismus

Qualifikationsziel:
Einarbeitung in die Phänomene von Elektrizitätslehre und Magnetismus, elektromagnetische Wellen und damit verwandte Phänomene

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Physik II (Elektromagnetismus)

Modul-Nr.: physik210

Lehrveranstaltung: Physik II (Elektromagnetismus)

LV-Nr.: physik211

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I (physik110)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die zweite Grundvorlesung Experimentalphysik behandelt zunächst die elektrischen Phänomene in Experimenten und in elementarer theoretischer Betrachtung. Im zweiten Teil werden die elektromagnetischen Wechselwirkungen bis zu elektromagnetischen Wellen behandelt, um schließlich die vollständigen Maxwell-Gleichungen zu behandeln, auch in Vorbereitung auf die theoretischen Vorlesungen zur Elektrodynamik.

Inhalte der LV:
Elektrostatik (Ladung, Coulomb-Gesetz, Feld, Dipol, elektrische Struktur der Materie, el. Fluss, Gauß-Gesetz, Poisson-Gleichung, Ladungsverteilung, Kapazität, Vergleich mit Gravitation). Elektrische Leitung (Stromdichte, Ladungserhaltung, Ohmsches Gesetz, Rotation des Vektorfeldes, Stokes-Satz, Stromkreise, Kirchhoff-Gesetze, Leitungsmechanismen). Magnetische Wechselwirkung, (Magnetismus als relativistischer Effekt, Magnetfeld, stationäre Maxwell-Gleichungen, Lorentz-Kraft, Hall-Effekt, Magnetischer Dipol, Vektorpotential, Biot-Savart-Gesetz). Materie in stationären Feldern (induzierte und permanente Dipole, Dielektrikum, Verschiebungsfeld, elektrische Polarisation, magnetische Dipole, H-Feld, Verhalten an Grenzflächen). Zeitabhängige Felder (Induktion, Maxwellscher Verschiebungsstrom, technischer Wechselstrom, Schwingkreise), Elektromagnetische Wellen (Hochfrequenz-Phänomene, Abstrahlung, freie EM-Wellen, Hertz-Dipol, Polarisation, Reflexion). Vollständige Maxwell-Gleichungen, Symmetrie zwischen elektrischen und magnetischen Feldern.

Literaturhinweise:
W. Demtröder; Experimentalphysik 2 (Springer, Heidelberg 4. Aufl. 2008)
D. Meschede; Gerthsen Physik (Springer, Heidelberg 24. Aufl. 2010)
Alonso Finn, Physics, Addison Wesley
Feynman, Vorlesungen über Physik, Bd. II (Oldenbourg)
W. Otten, Repetitorium der Experimentalphysik (Springer Verlag, Heidelberg)
P. Tipler, Physik (Spektrum Akad. Verlag, Heidelberg)

Modul-Nr.: physik220
Leistungspunkte: 9
Kategorie: Pflicht
vorgesehenes Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik I (Mechanik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik I (Mechanik)	physik221	9	Vorl. + Üb.	270 Std.	SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Analytische Mechanik

Qualifikationsziel:
Umgang mit Konzepten und Rechenmethoden der Klassischen Mechanik

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Theoretische Physik I (Mechanik)

Modul-Nr.: physik220

Lehrveranstaltung: Theoretische Physik I (Mechanik)

LV-Nr.: physik221

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	9	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I für Physiker (math140), Physik I (physik110)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Umgang mit Konzepten und Rechenmethoden der Klassischen Mechanik

Inhalte der LV:
Newtonsche Mechanik
Zentralkraftproblem
Mechanik des starren Körpers
Lagrangeformalismus
Symmetrien und Erhaltungssätze
Hamiltonformalismus
Hamilton/Jacobi-Gleichung

Literaturhinweise:
T. Fließbach; Lehrbuch der Theoretischen Physik 1: Mechanik (Spektrum Akademischer Vlg., Heidelberg 4. veränd. Aufl. 2003)
F. Kuypers; Klassische Mechanik (Wiley-VCH, Weinheim 7. erw. Aufl. 2005)
L. Landau; E. Lifschiz; Lehrbuch der Theoretischen Physik Band 1: Mechanik (Harri Deutsch, Frankfurt am Main, 14. korr. Aufl. 1997)
W. Nolting; Grundkurs Theoretische Physik 1: Klassische Mechanik (Springer, Heidelberg 7. Nachdruck 2005)
W. Nolting; Grundkurs Theoretische Physik 2: Analytische Mechanik (Springer, Heidelberg korr. Nachdruck 2005)
H. R. Petry, B. Metsch; Theoretische Mechanik (Oldenburg, München 2005)

Modul-Nr.: math240
Leistungspunkte: 11
Kategorie: Pflicht
vorgesehenes Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mathematik II für Physiker und Physikerinnen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Mathematik II (für Physiker und Physikerinnen)	math241	11	Vorl. + Üb.	330 Std.	SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur

Inhalt:
Analysis II

Qualifikationsziel:
Vermittlung der mathematischen Grundbegriffe und Methoden

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
11/163

Modul: Mathematik II für Physiker und Physikerinnen

Modul-Nr.: math240

Lehrveranstaltung: Mathematik II (für Physiker und Physikerinnen)

LV-Nr.: math241

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	11	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I für Physiker und Physikerinnen (math140)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Vermittlung der mathematischen Grundbegriffe und Methoden, erforderlich für die theoretischen Physikvorlesungen nach dem 2. Semester

Inhalte der LV:
Mehrdimensionale Integration:
Transformationssatz, Integration auf gekrümmten Objekten (Gramsche Determinate), Längenberechnung von Kurven, Flächeninhaltsberechnung von gekrümmten Flächen, Berechnung von Volumina.
Vektoranalysis in drei Dimensionen: grad, rot, div, Gaußscher und Stokesscher Satz, Erhaltungsgrößen, Maxwellgleichungen. Verallgemeinerung auf beliebige Dimension.
Fourieranalysis, Fourierreihen, Fouriertransformation, Hilberträume, vollständige Funktionensysteme

Literaturhinweise:
G. B. Arfken, H. J. Weber; Mathematical Methods for Physicists (Academic Press 6. Aufl. 2005)
S. Hassani; Mathematical Physics (Springer; New York 1999)
O. Forster; Analysis II (Vieweg, Wiesbaden 2005)
O. Forster; Analysis III (Vieweg, Wiesbaden 1984)

Modul-Nr.: physik260
Leistungspunkte: 3
Kategorie: Pflicht
vorgesehenes Semester: 2.

Modul: Praktikum Mechanik, Wärmelehre

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Praktikum Mechanik, Wärmelehre	physik261	3	Praktikum	90 Std.	SS

Teilnahmevoraussetzungen:
Teilnahme an der Klausur zu Modul physik110

Prüfungsform:
Mündliche Prüfung

Inhalt:
Vorbereiten auf physikalische Grundlagen; praktisches Durchführen und Auswerten von Experimenten

Qualifikationsziel:
Erlernen von Experimentiertechniken

Studienleistung/Kriterien zur Vergabe von LP:
Mündl. Überprüfung der Versuchsvorbereitung, erfolgreiche Durchführung der Versuche,
Erstellung von Versuchsprotokollen

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
3/163

Modul: Praktikum Mechanik, Wärmelehre

Modul-Nr.: physik260

Lehrveranstaltung: Praktikum Mechanik, Wärmelehre

LV-Nr.: physik261

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	3	3	SS

Teilnahmevoraussetzungen:
Teilnahme an Physik I (physik110). Das heißt: erfolgreiche Teilnahme an den Übungen plus Teilnahme an der Modulprüfung physik110

Empfohlene Vorkenntnisse:
Grundlagen der statistischen Datenauswertung

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur oder mündliche Prüfung): mündliche Überprüfung der Versuchsvorbereitung, erfolgreiche Durchführung der Versuche, Erstellung von Versuchsprotokollen

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit)

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten. Erarbeitung von Versuchsprotokollen.

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
Ausgewählte Versuche im Praktikum zur Mechanik und Wärmelehre

Auswahl: Einführungsversuch mit Seminar; Elastizitätskonstanten; Biegung und Knickung; Schwingungen; freie und erzwungene Schwingungen (Pohlsches Drehpendel);Trägheitsmoment und physisches Pendel; spezifische Wärmekapazität; Adiabatenkoeffizient; Wärmeausdehnungskoeffizient; ideales Gas; statistische Schwankungen

Literaturhinweise:
Versuchsanleitungen: http://www.praktika.physik.uni-bonn.de/
W. Walcher; Praktikum der Physik (Teubner, Wiesbaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel; E. Lohrmann; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999)
S. Brandt; Datenanalyse (Spektrum Akademischer Vlg., Heidelberg 4. Aufl. 1999)
E.W. Otten: Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Westphal; Physikalisches Praktikum (Vieweg); Titel vergriffen, aber in der ULB vorhanden
Kohlrausch; Praktische Physik Bd. 1-3 (Teubner, Wiesbaden) Titel vergriffen, aber in der ULB vorhanden

Modul-Nr.: physik310
Leistungspunkte: 7
Kategorie: Pflicht
vorgesehenes Semester: 3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik III (Optik und Wellenmechanik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik III (Optik und Wellenmechanik)	physik311	7	Vorl. + Üb.	210 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Grundzüge der Optik; Grundzüge der mikroskopischen Physik

Qualifikationsziel:
Einarbeitung in die Phänomene der linearen und der Wellenoptik und der mikroskopischen Physik

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Physik III (Optik und Wellenmechanik)

Modul-Nr.: physik310

Lehrveranstaltung: Physik III (Optik und Wellenmechanik)

LV-Nr.: physik311

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - II (physik110, physik210)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die dritte Grundvorlesung Experimentalphysik stellt im ersten Teil optische Phänomene in Experimenten und elementarer theoretischer Behandlung als Erweiterung der Elektrizitätslehre dar. Insbesondere die Interferenzphänomene der Wellenlehre bieten eine sehr gute propädeutische Basis, um im zweiten Teil eine Einführung in die mikroskopische Physik mit Hilfe elementarer Wellenfunktionen der Quantenmechanik zu realisieren

Inhalte der LV:
Optik: Strahlenoptik und Matrizenoptik; Abbildungen und Abbildungsfehler; Mikroskop und Teleskop; Wellengleichung und Wellentypen; Brechung und Dispersion; Wellenleiter; Polarisation und Doppelbrechung; Beugung (Kirchhoffsche Theorie der Beugung, Fraunhofer-Beugung, Beugung am Einzelspalt, am Doppelspalt und am Gitter); Kohärenz und Zweistrahl-Interferometer; Vielstrahl-Interferometer; Räumliche und zeitliche Wellenpakete

Wellenmechanik: Teilchenphänomene mit Licht (Schwarzkörperstrahlung, Photo-Effekt, Compton-Effekt, Photon); Materiewellen (Doppelspalt mit Materiewellen, de Broglie Wellenlänge, Wellenfunktion und Schrödingergleichung); Tunnel-Effekt; Teilchen im externen Potenzial; Paul-Falle; Aufbau der Atome (Rutherford-Experiment, Franck-Hertz-Versuch); Spektrum des Wasserstoff-Atoms, Bohrsches Atommodell; Stern-Gerlach-Experiment

Literaturhinweise:
Hecht, Optik (Oldenbourg-Verlag, München 4. Aufl. 2005)
D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2. überarb. Aufl. 2005)
W. Demtröder; Experimentalphysik 2: Elektrizität und Optik (Springer, Heidelberg 5. überarb. Aufl. 2009)
W. Demtröder; Experimentalphysik 3: Atome, Moleküle und Festkörper (Springer, Heidelberg 4. überarb. Aufl. 2010)
D. Meschede; Gerthsen Physik (Springer, Heidelberg 23. Aufl. 2006)

Modul-Nr.: physik320
Leistungspunkte: 9
Kategorie: Pflicht
vorgesehenes Semester: 3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik II (Elektrodynamik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik II (Elektrodynamik)	physik321	9	Vorl. + Üb.	270 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur

Inhalt:
Theoretische Elektrodynamik

Qualifikationsziel:
Umgang mit Konzepten und Rechenmethoden der Klassischen Elektrodynamik und der Speziellen Relativitätstheorie

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
9/163

Modul: Theoretische Physik II (Elektrodynamik)

Modul-Nr.: physik320

Lehrveranstaltung: Theoretische Physik II (Elektrodynamik)

LV-Nr.: physik321

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	9	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - II für Physiker (math140, math240)
Theoretische Physik I (physik220)
Physik I - II (physik110, physik210)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Umgang mit Konzepten und Rechenmethoden der Klassischen Elektrodynamik und der Speziellen Relativitätstheorie

Inhalte der LV:
Maxwellgleichungen
Elektro- und Magnetostatik, Poisson- und Laplace-Gleichung, Kugelflächenfunktionen
Elektromagnetische Wellen
spezielle Relativitätstheorie
bewegte Ladungen, retardierte Potentiale
Strahlung, Hertzscher Dipol
kovariante Elektrodynamik
Elektrodynamik in Medien

Literaturhinweise:
T. Fließbach; Lehrbuch der Theoretischen Physik 2: Elektrodynamik (Spektrum Akademischer Verlag, Heidelberg 4. Aufl. 2004)
J. Jackson; Klassische Elektrodynamik (de Gruyter, Berlin 4. überarb. Aufl. 2006)
L. Landau, E. Lifschitz; Lehrbuch der Theoretischen Physik Band 2: Klassische Feldtheorie (Harri Deutsch, Frankfurt am Main 12. überarb. Aufl. 1991)
J.S. Schwinger, L.L. Deraad, K.A. Milton, W.Y. Tsai; Classical Electrodynamics (Perseus Books 1998)

Modul-Nr.: math340
Leistungspunkte: 11
Kategorie: Pflicht
vorgesehenes Semester: 3.

Fachgruppe Physik und Astronomie Universität Bonn

Modul: Mathematik III für Physiker und Physikerinnen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Mathematik III (für Physiker und Physikerinnen)	math341	11	Vorl. + Üb.	330 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur

Inhalt:
Funktionentheorie

Qualifikationsziel:
Vermittlung der mathematischen Grundbegriffe und Methoden

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
11/163

Modul: Mathematik III für Physiker und Physikerinnen

Modul-Nr.: math340

Lehrveranstaltung: Mathematik III (für Physiker und Physikerinnen)

LV-Nr.: math341

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	11	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - II für Physiker und Physikerinnen (math140, math240)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Vermittlung der mathematischen Grundbegriffe und Methoden, erforderlich für die - theoretischen - Physikvorlesungen nach dem 3. Semester

Inhalte der LV:
Funktionentheorie: Potenzreihen, Laurentreihen, Residuensatz, spezielle Funktionen.
Partielle Differentialgleichungen + Variationsrechnung. Harmonische Funktionen, Poissongleichung, Green'sche Funktion

Literaturhinweise:
G.B. Arfken, H.J. Weber; Mathematical Methods for Phycisists (Academic Press 6. Aufl. 2005)
S. Hassani; Mathematical Physics (Springer; New York 1999)
R. Remmert, G. Schumacher; Funktionentheorie I (Springer; Berlin 2001)

Modul-Nr.: physik360
Leistungspunkte: 6
Kategorie: Pflicht
vorgesehenes Semester: 3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Praktikum Elektromagnetismus/Optik

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Praktikum Elektromagnetismus	physik361		Praktikum	90 Std.	WS
2.	Praktikum Optik, Wellenmechanik	physik362		Praktikum	90 Std.	WS

Teilnahmevoraussetzungen:
Teilnahme an der Klausur zu Modul physik210

Prüfungsform:
Mündliche Prüfung

Inhalt:
Praktikumsversuche aus den Themengebieten Elektromagnetismus und klassische Optik

Qualifikationsziel:
Erlernen von Experimentiertechniken und Vertiefung der Grundlagen anhand von Versuchen zur Elektrizitätslehre und Magnetismus, elektromagnetischen Wellen und klassischer Optik

Studienleistung/Kriterien zur Vergabe von LP:
Mündliche Überprüfung der Versuchsvorbereitung, erfolgreiche Durchführung der Versuche, Erstellung von Versuchsprotokollen

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
6/163

Modul: Praktikum Elektromagnetismus/Optik

Modul-Nr.: physik360

Lehrveranstaltung: Praktikum Elektromagnetismus

LV-Nr.: physik361

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	3		WS

Teilnahmevoraussetzungen:
Teilnahme an Physik II (physik210). Das heißt: erfolgreiche Teilnahme an den Übungen plus Teilnahme an der Modulprüfung physik210

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
mündliche Überprüfung der Versuchsvorbereitung, erfolgreiche Durchführung der Versuche, Erstellung von Versuchsprotokollen

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit)

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten. Anfertigen von Versuchsprotokollen

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
Ausgewählte Versuche im Praktikum zum Elektromagnetismus

Auswahl: Gleichströme; Spannungsquellen; Widerstände; elektrische und magnetische Felder; Galvanometer und gedämpfte Schwingungen; Wechselstromwiderstände, Schwingkreis und Phasenschieber; Transformator; Fourieranalyse von Signalen; Hysterese der Magnetisierung von Eisen; elektrische und magnetische Kraftwirkung auf geladene Teilchen (Fadenstrahlrohr, Millikanversuch);

Literaturhinweise:
Versuchsanleitungen: http://www.praktika.physik.uni-bonn.de/
W. Walcher; Praktikum der Physik (Teubner, Wiebaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel, E. Lohrmann; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999)
S. Brandt; Datenanalyse (Spektrum Akademischer Vlg., Heidelberg 4. Aufl. 1999)
E.W. Otten; Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Westphal; Physikalisches Praktikum (Vieweg) Titel vergriffen, aber in der ULB vorhanden
Kohlrausch; Praktische Physik Bd. 1-3 (Teubner, Wiesbaden) Titel vergriffen, aber in der ULB vorhanden

Modul: Praktikum Elektromagnetismus/Optik

Modul-Nr.: physik360

Lehrveranstaltung: Praktikum Optik, Wellenmechanik

LV-Nr.: physik362

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	3		WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
mündliche Überprüfung der Versuchsvorbereitung, erfolgreiche Durchführung der Versuche, Erstellung von Versuchsprotokollen

Dauer der Lehrveranstaltung:
1 Semester (im Blockkurs in der vorlesungsfreien Zeit)

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten; Anfertigung von Versuchsprotokollen

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
Ausgewählte Versuche im Praktikum zur Optik und Wellenmechanik.

Auswahl: Linsen und Linsensysteme; optische Instrumente (Fernrohr, Mikroskop, Projektor); Dispersion, Brechung; Spektrometer; Beugung und Interferenz; Polarisation von Licht; Elektro- und Magnetooptik; Absorption und Streuung; Wärmestrahlung

Literaturhinweise:
W. Walcher; Praktikum der Physik (Teubner, Wiebaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel, E. Lohrmann; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999)
S. Brandt; Datenanalyse (Spektrum Akademischer Vlg., Heidelberg 4. Aufl. 1999)
E.W. Otten; Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Westphal; Physikalisches Praktikum (Vieweg) Titel vergriffen, aber in der ULB vorhanden
Kohlrausch; Praktische Physik Bd. 1-3 (Teubner, Wiesbaden) Titel vergriffen, aber in der ULB vorhanden

Modul-Nr.: physik410
Leistungspunkte: 7
Kategorie: Pflicht
vorgesehenes Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik IV (Atome, Moleküle, Kondensierte Materie)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik IV (Atome, Moleküle, Kondensierte Materie)	physik411	7	Vorl. + Üb.	210 Std.	SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Grundzüge der Atom-, Molekül- und Festkörperphysik

Qualifikationsziel:
Es soll ein Verständnis der elektronischen Struktur der Materie auf atomarer und molekularer Ebene sowie der Struktur von allgemein festen Materialien und von Halbleitern erlangt werden.

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Physik IV (Atome, Moleküle, Kondensierte Materie)

Modul-Nr.: physik410

Lehrveranstaltung: Physik IV (Atome, Moleküle, Kondensierte Materie)

LV-Nr.: physik411

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - III (physik110, physik210, physik310); Theoretische Physik I - II (physik220, physik320)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die vierte Grundvorlesung Experimentalphysik präsentiert eine Einführung in die Struktur der elektronisch dominierten Materie, wobei ein Bogen geschlagen wird von den atomaren Modellsystemen über die Grundzüge der Chemie zur Festkörperphysik und kondensierten Materie

Inhalte der LV:
Atome: Quantenmechanik des Wasserstoffatoms; Quantenmechanischer Drehimpuls und Spin; Feinstruktur und Hyperfeinstruktur; Atome in Magnetfeldern; Identische Teilchen, Helium und Mehrelektronenatome; das periodische System der Elemente; Wechselwirkung zwischen Licht und Materie, Laser

Moleküle: Zweiatomige Moleküle: Born-Oppenheimer-Näherung; Molekulare Bindung; Vibrationen, Normalkoordinaten von Molekülen; Rotationsstruktur von Molekülen

Kondensierte Materie: Kristallstrukturen, Strukturanalyse, Bindungstypen; Gitterdynamik (Phononen, Dispersionsrelation, spezifische Wärme); Modell des freien Elektronengases; Bandstruktur, elektrische Eigenschaften von Festkörpern, Halbleiter; Magnetische Eigenschaften von Festkörpern

Literaturhinweise:
W. Demtröder; Experimentalphysik 3: Atome, Moleküle und Festkörper (Springer, Heidelberg 4. überarb. Aufl. 2010)
H. Ibach, H. Lüth; Festkörperphysik (Springer Heidelberg 6. Aufl. 2002)
H. Haken, H.C. Wolf; Atom- und Quantenphysik (Springer, Heidelberg 8. aktual. u. erw. Aufl. 2003)
C. Kittel; Einführung in die Festkörperphysik (R. Oldenbourg Vlg., München 14. Aufl. 2005)

Modul-Nr.: physik420
Leistungspunkte: 9
Kategorie: Pflicht
vorgesehenes Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik III (Quantenmechanik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik III (Quantenmechanik)	physik421	9	Vorl. + Üb.	270 Std.	SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur

Inhalt:
Nichtrelativistische Quantenmechanik

Qualifikationsziel:
Fähigkeit zur Lösung von Problemen der nichtrelativistischen Quantenmechanik

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
9/163

Modul: Theoretische Physik III (Quantenmechanik)

Modul-Nr.: physik420

Lehrveranstaltung: Theoretische Physik III (Quantenmechanik)

LV-Nr.: physik421

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	9	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - III für Physiker (math140, math240, math340)
Theoretische Physik I - II (physik220, physik320)
Physik I - III (physik110, physik210, physik310)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Fähigkeit zur Lösung von Problemen der nichtrelativistischen Quantenmechanik

Inhalte der LV:
Schrödinger-Gleichung, einfache Potentialprobleme, harmonischer Oszillator
Formale Grundlagen, Operatoren auf Hilberträumen, Unschärferelation
Theorie des Drehimpulses, sphärisch-symmetrische Potentiale, Wasserstoffatom
Theorie des Spins, Drehimpulskopplung
stationäre Störungstheorie
Mehrelektronensysteme, Pauliprinzip, Heliumatom, Periodensystem
zeitabhängige Störungstheorie: elektromagnetische Übergänge, Goldene Regel

Literaturhinweise:
S. Gasiorowicz; Quantenphysik (R. Oldenbourg Vlg., München 9. erw. u. überarb. Aufl. 2005)
L. Landau, E. Lifschitz; Lehrbuch der Theoretischen Physik Band : Quantenmechanik (Harri Deutsch, Frankfurt am Main 9. bearb. Aufl. 1992)
W. Nolting; Grundkurs Theoretische Physik 5: Quantenmechanik Teil 1: Grundlagen (Springer, Heidelberg 4. verb. Aufl. 2000)
W. Nolting; Grundkurs Theoretische Physik 5: Quantenmechanik Teil 2: Methoden und Anwendungen (Springer, Heidelberg 3. verb. Aufl. 2000)
F. Schwabl; Quantenmechanik (QMI) (Springer, Heidelberg 6. korr. Nachdruck 2004)
J.J. Sakurai; Modern Quantum Mechanics (Addison-Wesley, 1995)
R. Shankar; Principles of Quantum Mechanics (Kluwer 1994)
G. Münster; Quantentheorie (de Gruyter 2010)

Modul-Nr.: physik440
Leistungspunkte: 6
Kategorie: Pflicht
vorgesehenes Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Computerphysik

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Computerphysik	physik441	6	Vorl. + Üb.	180 Std.	SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Schriftliche Ausarbeitungen

Inhalt:
Anwendung numerischer Methoden auf Problemlösungen in der Physik

Qualifikationsziel:
Die Studierenden sollen lernen, ein physikalisches Problem in eine auf dem Rechner lösbare Form zu bringen, das Problem mit Hilfe der in der Vorlesung erlernten Methoden zu lösen und ihre Ergebnisse darzustellen.

Studienleistung/Kriterien zur Vergabe von LP:
keine

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
6/163

Modul: Computerphysik

Modul-Nr.: physik440

Lehrveranstaltung: Computerphysik

LV-Nr.: physik441

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	3+2	6	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Theoretische Physik I-II (physik220, physik320), Physik I - III (physik110, physik210, physik310), EDV (physik130), Lineare Algebra, Analysis.

Studien- und Prüfungsmodalitäten:
Die Prüfung erfolgt in der Form von sechs Übungsaufgaben. Die Übungsaufgaben werden über das Semester verteilt in Gruppen von zwei Studierenden bearbeitet und bewertet.

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Lösung eines physikalischen Problems im Team mit Hilfe numerischer Methoden. Darstellung der Lösung. Vorbereitung für Softwareentwicklung auch für nichtuniversitäre Bereiche.

Inhalte der LV:
Rechengenauigkeit, numerische und algorithmische Fehler; Lösung wissenschaftlicher Probleme mit numerischen Methoden: Lösung linearer Gleichungssysteme, Lösung von Differentialgleichungen, Nullstellensuche, Approximation (Schnelle Fourier Transformation), Numerische Integration, Minimierungsprobleme

Literaturhinweise:
S.E. Koonin, Computational Physics; (Benjamin/Cummings, 1986)
T. Pang, Computational Physics; (Cambridge University Press, 2006)
F. J. Vesely, Computational Physics; (Plenum Press, 1994)
W.H. Press et al.; Numerical Recipes in C (Cambridge University Press, 1992)
H. R. Schwarz, N. Köckler; Numerische Mathematik (Vieweg+Teubner, 2009)

Modul-Nr.: physik450
Leistungspunkte: 6
Kategorie: Wahlpflicht
vorgesehenes Semester: 4.-6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Fachgebundenes Wahlpflichtmodul

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	siehe umseitige Liste	siehe umseitige Liste	6/7*	Vorl. + Üb.	180 Std./ 210 Std.	WS/SS
2.	Projektpraktikum Physik	physik458	6	Praktikum	180 Std.	WS/SS
3.	Betriebspraktikum	physik459	6	Praktikum	180 Std.	WS/SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur bzw. schriftliche Ausarbeitung

Inhalt:
Eine weiterführende/vertiefende Vorlesung aus den Masterstudiengängen Physik und Astrophysik
oder: Betriebspraktikum im Umfang von 180 Arbeitsstunden

Qualifikationsziel:
Mit den Wahlpflichtvorlesungen wird die Möglichkeit eröffnet, den Stoff des Pflichtkanons mit einer ausgewählten, fortgeschrittenen Lehrveranstaltung der Physik oder Astrophysik zu ergänzen; zum Teil dienen sie der Vorbereitung auf das Masterstudium. Alternativ kann im Betriebspraktikum Erfahrung mit der Arbeit in der Industrie oder in einer anderen Institution, in der physikalische Kenntnisse erforderlich sind, gesammelt werden. Forschungseinrichtungen (z. B. DLR, FhG, MPI) sind davon ausgenommen.

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben, des Projektes, bzw. Bescheinigung über ein Betriebspraktikum

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
6/163

* Wird für B.Sc. als 6 LP angerechnet

Eine Veranstaltung aus:

physics611: Particle Physics
physics612: Accelerator Physics
physics613: Condensed Matter Physics
physics615: Theoretical Particle Physics
physics616: Theoretical Hadron Physics
physics617: Theoretical Condensed Matter Physics
physics618: Physics of Particle Detectors
physics620: Advanced Atomic, Molecular, and Optical Physics

physics631: Quantum Optics
physics632: Physics of Hadrons
physics633: High Energy Collider Physics
physics634: Magnetism/Superconductivity
physics641: Photonics
physics642: Quantum Technology

physics606: Advanced Quantum Theory
physics751: Group Theory
physics754: General Relativity and Cosmology
physics755: Quantum Field Theory

astro608: Theoretical Astrophysics

astro811: Stars and Stellar Evolution
astro812: Cosmology
astro821: Astrophysics of Galaxies
astro822: Physics of the Interstellar Medium

Nähere Informationen dazu finden Sie in den Modulhandbüchern Master of Science Physik bzw. Master of Science Astrophysik der Fachgruppe Physik/Astronomie.

Stand: Sommersemester 2015

Modul: Fachgebundenes Wahlpflichtmodul

Modul-Nr.: physik450

Lehrveranstaltung: Projektpraktikum Physik

LV-Nr.: physik458

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Praktikum	deutsch	6	6	WS/SS

Teilnahmevoraussetzungen:
Erfolgreiche Teilnahme an physik260 und physik360

Empfohlene Vorkenntnisse:
physik110, physik210, physik310

Studien- und Prüfungsmodalitäten:
Führen eines Laborbuches, erfolgreiche Bearbeitung des Projekts, Posterpräsentation und Diskussion

Dauer der Lehrveranstaltung:
1 Semester (während Vorlesungszeit und evtl. vorlesungsfreier Zeit)

Lernziele der LV:
Einüben des experimentell-wissenschaftlichen Prozesses anhand ausgewählter (kleiner) Projekte. Dies beinhaltet u. a. eine "Forschungsfrage" zu formulieren, entsprechende Fachliteratur zu finden und zu verstehen, ein adäquates Versuchsdesign zu entwickeln, den entwickelten Versuch durchzuführen, Daten zu nehmen und auszuwerten, Ergebnisse zu dokumentieren und zu diskutieren. Grundlegend dafür sind entsprechende Fachkenntnisse.

Inhalte der LV:
Die Studenten identifizieren experimentelle Themen, die sie bearbeiten möchten und entwickeln einen Projektplan in Abstimmung mit der Praktikumsleitung, um die abgesprochenen Versuche zu entwickeln und durchzuführen. Die Themen sollen einen Bezug zu physikalischen Fragestellungen der experimentellen Vorlesungen des Bachelorstudiengangs (Physik 1 – Physik 5) haben. Physikalische Versuche werden entwickelt und durchgeführt. Die Ergebnisse werden in einer Posterpräsentation dem gesamten Kurs vorgestellt und diskutiert.

Literaturhinweise:

Modul: Fachgebundenes Wahlpflichtmodul

Modul-Nr.: physik450

Lehrveranstaltung: Betriebspraktikum

LV-Nr.: physik459

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Praktikum	deutsch	n.a.	6	WS/SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Lehrveranstaltungen des 1.-3. Semesters

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (schriftlicher Bericht): erfolgreiche Teilnahme am Praktikum

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Der Studierende soll in einem Praktikum in einem Industriebetrieb oder in einer Institution, in der physikalische Kenntnisse erforderlich sind, erste praktische Erfahrungen sammeln

Inhalte der LV:
Sammeln erster berufsnaher Erfahrungen in einem Betrieb der öffentlichen Hand oder der Wirtschaft.
Verfassen eines Erfahrungsberichtes

Literaturhinweise:

Die Durchführung eines Betriebspraktikums muss von den Studierenden in Eigeninitiative realisiert werden. Die Fachgruppe Physik/Astronomie kann Praktikumsplätze nicht garantieren

Modul-Nr.:	physik460
Leistungspunkte:	4
Kategorie:	Pflicht
vorgesehenes Semester:	4.

Fachgruppe Physik und Astronomie Universität Bonn

Modul: Elektronikpraktikum

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Elektronikpraktikum	physik461	4	Vorles. u. Praktikum	120 Std.	SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur

Inhalt:
Blockvorlesung und ausgewählte Versuche zur Elektronik.

Qualifikationsziel:
Verständnis und Anwendungen der Grundlagen der Elektronik in der Praxis

Studienleistung/Kriterien zur Vergabe von LP:
Mündliche Überprüfung der Versuchsvorbereitung, erfolgreiche Durchführung der Versuche, Erstellung von Versuchsprotokollen

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
4/163

Modul: Elektronikpraktikum

Modul-Nr.: physik460

Lehrveranstaltung: Elektronikpraktikum

LV-Nr.: physik461

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung, Praktikum	deutsch	4	4	SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - II (physik110, physik210)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur):
mündliche Überprüfung der Versuchsvorbereitung, erfolgreiche Durchführung der Versuche, Erstellung von Versuchsprotokollen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis und Anwendungen der Grundlagen der Elektronik in der Praxis

Inhalte der LV:
Blockvorlesung und ausgewählte Versuche zur Elektronik. Diese Lehrveranstaltung wird zum Teil in der vorlesungsfreien Zeit durchgeführt.

Auswahl:
Ausbreitung von Signalen auf Leitungen
Diode
Transistor
Transistorverstärker
Operationsverstärker
Anwendung des Operationsverstärkers
Computeralgebra
Mikroprozessor

Literaturhinweise:
P. Horowitz, W. Hill; The Art of Electronics (Cambridge University Press, 2. Aufl. 1999)
A. Schlachetzki; Halbleiterelektronik (Teubner, Wiesbaden 1990)
U. Tietze, C. Schenk; Halbleiter-Schaltungstechnik (Springer, Heidelberg 12. Aufl. 2002)
K.-H. Rohe: Elektronik für Physiker: Eine Einführung in analoge Grundschaltungen (Teubner, Wiesbaden 1987)

Modul-Nr.: physik470
Leistungspunkte: 3
Kategorie: Pflicht
vorgesehenes Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mündliche Übersichtsprüfung Experimentalphysik Teil I

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Übersichtsprüfung Experimentalphysik Teil I	physik471	3	angeleit. Selbstst.	90 Std.	WS/SS

Teilnahmevoraussetzungen:
physik110, physik210 und physik310

Prüfungsform:
Mündliche Prüfung (mindestens 30 und höchstens 45 Minuten)

Inhalt:
Mündliche Prüfung über die Inhalte und Zusammenhänge der Module physik110, -210 und -310 nach angeleitetem Selbststudium

Qualifikationsziel:
Die Studierenden sollen die modulübergreifenden Zusammenhänge der Module physik110, -210 und -310 erarbeiten, erkennen und mündlich darstellen können.

Studienleistung/Kriterien zur Vergabe von LP:
keine

Dauer: 1 Semester

Max. Teilnehmerzahl:

Gewichtung:
24/163

Modul: Mündliche Übersichtsprüfung Experimentalphysik Teil I

Modul-Nr.: physik470

Lehrveranstaltung: Übersichtsprüfung Experimentalphysik Teil I

LV-Nr.: physik471

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Angeleitetes Selbststudium	deutsch	n.a.	3	WS/SS

Teilnahmevoraussetzungen:
bestandene Module physik110, -210 und -310

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Mündliche Prüfung von mindestens 30, höchstens 45 Minuten

Dauer der Lehrveranstaltung:
Prüfungs-Vorbereitungszeit

Lernziele der LV:
Die Studierenden sollen sich Überblickswissen erarbeiten

Inhalte der LV:
Mündliche Prüfung über den Inhalt der Module physik110, -210 und -310

Literaturhinweise:
Siehe Hinweise zu den Lehrveranstaltungen physik110, -210, -310

Modul-Nr.:	physik510
Leistungspunkte:	7
Kategorie:	Pflicht
vorgesehenes Semester:	5.

Fachgruppe Physik und Astronomie Universität Bonn

Modul: Physik V (Kerne und Teilchen)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik V (Kern- und Teilchenphysik)	physik511	7	Vorl. + Üb.	210 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Grundlagen des Aufbaus und der Physik der Atomkerne, Physik der Elementarteilchen, grundlegende Experimente dazu im Kontext detektor- und beschleunigerspezifischer Aspekte

Qualifikationsziel:
Verständnis der Grundlagen der Kernphysik und der Elementarteilchenphysik sowie der Experimente, die zu dem derzeitigen Stand der Erkenntnis geführt haben

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Physik V (Kerne und Teilchen)

Modul-Nr.: physik510

Lehrveranstaltung: Physik V (Kern- und Teilchenphysik)

LV-Nr.: physik511

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - IV (physik110, physik210, physik310, physik410)
Theoretische Physik I - III (physik220, physik320, physik420)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis der Grundlagen der Kernphysik und der Elementarteilchenphysik sowie der wichtigsten Experimente, die zu dem derzeitigen Wissensstand auf diesen Gebieten geführt haben

Inhalte der LV:
Nukleonen und Kernaufbau, Isotope und Stabilität, versch. Kernmodelle, alpha-, beta- und gamma-Zerfall, Kernspaltung, Kernfusion, Sonnenzyklus, grundlegende Experimente der Kernphysik; Elementarteilchen, Wechselwirkungen, relativistische Kinematik, Wirkungsquerschnitte u. Lebensdauern, Symmetrien und Erhaltungssätze, Quarkmodell, Beschleuniger und Detektoren, grundlegende Experimente zur Struktur des Nukleons, zur elektromagnetischen, schwachen und starken Wechselwirkung, kurze Einführung in das Standardmodell der Elementarteilchenphysik und Experimente dazu

Literaturhinweise:
C. Berger; Elementarteilchenphysik (Springer, Heidelberg)
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg)
C. Amsler, Kern- und Teilchenphysik (vdf Hochschulverlag, 2007)
D. Griffith; Introduction to Elementary Particle Physics (J. Wiley, Weinheim)
D. Perkins; Introduction to High Energy Physics (Cambridge University Press)
A. Bettini; Introduction to Elementary Particle Physics (Cambridge University Press)

Modul-Nr.: physik520
Leistungspunkte: 9
Kategorie: Pflicht
vorgesehenes Semester: 5.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik IV (Statistische Physik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik IV (Statistische Physik)	physik521	9	Vorl. + Üb.	270 Std.	WS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Klausur unbenotet

Inhalt:
Statistische Mechanik und Thermodynamik

Qualifikationsziel:
Umgang mit Konzepten und Rechenmethoden der Statistischen Physik

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche Bearbeitung der Übungsaufgaben + bestandene Klausur

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
0/163

Modul: Theoretische Physik IV (Statistische Physik)

Modul-Nr.: physik520

Lehrveranstaltung: Theoretische Physik IV (Statistische Physik)

LV-Nr.: physik521

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	9	WS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - III für Physiker (math140, math240, math340)
Theoretische Physik I - III (physik220, physik320, physik420)
Physik I - IV (physik110, physik210, physik310, physik410)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der unbenoteten Klausur: erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Umgang mit Konzepten und Rechenmethoden der Statistischen Physik

Inhalte der LV:
Klassische Thermodynamik:
Hauptsätze, thermodynamische Potentiale, Entropie, ideale/reale Gase, thermodynamische Maschinen, Phasenübergänge
Klassische und Quanten-Statistik:
Mikrokanonische, kanonische und großkanonische Gesamtheit, Dichteoperator, Zustandssumme, Verteilungsfunktion, Fermi- und Bosegas, Bosekondensation, Schwarzkörperstrahlung, Magnetismus, Isingmodell, stochastische Prozesse

Literaturhinweise:
L. Landau, E. Lifschitz; Lehrbuch der Theoretischen Physik Bd. 5: Statistische Physik Teil 1 (Harri Deutsch, Frankfurt a. Main 8. korr. Aufl. 1991)
L. Landau; E. Lifschitz; Lehrbuch der Theoretischen Physik Bd. 9: Statistische Physik Teil 2 (Harri Deutsch, Frankfurt a. Main 4. ber. Aufl. 1992)
R. K. Pathria; Statistical Mechanics (Butterworth Heinemann, Oxford 1996)
L. E. Reichl; A Modern Course in Statistical Physics (Wiley + Sons, Wiesbaden, 2. Aufl. 1998)
F. Schwabl; Statistische Mechanik (Springer, Heidelberg 2. Aufl. 2004)

Modul-Nr.: physik540
Leistungspunkte: 5
Kategorie: Pflicht
vorgesehenes Semester: 5.-6.

Modul: Präsentation

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Proseminar Präsentationstechnik	physik541	3	Proseminar	90 Std.	WS/SS
2.	Seminar zur Bachelorarbeit	physik542	2	Seminar	60 Std.	WS/SS

Teilnahmevoraussetzungen:
keine

Prüfungsform:
Präsentation im Proseminar Präsentationstechnik (60 %) + Präsentation der Bachelorarbeit im Seminar zur Bachelorarbeit (40 %)

Inhalt:
Abfassung von Texten, Relevanz der gewählten Einteilung, Bedeutung von Tabellen und Bildern, Quellenangaben; Vortragsstil, Vortragsgestaltung, Medien.

Qualifikationsziel:
Die Studierenden sollen in die Problematik der Präsentation eingeführt werden, sollen selbst Texte und Vorträge verfassen und schließlich den Vortrag zur Bachelorarbeit halten. Fähigkeiten zu Präsentationen sollen entwickelt werden.

Studienleistung/Kriterien zur Vergabe von LP:

Dauer: 2 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
5/163

Modul: Präsentation

Modul-Nr.: physik540

Lehrveranstaltung: Proseminar Präsentationstechnik

LV-Nr.: physik541

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Seminar mit Übungen	deutsch	3	3	WS/SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Lehrveranstaltungen in der Physik der ersten vier Semester

Studien- und Prüfungsmodalitäten:
Prüfung: Vortrag (ca. 30 min.) + schriftliche Ausarbeitung (3-seitig als wissenschaftlicher Artikel) zu einem vorgegebenen Thema

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen zu einem vorgegebenen Thema Inhalte recherchieren, diese in einem Vortrag präsentieren sowie in einem wissenschaftlichen Fachbericht niederschreiben. Hier sollte auf eine geeignete Stoffauswahl im Hinblick auf die Zielgruppe (die anderen Teilnehmer des Proseminars) geachtet werden. Besonderer Wert liegt auf der Gestaltung des Vortrages (didaktischer Anspruch, logischer Aufbau sowie Design der Folien).

Inhalte der LV:
Die Studierenden bereiten zu einem vorgegebenen Thema einen Vortrag von ca. 30 Minuten Länge vor, den sie im Rahmen des Proseminars vor ihren Kommilitonen präsentieren. Die Themen orientieren sich am Wissensstand von Studierenden des 4./5. Semesters und spiegeln die Gesamtheit der Physik wider. Die gängigen Methoden wissenschaftlicher Präsentation sowohl in mündlicher (Vortrag) als auch in schriftlicher Form werden vom Dozenten erörtert.

Vortrag:
Zielgruppen-orientierter Vortrag, geeignete Gliederung, übersichtliche Foliengestaltung, graphische Darstellung auf den Folien (Erstellen von Abbildungen), Umgang mit Quellenangaben
Körperhaltung beim Vortrag, Blickkontakt mit dem Publikum, Pausen beim Sprechen, Vermeidung von Füllwörtern, Umgang mit Präsenter, Laserpointer und ggf. Tafel
Eingehen auf Fragen während des Vortrags und in der anschließenden Fachdiskussion

Wissenschaftliche Texte:
Erstellen eines wissenschaftlichen Textes in vorgegebenem Format unter Berücksichtigung korrekten Zitierens. Wissenschaftliches Formulieren, Vollständigkeit und Eindeutigkeit der wissenschaftlichen Sprache. Arten wissenschaftlicher Texte, z.B. Bachelorarbeit. Gliederung wissenschaftlicher Texte.

Literaturhinweise:

Modul: Präsentation

Modul-Nr.: physik540

Lehrveranstaltung: Seminar zur Bachelorarbeit

LV-Nr.: physik542

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Seminar	deutsch	2	2	WS/SS

Teilnahmevoraussetzungen:

Empfohlene Vorkenntnisse:
Abgeschlossenes viertes Semester

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Prüfungsteilnahme (Vortrag): regelmäßige Teilnahme

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen lernen über ein Projekt zu berichten. Sie sollen aus den Vorträgen der Kommilitonen ersehen, wie Vorträge gehalten und gestaltet werden sollen

Inhalte der LV:
Die Studierenden sollen über ihre durchgeführten Projekte (die Bachelorarbeit) berichten. Sie sollen zugleich das im Proseminar physik541 (zum Gestalten und Halten von Vorträgen) Gelernte noch einmal in der Praxis unter Beweis stellen

Literaturhinweise:

Modul-Nr.: physik560
Leistungspunkte: 5
Kategorie: Pflicht
vorgesehenes Semester: 5.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Praktikum Atome, Moleküle, Kondensierte Materie

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Praktikum Atome, Moleküle, Kondensierte Materie	physik561	5	Praktikum	150 Std.	WS/SS

Teilnahmevoraussetzungen:
Teilnahme an der Klausur zu Modul physik410

Prüfungsform:
Schriftliche Ausarbeitungen (Ein Versuchsprotokoll pro durchgeführtem Versuch)

Inhalt:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen

Qualifikationsziel:
Verständnis der Grundlagen der Experimente der Atomphysik und der kondensierten Materie. Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten.

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
5/163

Modul: Praktikum Atome, Moleküle, Kondensierte Materie

Modul-Nr.: physik560

Lehrveranstaltung: Praktikum Atome, Moleküle, Kondensierte Materie

LV-Nr.: physik561

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	5	5	WS/SS

Teilnahmevoraussetzungen:
Teilnahme an Physik IV (physik411). Das heißt: erfolgreiche Teilnahme an den Übungen plus Teilnahme an der Modulprüfung physik411

Empfohlene Vorkenntnisse:
Physik I - III (physik110, physik210, physik310)
Theoretische Physik I - III (physik220, physik320, physik420)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Prüfungsteilnahme (Versuchsprotokolle): erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit oder im Blockkurs in der vorlesungsfreien Zeit)

Lernziele der LV:
Verständnis der Grundlagen der Experimente der Atomphysik und der kondensierten Materie. Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten.

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen. Ausgewählte Versuche im Praktikum zur Atomphysik und kondensierten Materie.

Auswahl:
Balmerserie, Frank-Hertz-Versuch, optisches Pumpen; Plancksches Wirkungsquantum; Zeeman-Effekt, Hall-Effekt in Halbleitern, Rastertunnelmikroskopie, kernmagnetische Relaxation, Laser, Weißlichspektroskopie an Gold-Nanostrukturen, Röntgenstrahlung und Materialanalyse, Spektroskopie von Sternen

Literaturhinweise:
C. Kittel; Einführung in die Festkörperphysik (R. Oldenbourg Vlg., München 14. Aufl. 2005)
L. Bergmann, C. Schaefer; Lehrbuch der Experimentalphysik Bd. 6: Festkörperphysik (de Gruyter, Berlin 2. Aufl. 2005)
H. Haken, H.C. Wolf; Atom- und Quantenphysik (Springer, Heidelberg 8. Aufl. 2003)
T. Mayer-Kuckuk; Atomphysik (Teubner, Wiesbaden 5. Aufl. 1997)

Modul-Nr.: physik660
Leistungspunkte: 5
Kategorie: Pflicht
vorgesehenes Semester: 6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Praktikum Kerne und Teilchen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Praktikum Kern- und Teilchenphysik	physik661	5	Praktikum	150 Std.	SS/WS

Teilnahmevoraussetzungen:
Teilnahme an der Klausur zu Modul physik510

Prüfungsform:
Schriftliche Ausarbeitungen (Ein Versuchsprotokoll pro durchgeführtem Versuch)

Inhalt:
Erlernen der physikalischen Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.

Qualifikationsziel:
Verständnis der Grundlagen der Experimente der Kernphysik und der Teilchenphysik.
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten

Studienleistung/Kriterien zur Vergabe von LP:
Erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer: 1 Semester

Max. Teilnehmerzahl: ca. 200

Gewichtung:
5/163

Modul: Praktikum Kerne und Teilchen

Modul-Nr.: physik660

Lehrveranstaltung: Praktikum Kern- und Teilchenphysik

LV-Nr.: physik661

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	5	5	SS/WS

Teilnahmevoraussetzungen:
Teilnahme an Physik V (physik511). Das heißt: erfolgreiche Teilnahme an den Übungen plus Teilnahme an der Modulprüfung physik511

Empfohlene Vorkenntnisse:
Physik I - IV (physik110, physik210, physik310, physik410)
Theoretische Physik I - III (physik220, physik320, physik420)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Prüfungsteilnahme (Versuchsprotokolle): erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit oder im Blockkurs in der vorlesungsfreien Zeit)

Lernziele der LV:
Verständnis der Grundlagen der Experimente der Kernphysik und der Teilchenphysik.
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten

Inhalte der LV:
Erlernen der physikalischen Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
Ausgewählte Versuche im Praktikum zur Kern- und/oder Teilchenphysik.

Auswahl:
Gamma-Spektroskopie, Höhenstrahlung (zählt doppelt), Compton-Effekt, Beta-Spektroskopie, Nukleare Elektronik, Halbleiterdetektoren (zählt doppelt), Driftkammern, Mottstreuung von Elektronen, Dosimetrie

Literaturhinweise:
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2. überarb. Aufl. 2006)
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
E. Bodenstedt; Experimente der Kernphysik und ihre Deutung Bd. 1-3 (Bibliographisches Institut, Mannheim) Titel vergriffen, aber in der ULB vorhanden
T.Mayer-Kuckuk; Kernphysik (Teubner, Wiesbaden 7. Aufl. 2002)

Modul-Nr.: physik670
Leistungspunkte: 3
Kategorie: Pflicht
vorgesehenes Semester: 6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mündliche Übersichtsprüfung Experimentalphysik Teil II

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Übersichtsprüfung Experimentalphysik Teil II	physik671	3	angeleit. Selbstst.	90 Std.	WS/SS

Teilnahmevoraussetzungen:
physik410 und physik510

Prüfungsform:
Mündliche Prüfung (mindestens 30 und höchstens 45 Minuten)

Inhalt:
Mündliche Prüfung über die Inhalte und Zusammenhänge der Module physik410 und physik510 nach angeleitetem Selbststudium

Qualifikationsziel:
Die Studierenden sollen die modulübergreifenden Zusammenhänge der Module physik410 und physik510 erarbeiten, erkennen und mündlich darstellen können.

Studienleistung/Kriterien zur Vergabe von LP:
keine

Dauer: 1 Semester

Max. Teilnehmerzahl:

Gewichtung:
17/163

Modul: Mündliche Übersichtsprüfung Experimentalphysik Teil II

Modul-Nr.: physik670

Lehrveranstaltung: Übersichtsprüfung Experimentalphysik Teil II

LV-Nr.: physik671

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Angeleitetes Selbststudium	deutsch	n.a.	3	WS/SS

Teilnahmevoraussetzungen:
bestandene Module physik410 und -510

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Mündliche Prüfung von mindestens 30, höchstens 45 Minuten

Dauer der Lehrveranstaltung:
Prüfungs-Vorbereitungszeit

Lernziele der LV:
Die Studierenden sollen sich Überblickswissen erarbeiten

Inhalte der LV:
Mündliche Prüfung über den Inhalt der Module physik410 und -510

Literaturhinweise:
Siehe Hinweise zu den Lehrveranstaltungen physik410, -510

Modul-Nr.: physik680
Leistungspunkte: 4
Kategorie: Pflicht
vorgesehenes Semester: 6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mündliche Übersichtsprüfung Theoretische Physik

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Übersichtsprüfung Theoretische Physik	physik681	4	angeleit. Selbstst.	120 Std.	WS/SS

Teilnahmevoraussetzungen:
physik220, physik320, physik420 und physik520

Prüfungsform:
Mündliche Prüfung (mindestens 30 und höchstens 45 Minuten)

Inhalt:
Mündliche Prüfung über die Inhalte und Zusammenhänge von 2 Modulen aus physik220, physik320, physik420 und physik520, davon mindestens ein unbenotetes, nach angeleitetem Selbststudium

Qualifikationsziel:
Die Studierenden sollen die modulübergreifenden Zusammenhänge der Module physik220, physik320, physik420 und physik520 erarbeiten, erkennen und mündlich darstellen können.

Studienleistung/Kriterien zur Vergabe von LP:
keine

Dauer: 1 Semester

Max. Teilnehmerzahl:

Gewichtung:
22/163

Modul: Mündliche Übersichtsprüfung Theoretische Physik

Modul-Nr.: physik680

Lehrveranstaltung: Übersichtsprüfung Theoretische Physik

LV-Nr.: physik681

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Angeleitetes Selbststudium	deutsch	n.a.	4	WS/SS

Teilnahmevoraussetzungen:
bestandene Module physik220, -320, -420 und -520

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Mündliche Prüfung von mindestens 30, höchstens 45 Minuten

Dauer der Lehrveranstaltung:
Prüfungs-Vorbereitungszeit

Lernziele der LV:
Die Studierenden sollen sich Überblickswissen erarbeiten

Inhalte der LV:
Mündliche Prüfung über den Inhalt von 2 Modulen aus physik220, -320, -420 und -520, davon mindestens ein unbenotetes

Literaturhinweise:
Siehe Hinweise zu den Lehrveranstaltungen physik220, -320, -420 und -520

Modul-Nr.:	physik690
Leistungspunkte:	12
Kategorie:	Pflicht
vorgesehenes Semester:	5.-6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Bachelorarbeit

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Bachelorarbeit	physik691	12	BA-Arbeit	360 Std.	WS/SS

Teilnahmevoraussetzungen:
mindestens 90 LP aus dem Bachelorstudium

Prüfungsform:
Bachelorarbeit

Inhalt:
Die Studierenden sollen ein Projekt physikalischer Art durchführen bzw. eine physikalische Fragestellung bearbeiten.
Variante FV:
Die wissenschaftliche Vorbereitung basiert auf dem Inhalt einer weiterführenden/vertiefenden Vorlesung aus den Bereichen Experimentalphysik, Theoretische Physik oder Astronomie/Astrophysik (siehe nächste Seite)
Variante AG:
Die wissenschaftliche Vorbereitung basiert auf der Methoden- und Projektplanung in einer wissenschaftlichen Arbeitsgruppe.

Qualifikationsziel:
Die Studierenden sollen dokumentieren, dass sie in der Lage sind, ein physikalisches Projekt durchzuführen bzw. eine physikalische Fragestellung zu bearbeiten und darüber eine schriftliche Ausarbeitung anzufertigen.

Studienleistung/Kriterien zur Vergabe von LP:
keine

Dauer: 1 Semester

Max. Teilnehmerzahl:

Gewichtung:
12/163

Die Bachelorarbeit kann im Einvernehmen mit der Betreuerin bzw. dem Betreuer wahlweise in deutscher oder englischer Sprache abgefasst werden.

Mögliche Lehrveranstaltungen bei Variante „FV“: Vorlesungen aus den Bereichen Experimentalphysik, Theoretische Physik, Astronomie/Astrophysik

physics611	Particle Physics
physics612	Accelerator Physics
physics618	Physics of Particle Detectors
physics613	Condensed Matter Physics
physics614	Laser Physics and Nonlinear Optics
physics620	Advanced Atomic, Molecular, and Optical Physics
physics615	Theoretical Particle Physics
physics616	Theoretical Hadron Physics
physics617	Theoretical Condensed Matter Physics
physics632	Physics of Hadrons
physics633	High Energy Collider Physics
physics631	Quantum Optics
physics634	Magnetism/Superconductivity
physics640	Photonic Devices
physics606	Advanced Quantum Theory
physics751	Group Theory
physics754	General Relativity and Cosmology
physics755	Quantum Field Theory
astro811	Stars and Stellar Evolution
astro812	Cosmology
astro821	Astrophysics of Galaxies
astro822	Physics of the Interstellar Medium

Modul: Bachelorarbeit

Modul-Nr.: physik690

Lehrveranstaltung: Bachelorarbeit

LV-Nr.: physik691

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Bachelorarbeit	deutsch	n.a.	12	WS/SS

Teilnahmevoraussetzungen:
Das Thema der Bachelorarbeit kann erst ausgegeben werden, wenn die Studentin, der Student mindestens 90 Leistungspunkte aus dem Bachelorstudium erworben hat.

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Die Prüfungsleistung ist eine schriftliche Ausarbeitung über ein selbst durchgeführtes Projekt im Rahmen eines "Praktikums in einer Arbeitsgruppe" oder über ein selbst bearbeitetes Thema einer weiterführenden/vertiefenden Wahlpflichtvorlesung (s. oben genannte Lehrveranstaltungen). Sie soll in der Regel den Umfang von 20 DIN A4 Seiten nicht überschreiten. Die Bestätigung über die erfolgreiche Durchführung des Praktikums in der Arbeitsgruppe bzw. über die Teilnahme an der Vorlesung wird zusammen mit der Beurteilung der schriftlichen Ausarbeitung von der betreuenden Dozentin / dem betreuenden Dozenten vorgenommen. Die Note der Bachelorarbeit wird durch die Beurteilung der schriftlichen Ausarbeitung festgelegt und wird mit dem Gewicht von 12 Leistungspunkten in der Endnote berücksichtigt. Das Modul muss insgesamt innerhalb von 4 Monaten abgeschlossen werden. Auf begründeten Antrag hin kann der Prüfungsausschuss eine Verlängerung der Bearbeitungszeit um bis zu 4 Wochen genehmigen.

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen dokumentieren, dass sie in der Lage sind, ein physikalisches Projekt durchzuführen bzw. eine physikalische Fragestellung zu bearbeiten und darüber eine schriftliche Ausarbeitung anzufertigen.

Inhalte der LV:
Die Studierenden sollen ein Projekt physikalischer Art durchführen bzw. eine physikalische Fragestellung bearbeiten.
Variante FV:
Die wissenschaftliche Vorbereitung basiert auf dem Inhalt einer weiterführenden/vertiefenden Vorlesung aus den Bereichen Experimentalphysik, Theoretische Physik oder Astronomie/Astrophysik
Variante AG:
Die wissenschaftliche Vorbereitung basiert auf der Methoden- und Projektplanung in einer wissenschaftlichen Arbeitsgruppe.

Literaturhinweise:
siehe die entsprechenden Modulbeschreibungen des Masterstudienganges Physik bzw. Astrophysik

Wichtig: Falls Variante "AG" gewählt wird, kann der Antrag auf Genehmigung des Themas beim Prüfungsausschuss zu jedem Zeitpunkt von der Studentin, dem Studenten gestellt werden. Falls Variante "FV" gewählt wird, soll der Beginn der Bachelorarbeit bzw. die gewählte Lehrveranstaltung im Wintersemester bis zum 30. November und im Sommersemester bis zum 31. Mai vom Prüfungsausschuss genehmigt worden sein, damit die Bachelorarbeit noch im selben Semester abgeschlossen werden kann.

s. auch http://bamawww.physik.uni-bonn.de

Modul-Nr.: zus.Angebote
Leistungspunkte:
Kategorie:
Semester:

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Zusätzliche Angebote

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physics in the Private Sector	PhysPrivSec	0		90 hrs	

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Inhalt:

Lernziele/Kompetenzen:

Prüfungsmodalitäten:

Dauer des Moduls:

Max. Teilnehmerzahl:

Anmeldeformalitäten:

Modul: Zusätzliche Angebote

Modul-Nr.: zus.Angebote

Lehrveranstaltung: Physics in the Private Sector

LV-Nr.: PhysPrivSec

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Elective	Lecture with exercises	English	2+1	0	

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematical, theoretical and experimental foundations in physics

Studien- und Prüfungsmodalitäten:
Requirements for the module examination (written examination): successful work with exercises

Dauer der Lehrveranstaltung:
1 semester

Lernziele der LV:
The vast majority of graduates with a physics degree or a doctorate in physics work in the private sector in very different areas, ranging from industrial research and software development to management consultancies, financial institutions and patent attorneys. In this lecture, the basics of these different fields are explained, deepened in the exercises and supplemented by guest lectures by physicists from the private sector.

Successful participants will receive a document about their attendance and the course contents.

Inhalte der LV:
- Management Consulting
- Financial Physics
- Professional Software Development
- Patent Law
- Physics in Insurances
- Simulations in Physics
- Entrepreneurship

Literaturhinweise:
- Grundprinzipien der Finanz- und Versicherungsmathematik: Grundlagen und Anwendungen der Bewertung von Zahlungsströmen, Peter Albrecht
- Patentrecht für Studierende der Naturwissenschaften: Eine kompakte Einführung in die Grundlagen, Gernot Krobath
- A Friendly Guide to Software Development: What You Should Know Without Being a Developer (Friendly Guides to Technology) (English Edition), Leticia Portella
- Cracked it!: How to solve big problems and sell solutions like top strategy consultants, Bernard Garrette , Corey Phelps

Module-Handbook
Master in Physics
PO von 2014

SS 2024

July 2024

We don’t offer each of these modules regularly.

For any update please see:

https://www.physik-astro.uni-bonn.de/de/studium/

lehrveranstaltungen/termine-und-lehrveranstaltungen

Master of Physics

Rheinische Friedrich-Wilhelms-Universität Bonn

(valid from WS 2014/2015)

Course Phase

Compulsory

1. Sem. – 2. Sem.	Feb – May	physics601: Advanced Laboratory Course	7 cp

Elective

1. Sem. – 2. Sem.	Oct – July	Theoretical Physics (**physics606** or - if done previously - 1 module out of physics751, physics754, physics755, physics760, physics7501)	7 cp
1. Sem. – 2. Sem.	Oct – July	Specialization (at least 24 cp out of physics61a, -61b, -61c and/or physics62a, -62b, -62c)	24 cp
1. Sem. – 2. Sem.	Oct – Sep	Elective Advanced Lectures (at least 18 cp out of physics70a, -70b, -70c, -70d)	18 cp
2. Sem.	Apr – July	Seminar (1 seminar out of physics65a, -65b, -65c)	4 cp

Research Phase

3. Sem.	Oct – Mar	physics910: Scientific Exploration of the Master thesis topic	15 cp
3. Sem.	Oct – Mar	physics920: Methods and Project Planning	15 cp
4. Sem.	Apr – Sep	physics930: Master Thesis	30 cp

Table of Contents: M.Sc. in Physics (PO von 2014)

physics601 Advanced Laboratory Course 1
physics601 Advanced Laboratory Course 2
ECThPhysics Elective Courses Theoretical Physics 4
physics606 Advanced Quantum Theory 5
physics751 Group Theory (T) 6
physics754 General Relativity and Cosmology (T) 7
physics755 Quantum Field Theory (T) 8
physics760 Computational Physics (T) 9
physics7501 Advanced Quantum Field Theory (T) 10
physics61a Specialization: Experimental Physics 11
physics611 Particle Physics 12
physics612 Accelerator Physics 13
physics618 Physics of Particle Detectors 14
physics613 Condensed Matter Physics 15
physics620 Advanced Atomic, Molecular, and Optical Physics 16
physics631 Quantum Optics 17
Condensed Matter Physics I 18
Molecular Physics I 19
physics62a Specialization: Advanced Experimental Physics 20
physics632 Physics of Hadrons 21
physics633 High Energy Collider Physics 22
physics639 Advanced Topics in High Energy Particle Physics 23
physics634 Magnetism/Superconductivity 24
physics641 Photonics 25
physics642 Quantum Technology 26
Molecular Physics II 27
physics61b Specialization: Applied Physics 28
physics62b Specialization: Advanced Applied Physics 29
physics61c Specialization: Theoretical Physics 30
physics615 Theoretical Particle Physics 31
physics616 Theoretical Hadron Physics 32
physics617 Theoretical Condensed Matter Physics 33
Solid State Theory I 34
physics62c Specialization: Advanced Theoretical Physics 35
physics636 Advanced Theoretical Particle Physics 36
physics637 Advanced Theoretical Hadron Physics 37
physics638 Advanced Theoretical Condensed Matter Physics 38
physics65a Seminar: Experimental Physics 39
physics65b Seminar: Applied Physics 40
physics65c Seminar: Theoretical Physics 41
physics70a Elective Advanced Lectures: Experimental Physics 42
physics711 Particle Astrophysics and Cosmology (E) 43
physics712 Advanced Electronics and Signal Processing (E/A) 44
physics713 Particle Detectors and Instrumentation (E/A) 45
physics714 Advanced Accelerator Physics (E/A) 46
physics715 Experiments on the Structure of Hadrons (E) 47
physics716 Statistical Methods of Data Analysis (E) 48
physics717 High Energy Physics Lab (E) 49

physics718 Programming in Physics and Astronomy with C++ or Python (E/A) 50
physics719 Intensive Week: Advanced Topics in High Energy Physics (E) 51
physics720 Physics with Antiprotons (E) 52
physics721 Intensive Week: Advanced Topics in Hadron Physics (E) 53
physics722 Advanced Gaseous Detectors - Theory and Practice (E) 54
physics723 Hands-on Seminar: Detector Construction (E/A) 55
physics724 Advanced Methods of Data Analysis (E) 56
physics725 Scientific Programming with Python (E/A) 57
physics731 Low Temperature Physics (E/A) 58
physics732 Optics Lab (E/A) 59
physics734 Holography (E/A) 60
physics735 Laser Cooling and Matter Waves (E) 61
physics736 Crystal Optics (E/A) 62
physics737 Intensive Week: Advanced Topics in Photonics and Quantum Optics (E) 63
physics738 Lecture on Advanced Topics in Quantum Optics (E) 64
physics739 Lecture on Advanced Topics in Photonics (E/A) 65
physics740 Hands-on Seminar: Experimental Optics and Atomic Physics (E/A) 66
physics741 Modern Spectroscopy (E/A) 67
physics742 Ultracold Atomic Gases (E/T) 68
physics743 Platforms for Quantum Technologies (E) 69
physics744 Precision Metrology (E) 70
physics799 Research Project 71
physics70b Elective Advanced Lectures: Applied Physics 72
physics712 Advanced Electronics and Signal Processing (E/A) 73
physics713 Particle Detectors and Instrumentation (E/A) 74
physics714 Advanced Accelerator Physics (E/A) 75
physics725 Scientific Programming with Python (E/A) 76
physics718 Programming in Physics and Astronomy with C++ or Python (E/A) 77
physics723 Hands-on Seminar: Detector Construction (E/A) 78
physics731 Low Temperature Physics (E/A) 79
physics732 Optics Lab (E/A) 80
physics734 Holography (E/A) 81
physics736 Crystal Optics (E/A) 82
physics739 Lecture on Advanced Topics in Photonics (E/A) 83
physics740 Hands-on Seminar: Experimental Optics and Atomic Physics (E/A) 84
physics741 Modern Spectroscopy (E/A) 85
physics771 Environmental Physics & Energy Physics (A) 86
physics772 Physics in Medicine: Fundamentals of Analyzing Biomedical Signals (A) 87
physics773 Physics in Medicine: Fundamentals of Medical Imaging (A) 88
physics774 Electronics for Physicists (E/A) 89
physics775 Nuclear Reactor Physics (A) 90
physics776 Physics in Medicine: Physics of Magnetic Resonance Imaging (A) 91
physics777 Physics in Medicine: Cardiovascular Magnetic Resonance Imaging (CMRI) (A) 92
physics778 "Energy Production" (A) 94
physics799 Research Project 95
physics70c Elective Advanced Lectures: Theoretical Physics 96
physics742 Ultracold Atomic Gases (E/T) 97
physics751 Group Theory (T) 98
physics752 Superstring Theory (T) 99
physics753 Theoretical Particle Astrophysics (T) 100
physics754 General Relativity and Cosmology (T) 101

physics755 Quantum Field Theory (T) ... 102
physics756 Critical Phenomena (T) ... 103
physics757 Effective Field Theory (T) ... 104
physics758 Quantum Chromodynamics (T) ... 105
physics759a Quantum Field Theory for Condensed Matter Physics (T) ... 106
physics759b Advanced Quantum Field Theory for Condensed Matter Physics (T) ... 107
physics760 Computational Physics (T) ... 108
physics761 Supersymmetry (T) ... 109
physics762 Transport in mesoscopic systems (T) ... 110
physics763 Advanced Topics in String Theory (T) ... 111
physics764 Advanced Topics in Field and String Theory (T) ... 112
physics765 Advanced Topics in Quantum Field Theory (T) ... 113
physics766 Physics of Higgs Bosons (T) ... 114
physics767 Computational Methods in Condensed Matter Theory (T) ... 115
physics768 General Relativity for Experimentalists (T) ... 116
physics769 Lattice QCD (T) ... 117
physics7501 Advanced Quantum Field Theory (T) ... 118
physics7502 Random Walks and Diffusion (T) ... 119
physics7503 Selected Topics in Modern Condensed Matter Theory (T) ... 120
physics7504 Theory of Superconductivity and Superfluidity (T) ... 121
physics7505 High performance computing: Modern computer architectures and applications ... 122
physics7506 Quark Distributions Functions (T) ... 123
physics7507 Theory of Quantum Magnetism (T) ... 124
physics7508 Quantum Computing (T) ... 125
physics7509 Advanced Topics in Particle and Astroparticle Physics (T) ... 126
physics7510 QCD at colliders (T) ... 127
physics7511 Introduction to Integrability (T) ... 128
physics7512 Introduction to Random Matrix Theory (T) ... 129
physics7513 Introduction to Conformal Field Theory (T) ... 130
physics7514 Introduction to Quantum Computing (T) ... 131
physics7515 Introduction to the AdS/CFT Correspondence (T) ... 132
physics7516 Machine Learning for Quantum Scientists (T) ... 133
physics7517 Quantum chaos: tools and applications (T) ... 134
physics799 Research Project ... 136
physics70d Elective Advanced Lectures: BCGS Courses ... 137
Relativity and Cosmology I (T) ... 138
Relativity and Cosmology II (T) ... 139
Quantum Field Theory I (T) ... 140
Quantum Field Theory II (T) ... 141
Geometry in Physics (T) ... 142
Topology for Physicists (T) ... 143
Nuclear physics II (E) ... 144
Physics of Detectors (E/A) ... 145
Particle physics (E) ... 146
Groundbreaking experiments in nuclear physics (E) ... 147
Condensed Matter Physics II (E) ... 148
Semiconductor Physics and Nanoscience (E/A) ... 149
Superconductivity (E/A) ... 150
Magnetism (E/A) ... 151
Experimental methods in condensed matter physics (E/A) ... 152
Physics of Surfaces and Nanostructures (E/A) ... 153

Introduction to neutron scattering (E/A) 154
Optical Spectroscopy (E/A) 155
Astrochemistry (E/A) 156
Fundamentals of Molecular Symmetry (E/A/T) 157
Physical biology (T/A) 158
Statistical physics of soft matter and biomolecules (T/A) 159
Statistical physics far from equilibrium (T) 160
Disordered systems (T) 161
Nonequilibrium physics with interdisciplinary applications (T) 162
Probability theory and stochastic processes for physicists (T) 163
physics910 Scientific Exploration of the Master Thesis Topic 164
physics920 Methods and Project Planning 165
physics930 Master Thesis 166
add. Courses additional courses 167
PhysPrivSec Physics in the Private Sector 168

Degree: M.Sc. in Physics (PO von 2014)

Module No.: physics601
Credit Points (CP): 7
Category: Required
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Advanced Laboratory Course

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Laboratory Course	physics601	7	Laboratory	210 hrs	WT/ST

Requirements for Participation:

Form of Examination:
written report for every laboratory

Content:
Every student has to complete this Laboratory Course. The course consists of advanced experiments introducing into important subfields of contemporary experimental physics and astrophysics. The lab-course is accompanied by a seminar.

Aims/Skills:
The students shall gain insight in the conceptual and complex properties of relevant contemporary experiments. The students gain experience in setting up an experiment, data logging and data analysis. They experience the intricacies of forefront experimental research

Course achievement/Criteria for awarding cp's:
Before carrying out an experiment, the students shall demonstrate to have acquired the necessary preparatory knowledge. Experiments are selected from the catalogue of laboratory set-ups offered. Cumulative lab-units of >= 9 are required.
Requirements for the examination (written report for every laboratory): successful completion of the experiment and initial oral questioning plus seminar talk

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Advanced Laboratory Course

Module No.: physics601

Course: Advanced Laboratory Course

Course No.: physics601

Category	Type	Language	Teaching hours	CP	Semester
Required	Laboratory	English	3+2	7	WT/ST

Requirements for Participation:
Lab course physik661 "Praktikum Kerne und Teilchen" or successful completion of the experiment "Nuclear electronics and lifetime measurement" of physik661.

Preparation:
An appropriate knowledge of the physics background and the experimental environment of the laboratories is required. Recommended lectures are specified in the catalogue of laboratories.

Form of Testing and Examination:
Experiments are selected from the catalogue of laboratory setups offered. Five experiments are required. One of the experiments 1-3 is compulsory for physics students. Two of the experiments 14-17 are compulsory for astrophysics students. Requirements for the module examination (written report for every laboratory): successful completion of the experiment and initial oral questioning

Length of Course:
1 semester

Aims of the Course:
The student shall gain insight in the intricate workings of physics in relevant advanced experiments. The student gains experience in the setting up of a proper experimental environment and experiences the intricacies of forefront experimental research and presenting his/her results.

Contents of the Course:
Advanced experiments are carried out. Experimenting time ~8 to 16 hrs, preparation time and report writing each ~15 hrs. The experiments are chosen among those being offered and after consultation with the head of the course.
In the accompanying seminar the students report about one experiment. This experiment will be selected after consultation with the head of the course.

Recommended Literature:
Hand outs and literature will be distributed with the registration for an experiment

Catalogue of laboratories: (subject to change, for an up-to-date catalogue see https://www.physik-astro.uni-bonn.de/praktika/en/modules/physics601)

1. Analysis of decays of heavy vector boson Z0
2. ATLAS
3. Investigation of particle-antiparticle oscillations at BELLE-II
4. Radiofrequency cavities for particle acceleration
5. Lab course accelerator Bonn (LAB)
6. Properties of elementary particles
7. STYX
8. Positron lifetime in metals and insulators
9. Nuclear y-y angular correlations
10. Optical frequency doubling
11. Laser spectroscopy
12. Magneto-optic trap

13. Laser Gyroscope
14. Optical astronomy (Recommended: astro800 Introduction to Astrophysics or an equivalent basic knowledge in astrophysics)
15. Setting up a Radio-astronomical receiver / Setting up a Radio Interferometer (Recommended: lecture astro123 "Einführung in die Radioastronomie" or lecture astro841 Radio Astronomy: tools, application, impacts)
16. Photometry of star clusters
17. Radio astronomical observing course (Recommended: lecture astro123 "Einführung in die Radioastronomie" or lecture astro841 Radio Astronomy: tools, application, impacts

Module No.: ECThPhysics
Credit Points (CP): 7
Category: Elective
Semester: 1.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Elective Courses Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Quantum Theory	physics606	7	Lect. + ex.	210 hrs	WT
2.	Group Theory (T)	physics751	7	Lect. + ex.	210 hrs	WT
3.	General Relativity and Cosmology (T)	physics754	7	Lect. + ex.	210 hrs	ST
4.	Quantum Field Theory (T)	physics755	7	Lect. + ex.	210 hrs	ST
5.	Computational Physics (T)	physics760	7	Lect. + ex. + proj.	210 hrs	WT/ST
6.	Advanced Quantum Field Theory (T)	physics7501	7	Lect. + ex.	210 hrs	WT

Requirements for Participation:
for physics606: none
for all other modules: physics606

Form of Examination:
written examination

Content:
see with the course

Aims/Skills:
see with the course

Course achievement/Criteria for awarding cp's:
successfull work with the exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

at least 7 cp out of this area must be achieved

Module: Elective Courses Theoretical Physics

Module No.: ECThPhysics

Course: Advanced Quantum Theory

Course No.: physics606

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
Ability to solve problems in relativistic quantum mechanics, scattering theory and many-particle theory

Contents of the Course:
Born approximation, partial waves, resonances
advanced scattering theory: S-matrix, Lippman-Schwinger equation
relativistic wave equations: Klein-Gordon equation, Dirac equation
representations of the Lorentz group
many body theory
second quantization
basics of quantum field theory
path integral formalism
Greens functions, propagator theory

Recommended Literature:
L. D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.3 Quantum Mechanics (Butterworth-Heinemann 1997)
J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley 1995)
F. Schwabl, Advanced Quantum Mechanics. (Springer, Heidelberg 3rd Ed. 2005)

Modules:

ECThPhysics **Elective Courses Theoretical Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: universitätbonn Group Theory (T)

Course No.: physics751

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
physik421 (Quantum Mechanics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Acquisition of mathematical foundations of group theory with regard to applications in theoretical physics

Contents of the Course:
Mathematical foundations:
Finite groups, Lie groups and Lie algebras, highest weight representations, classification of simple Lie algebras, Dynkin diagrams, tensor products and Young tableaux, spinors, Clifford algebras, Lie super algebras

Recommended Literature:
B. G. Wybourne; Classical Groups for Physicists (J. Wiley & Sons 1974)
H. Georgi; Lie Algebras in Particle Physics (Perseus Books 2. Aufl. 1999)
W. Fulton, J. Harris; Representation Theory (Springer, New York 1991)

Modules:	ECThPhysics	**Elective Courses Theoretical Physics**
	physics70c	**Elective Advanced Lectures: Theoretical Physics**

Course: universitätbonn General Relativity and Cosmology (T)

Course No.: physics754

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
physik221 and physik321 (Theoretical Physics I and II)
Differential geometry

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the general theory of relativity and its cosmological implications

Contents of the Course:
Relativity principle
Gravitation in relativistic mechanics
Curvilineal coordinates
Curvature and energy-momentum tensor
Einstein-Hilbert action and the equations of the gravitational field
Black holes
Gravitational waves
Time evolution of the universe
Friedmann-Robertson-Walker solutions

Recommended Literature:
S.Weinberg; Gravitation and Cosmology (J. Wiley & Sons 1972)
R. Sexl: Gravitation und Kosmologie, Eine Einführung in die Allgemeine Relativitätstheorie (Spektrum Akadem. Verlag 5. Aufl 2002)
L.D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.2: Classical field theory (Butterworth-Heinemann 1995), also available in German from publisher Harry Deutsch

Modules:

ECThPhysics	**Elective Courses Theoretical Physics**
physics70c	**Elective Advanced Lectures: Theoretical Physics**

Course: Quantum Field Theory (T)

Course No.: physics755

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
Advanced quantum theory (physics606)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding quantum field theoretical methods, ability to compute processes in quantum electrodynamics (QED) and many particle systems

Contents of the Course:
Classical field theory
Quantization of free fields
Path integral formalism
Perturbation theory
Methods of regularization: Pauli-Villars, dimensional
Renormalizability
Computation of Feynman diagrams
Transition amplitudes in QED
Applications in many particle systems

Recommended Literature:
N. N. Bogoliubov, D.V. Shirkov; Introduction to the theory of quantized fields (J. Wiley & Sons 1959)
M. Kaku, Quantum Field Theory (Oxford University Press 1993)
M. E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Harper Collins Publ. 1995)
L. H. Ryder; Quantum Field Theory (Cambridge University Press 1996)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Modules:

ECThPhysics **Elective Courses Theoretical Physics**

physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: Computational Physics (T)

Course No.: physics760

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises and project work	English	2+2+1	7	WT/ST

Requirements for Participation:
Knowledge of a modern programming language (like C, C++)

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
successful participation in exercises,
presentation of an independently completed project

Length of Course:
1 semester

Aims of the Course:
ability to apply modern computational methods for solving physics problems

Contents of the Course:
Statistical Models, Likelihood, Bayesian and Bootstrap Methods
Random Variable Generation
Stochastic Processes
Monte-Carlo methods
Markov-Chain Monte-Carlo

Recommended Literature:
W.H. Press et al.: Numerical Recipes in C (Cambridge University Press)
http://library.lanl.gov/numerical/index.html
C.P. Robert and G. Casella: Monte Carlo Statistical Methods (Springer 2004)
Tao Pang: An Introduction to Computational Physics (Cambridge University Press)
Vesely, Franz J.: Computational Physics: An Introduction (Springer)
Binder, Kurt and Heermann, Dieter W.: Monte Carlo Simulation in Statistical Physics (Springer)
Fehske, H.; Schneider, R.; Weisse, A.: Computational Many-Particle Physics (Springer)

Modules:

ECThPhysics **Elective Courses Theoretical Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: Advanced Quantum Field Theory (T)

Course No.: physics7501

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
3-year theoretical physics course with extended interest in theoretical physics and mathematics

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to modern methods and developments in Theoretical Physics in regard to current research

Contents of the Course:
Selected Topics in Modern Theoretical Physics for example:
Anomalies
Solitons and Instantons
Quantum Fluids
Bosonization
Renormalization Group
Bethe Ansatz
Elementary Supersymmetry
Gauge Theories and Differential Forms
Applications of Group Theory

Recommended Literature:
M. Nakahara; Geometry, Topology and Physics (Institute of Physics Publishing, London 2nd Ed. 2003)
R. Rajaraman; Solitons and Instantons, An Introduction to Solitons and Instantons in Quantum Field Theory (North Holland Personal Library, Amsterdam 3rd reprint 2003)
A. M. Tsvelik; Quantum Field Theory in Condensed Matter Physics (Cambridge University Press 2nd Ed. 2003)
A. Zee; Quantum Field Theory in a Nutshell (Princeton University Press 2003)

Module No.: physics61a
Credit Points (CP): 6
Category: Elective
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Specialization: Experimental Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Particle Physics	physics611	6	Lect. + ex.	180 hrs	WT
2.	Accelerator Physics	physics612	6	Lect. + ex.	180 hrs	WT
3.	Physics of Particle Detectors	physics618	6	Lect. + ex.	180 hrs	WT
Condensed Matter and Photonics						
1.	Condensed Matter Physics	physics613	6	Lect. + ex.	180 hrs	WT
2.	Advanced Atomic, Molecular, and Optical Physics	physics620	6	Lect. + ex.	180 hrs	WT
3.	Quantum Optics	physics631	6	Lect. + ex.	180 hrs	WT
4.	Condensed Matter Physics I	CondMatter I	6	Lect. + ex.	180 hrs	WT
5.	Molecular Physics I	MolPhys I	6	Lect. + ex.	180 hrs	WT

Requirements for Participation:

Form of Examination:
see with the course

Content:
Fundamentals in experimental physics in Bonn or Cologne

Aims/Skills:
The students will get acquainted with modern research topics

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 24 CP out of all 6 Specialization Modules

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Particle Physics

Course No.: physics611

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Introductory particle physics and quantum mechanics courses

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the fundamentals of particle physics: properties of quarks and leptons and their interactions (electromagnetic, weak, strong), experiments that have led to this understanding, the Standard Model of particle physics and measurements that test this model, the structure of hadrons

Contents of the Course:
Basics: leptons and quarks, antiparticles, hadrons, forces / interactions, Feynman graphs, relativistic kinematics, two-body decay, Mandelstam variables, cross-section, lifetime
Symmetries and Conservation Laws. Positronium, Quarkonium. Accelerators and Detectors
Electromagnetic interactions: (g-2) experiments, lepton-nucleon scattering
Strong interactions: colour, gauge principle, experimental tests of QCD. Electroweak interactions and the Standard Model of particle physics: spontaneous symmetry breaking, Higgs mechanism, experimental tests of the Standard Model. Neutrino physics, neutrino oscillations; CP violation

Recommended Literature:
F Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1. Aufl. 1984)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2. überarb. Aufl. 2006)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
D. Griffith; Introduction to Elementary Particle Physics (J. Wiley, Weinheim 1. Aufl. 1987)
A. Seiden; Particle Physics : A Comprehensive Introduction (2005)
Martin & Shaw; Particle Physics, Wiley (2nd edition, 1997)

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Accelerator Physics

Course No.: physics612

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the functional principle of different types of particle accelerators
Layout and design of simple magneto-optic systems
Basic knowledge of radio frequency engineering and technology
Knowledge of linear beam dynamics in particle accelerators

Contents of the Course:
Elementary overview of different types of particle accelerators: electrostatic and induction accelerators, RFQ, Alvarez, LINAC, Cyclotron, Synchrotron, Microtron
Subsystems of particle accelerators: particle sources, RF systems, magnets, vacuum systems
Linear beam optics: equations of motion, matrix formalism, particle beams and phase space
Circular accelerators: periodic focusing systems, transverse beam dynamics, longitudinal beam dynamics
Guided tours through the ELSA accelerator of the Physics Institute and excursions to other particle accelerators (COSY, MAMI, HERA, ...) complementing the lecture

Recommended Literature:
F. Hinterberger; Physik der Teilchenbeschleuniger und Ionenoptik (Springer Heidelberg 1997)
H. Wiedemann; Particle Accelerator Physics (Springer, Heidelberg 2. Aufl. 1999)
K. Wille; Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen (Teubner, Wiesbaden 2. Aufl. 1996)
D. A. Edwards, M.J. Syphers; An Introduction to the Physics of High Energy Accelerators, Wiley & Sons 1993)
Script of the Lecture "Particle Accelerators"
http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Physics of Particle Detectors

Course No.: physics618

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Useful: physik510

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the basics of the physics of particle detectors, their operation and readout

Contents of the Course:
Physics of detectors and detection mechanisms, interactions of charged particles and photons with matter, ionization detectors, drift and diffusion, gas filled wire chambers, proportional and drift chambers, semiconductor detectors, microstrip detectors, pixel detectors, radiation damage, cerenkov detectors, transition radiation detectors, scintillation detectors (anorganic crystals and plastic scintillators), electromagnetic calorimeters, hadron calorimeters, readout techniques, VLSI readout and noise

Recommended Literature:
Wermes: Skriptum and web-based Teaching Module
K. Kleinknecht; Detectors for Particle Radiation (Cambridge University Press 2nd edition 1998)
W.R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2nd ed. 1994)
H. Spieler, Semiconductor detector system (Oxford University Press 2005)
L. Rossi, P. Fischer, T. Rohe, N. Wermes, Pixel Detectors: From Fundamentals to Applications (Springer 2006)

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Condensed Matter Physics

Course No.: physics613

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the concepts of condensed matter physics

Contents of the Course:
Crystallographic structures: Bravais lattices, Millers indices, crystallographic defects, structural analysis;
Chemical bonds: van der Waals bond, covalent bond, hybridisation, ionic bond, metallic bond, Hydrogen bridge bond;
Lattice vibrations: acoustic and optical phonons, specific heat, phonon-phonon interaction;
Free electrons in the solid state: free electron gas, Drude model, Fermi distribution, specific heat of the electrons;
Band structure: metals, semiconductors, insulators, effective masses, mobility of charge carrier, pn-transition, basic principles of diodes, bipolar and unipolar transistors;
Superconductivity: basic phenomena, Cooper pairs, BSC-theory and its consequences;
Magnetic properties: diamagnetism, Langevin-theory of paramagnetism, Pauli-paramagnetism, spontaneous magnetic order, molecular field, Heisenberg-exchange;
Nuclear solid state physics: Hyperfine interaction, Mössbauer spectroscopy, perturbed angular correlation, positron annihilation, typical applications.

Recommended Literature:
N. W. Ashcroft , N. D. Mermin , Solid State Physics (Brooks Cole 1976) ISBN-13: 978-0030839931
N. W. Ashcroft , N. D. Mermin, Festkörphysik (Oldenbourg 2001) ISBN-13: 978-3486248340
H. Ibach, H. Lüth, Solid-State Physics (Springer 2003) ISBN-13: 978-3540438700
H. Ibach, H. Lüth, Festkörperphysik (Springer 2002) ISBN-13: 978-3540427384
C. Kittel, Einführung in die Festkörperphysik (Oldenbourg 2006) ISBN-13: 978-3-486-57773-5
W. Demtröder, Experimentalphysik, Bd. 3. Atome, Moleküle und Festkörper (Springer 2005) ISBN-13: 978-3540214731
K. Kopitzki, P. Herzog Einführung in die Festkörperphysik (Vieweg+Teubner 2007) ISBN-13: 978-3835101449
L. Bergmann, C. Schaefer, R. Kassing, Lehrbuch der Experimentalphysik 6.: Festkörper (Gruyter 2005) ISBN-13: 978-3110174854
W. Buckel, R. Kleiner, Supraleitung (Wiley-VCH 2004) ISBN-13: 978-3527403486

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Advanced Atomic, Molecular, and Optical Physics

Course No.: physics620

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Fundamentals of Quantum Mechanics, Atomic Physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to give the students a deeper insight to the field of atomic, molecular and optical (AMO) physics. Building on prior knowledge from the Bachelor courses it will cover advanced topics of atomic and molecular physics, as well as the interaction of light and matter.

Contents of the Course:
Atomic physics: Atoms in external fields; QED corrections: Lamb-Shift; Interaction of light and matter: Lorentz oscillator, selection rules; magnetic resonance; Coherent control

Molecular physics: Hydrogen Molecule; Vibrations and rotations of molecules; Hybridization of molecular orbitals; Feshbach Resonances; Photoassociation; Cold Molecules

Bose Condensation; Matterwave Optics

Recommended Literature:
C. J. Foot, Atomic Physics, Oxford University Press 2005
H. Haken, The physics of atoms and quanta, Springer 1996
S. Svanberg, Atomic and molecular spectroscopy basic aspects and practical applications, Springer 2001
W. Demtröder, Molecular Physics, Wiley VCH 2005
T. Buyana, Molecular physics, World Scientific 1997
W. Demtröder, Atoms, Molecules and Photons, Springer 2010
P, Meystre, Atom Optics, Springer 2010

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Quantum Optics

Course No.: physics631

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Examination written or oral (announced at the beginning of the module).
Prerequisite for participation in the exam: successful work within the exercises.

Length of Course:
1 semester

Aims of the Course:
Make the students understand quantum optics and enable them to practically apply their knowledge in research and development.

Contents of the Course:
Quantization of the electromagnetic field, single-mode quantum optics
Representations of the light field; Quasi-probabilities
Coherence, correlation functions;
Nonclassical light
Interaction of quantized radiation and atoms;
Introduction to quantum information

Recommended Literature:
R. Loudon; The quantum theory of light (Oxford University Press 2000)
G. J. Milburn, D. F. Walls; Quantum Optics (Springer 1994)
C. Gerry, P. Knight; Introductory quantum optics (Cambridge University Press 2004)
D. Meschede; Optics, Light and Lasers (Wiley-VCH, 3rd ed. 2017)
M. O. Scully, M. S. Zubairy; Quantum Optics (Cambridge 1997)
P. Meystre, M. Sargent; Elements of Quantum Optics (Springer 1999)

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Condensed Matter Physics I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral or written examination

Length of Course:
2 semesters

Aims of the Course:
Comprehensive introduction to the basic principles of solid state physics and to some experimental methods. Examples of current research will be discussed.

Contents of the Course:
The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:
Crystal structure and binding
Reciprocal space
Lattice dynamics and thermal properties
Electronic structure (free-electron gas, Fermi surface, band structure)
Semiconductors and metals
Transport properties
Dielectric function and screening
Superconductivity
Magnetism

Recommended Literature:
Skriptum (available during the course)
Ashcroft/Mermin: Solid State Physics
Kittel: Introduction to Solid State Physics
Ibach/Lüth: Festkörperphysik

Module: Specialization: Experimental Physics

Module No.: physics61a

Course: Molecular Physics I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the first part of the core courses the students learn the main concepts of molecular physics: separation of electronic, vibrational and rotational motion. Simple molecular spectra can be analyzed on the basis of the problem class. Fundamental group theory is used to predict vibrational and rotational spectra of more complex molecules.

This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Basics of molecular spectroscopy, phenomenology, diatomic molecules
- Born-Oppenheimer Approximation, separation of rotation and vibration
- Molecular Dipole moment and rotational transitions
- Rotational spectra and the rigid rotor approach
- Selection rules, parallel and perpendicular type spectra
- Nuclear spin statistics
- Hyperfine structure of molecular lines

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module No.: physics62a
Credit Points (CP): 6
Category: Elective
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Specialization: Advanced Experimental Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Physics of Hadrons	physics632	6	Lect. + ex.	180 hrs	ST
2.	High Energy Collider Physics	physics633	6	Lect. + ex.	180 hrs	ST
3.	Advanced Topics in High Energy Particle Physics	physics639	6	Lect. + ex.	180 hrs	ST
Condensed Matter and Photonics						
1.	Magnetism/Superconductivity	physics634	6	Lect. + ex.	180 hrs	ST
2.	Photonics	physics641	6	Lect. + ex.	180 hrs	ST
3.	Quantum Technology	physics642	6	Lect. + ex.	180 hrs	ST
4.	Molecular Physics II	MolPhys II	6	Lect. + ex.	180 hrs	ST

Requirements for Participation:

Form of Examination:
see with the course

Content:
Fundamentals on an advanced level in experimental physics in Bonn or Cologne

Aims/Skills:
The students will get acquainted with modern research topics

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 24 CP out of all 6 Specialization Modules

Module: Specialization: Advanced Experimental Physics

Module No.: physics62a

Course: Physics of Hadrons

Course No.: physics632

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Completed B.Sc. in Physics, with experience in electrodynamics, quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the many-body structure of hadrons, understanding structural examinations with electromagnetic probes, introduction into experimental phenomenology

Contents of the Course:
Structure Parameters of baryons and mesons; hadronic, electromagnetic and weak probes; size, form factors and structure functions; quarks, asymptotic freedom, confinement, resonances; symmetries and symmetry breaking, hadron masses;
quark models, meson and baryon spectrum; baryon spectroscopy and exclusive reactions; missing resonances, exotic states

Recommended Literature:
B. Povh, K. Rith C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
K. Gottfried, F. Weisskopf; Concepts of Particle Physics (Oxford University Press 1986)

Module: Specialization: Advanced Experimental Physics

Module No.: physics62a

Course: High Energy Collider Physics

Course No.: physics633

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
physics611 (Particle Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
In depth treatment of particle physics at high energy colliders with emphasis on LHC

Contents of the Course:
Kinematics of electron-proton and proton-(anti)proton collisions,
Electron-positron, electron-hadron and hadron-hadron reactions, hard scattering processes,
Collider machines (LEP, Tevatron and LHC) and their detectors (calorimetry and tracking),
the Standard Model of particle physics in the nutshell, fundamental questions posed to the LHC,
spontaneous symmetry breaking and experiment,
QCD and electroweak physics with high-energy hadron colliders,
Physics of the top quark, top cross section and mass measurements,
Higgs Physics at the LHC (search strategies, mass measurement, couplings),
Supersymmetry and beyond the Standard Model physics at the LHC
Determination of CKM matrix elements, CP violation in K and B systems,
Neutrino oscillations

Recommended Literature:
V. D. Barger, R. Phillips; Collider Physics (Addison-Wesley 1996)
R. K. Ellis, W.J. Stirling, B.R. Webber; QCD and Collider Physics (Cambridge University Press 2003)
D. Green; High PT Physics at Hadron Colliders (Cambridge University Press 2004)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2nd revised edition 2006)
A. Seiden; Particle Physics A Comprehensive Introduction (Benjamin Cummings 2004)
T. Morii, C.S. Lim; S.N. Mukherjee Physics of the Standard Model and Beyond (World Scientific 2004)

Module: Specialization: Advanced Experimental Physics

Module No.: physics62a

Course: Advanced Topics in High Energy Particle Physics

Course No.: physics639

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
physics611 (Particle Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises.

Length of Course:
1 semester

Aims of the Course:
To discuss advanced topics of high energy particle physics which are the subject of current research efforts and to deepen understanding of experimental techniques in particle physics.

Contents of the Course:
Selected topics of current research in experimental particle physics. Topics will be updated according to progress in the field. For example:
- LHC highlights
- CP-violation experiments
- Experimental challenges in particle and astroparticle physics
- Current questions in neutrino physics

Recommended Literature:
A. Seiden; Particle Physics: A Comprehensive Introduction (Cummings 2004)
R.K. Ellis, B.R. Webber, W.J. Stirling; QCD and Collider Physics (Cambridge Monographs on Particle Physics 1996)
C. Burgess, G. Moore; The Standard Model: A Primer (Cambridge University Press 2006)
F. Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1998)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg, 2. überarb. Aufl. 2006)

Module: Specialization: Advanced Experimental Physics

Module No.: physics62a

Course: Magnetism/Superconductivity

Course No.: physics634

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
To give an introduction to the standard theories of both fields as major example of collective phenomena in condensed-matter physics and comparison with experiments

Contents of the Course:
Magnetism:
orbital and spin magnetism without interactions, exchange interactions, phase transitions, magnetic ordering and domains, magnetism in 1-3 dimensions, spin waves (magnons), itinerant magnetism, colossal magnetoresistance
Superconductivity:
macroscopic aspects, type I and type II superconductors, Ginzburg-Landau theory, BCS theory, Josephson effect, superfluidity, high-temperature superconductivity

Recommended Literature:
L. P. Lévy: Magnetism and superconductivity (Springer; Heidelberg 2000)
P. Mohn: Magnetism in the Solid State - An Introduction (Springer, Heidelberg 2005)
J. Crangle: Solid State Magnetism, Van Nostrand Reinhold (Springer, New York 1991)
C. N. R. Rao, B. Raveau: Colossal Magnetoresistance [...] of Manganese Oxides (World Scientific 2004)
J. F. Annett: Superconductivity, super fluids and condensates (Oxford University Press 2004)
A. Mourachkine: High-Temperature Superconductivity in Cuprates [...] (Springer/Kluwer, Berlin 2002)

Module: Specialization: Advanced Experimental Physics

Module No.: physics62a

Course: Photonics

Course No.: physics641

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Examination written or oral (announced at the beginning of the module).
Prerequisite for participation in the exam: successful work within the exercises.

Length of Course:
1 semester

Aims of the Course:
The lecture conveys the physical and technological foundations of laser-based photonics, and enables the students to practically apply their knowledge in research and development.

Contents of the Course:
Foundations: Advanced geometric and wave optics, Fourier optics;
Active and passive devices (Acoustooptics, electrooptics, detectors, imaging)
Advanced optics: Waveguides, Fibers; Photonic Crystals; Metamaterials; Resonators
Laser physics: Light-matter-interaction, principles, operation modes and properties
Nonlinear optics: Second- and third order processes, parametric oscillators, phase matching

Recommended Literature:
D. Meschede; Optics, Light and Lasers (Wiley-VCH, 3rd ed. 2017)
A. Yariv; Photonics: Optical Electronics in Modern Communications (Oxford Univ. Press 6th edition 2006)
B. Saleh, M. Teich; Fundamentals of Photonics (John Wiley & Sons, New York, 1991)
C. Yeh; Applied Photonics (Academic Press, 1994)
R. Menzel; Photonics (Springer, Berlin 2001)

You can not earn credit points for your master examination from this module once you have passed the module physics640: Photonic Devices

Module: Specialization: Advanced Experimental Physics

Module No.: physics62a

Course: Quantum Technology

Course No.: physics642

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Quantum mechanics,

Form of Testing and Examination:
Examination written or oral (announced at the beginning of the module).
Prerequisite for participation in the exam: successful work within the exercises.

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to introduce the students to modern applications of quantum physics. Both fundamental concepts of quantum technology as well as platforms for the implementation will be discussed.

Contents of the Course:
Basics of quantum information: Qubits, entanglement, EPR-tests
Quantum communication: Cryptography, teleportation
Quantum computing: circuit computation, paradigms, exotic computation
Quantum simulation
Quantum-enhanced metrology
Selected platforms: Ultracold atoms, single emitters, photonics

Recommended Literature:
S. M Barnett, Quantum information (Oxford University Press 2012)
M.A. Nielsen, I.L. Chuang, Quantum computation and quantum information (Cambridge 2010)
E. Göbel, U. Siegner, Quantum Metrology (Wiley VCH,2015)
W. Nawrocki, Introduction to Quantum Metrology (Springer 2019)
M. Lewenstein, A. Sanpera, V. Ahufinger, Ultracold atoms in optical lattices Simulating quantum many-body systems (Oxford University Press 2012)

Module: Specialization: Advanced Experimental Physics

Module No.: physics62a

Course: Molecular Physics II

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the second part of the core courses more complex issues of molecular spectra are introduced. The students will be enabled to analyze spectra of complex molecules which are subject to couplings between electronic, vibrational and rotational motions.
In the special courses basic and advanced molecular physics are applied to atmospherical and astronomical environments.
This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Vibrational modes of polyatomic molecules
- Fundamentals of point group symmetry
- Vibrational dipole moment and selection rules
- Characteristic ro-vibrational spectra of selected molecules
- Breakdown of Born-Oppenheimer Approximation
- Coupling of rotation and vibration
- Coupling of angular momenta in molecular physics

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module No.: physics61b
Credit Points (CP): 6
Category: Elective
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Specialization: Applied Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	t.b.a.					

Requirements for Participation:

Form of Examination:
see with the course

Content:
Fundamentals in applied physics in Bonn or Cologne

Aims/Skills:
The students will get acquainted with modern research topics

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 24 CP out of all 6 Specialization Modules

Module No.: physics62b
Credit Points (CP): 6
Category: Elective
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Specialization: Advanced Applied Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	t.b.a.					

Requirements for Participation:

Form of Examination:
see with the course

Content:
Fundamentals on an advanced level in applied physics in Bonn or Cologne

Aims/Skills:
The students will get acquainted with modern research topics

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 24 CP out of all 6 Specialization Modules

Module No.: physics61c
Credit Points (CP): 7
Category: Elective
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Specialization: Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Theoretical Physics						
1.	Theoretical Particle Physics	physics615	7	Lect. + ex.	210 hrs	WT
2.	Theoretical Hadron Physics	physics616	7	Lect. + ex.	210 hrs	WT
3.	Theoretical Condensed Matter Physics	physics617	7	Lect. + ex.	210 hrs	WT
4.	Solid State Theory I	TheoSolidSt	6	Lect. + ex.	180 hrs	WT

Requirements for Participation:

Form of Examination:
see with the course

Content:
Fundamentals in theoretical physics in Bonn or Cologne

Aims/Skills:
Mit den Spezialisierungsvorlesungen wird die Möglichkeit eröffnet, sich in einer bzw. mehreren der in Bonn vertretenen Forschungsrichtungen zu spezialisieren.
The students will get acquainted with modern research topics

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 24 CP out of all 6 Specialization Modules

Module: Specialization: Theoretical Physics

Module No.: physics61c

Course: Theoretical Particle Physics

Course No.: physics615

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Advanced quantum theory (physics606)
Quantum field theory (physics755)
Group theory (physics751)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the standard model of elementary particle physics and its extensions (unified theories)

Contents of the Course:
Classical field theory, gauge theories, Higgs mechanism;
Standard model of strong and electroweak interactions;
Supersymmetry and the supersymmetric extension of the standard model;
Grand unified theories (GUTs);
Neutrino physics;
Cosmological aspects of particle physics (dark matter, inflation)

Recommended Literature:
T. P. Cheng, L.F. Li: Gauge theories of elementary particle physics (Clarendon Press, Oxford 1984)
M. E. Peskin, D.V. Schroeder; An introduction to quantum field theory (Addison Wesley, 1995)
J. Wess; J. Bagger; Supersymmetry and supergravity (Princeton University Press 1992)

Module: Specialization: Theoretical Physics

Module No.: physics61c

Course: Theoretical Hadron Physics

Course No.: physics616

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Advanced quantum theory (physics606)
Quantum field theory (physics755)
Group theory (physics751)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the theory of strong interaction, hadron structure and dynamics

Contents of the Course:
Meson and Baryon Spectra: Group theoretical Classification, Simple Quark Models
Basics of Quantum Chromodynamics: Results in Perturbation Theory
Effective Field Theory
Bethe-Salpeter Equation

Recommended Literature:
F. E. Close, An Introduction to Quarks and Partons (Academic Press 1980)
F. Donoghue, E. Golowich, B.R. Holstein; Dynamics of the Standard Model (Cambridge University Press 1994)
C. Itzykson, J.-B. Zuber; Quantum Field Theory (Dover Publications 2005)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Module: Specialization: Theoretical Physics

Module No.: physics61c

Course: Theoretical Condensed Matter Physics

Course No.: physics617

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Advanced Quantum Theory (physics606)
Quantum Field Theory (physics755)
Group theory (physics751)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the theoretical standard methods and understanding important phenomena in the Physics of Condensed Matter

Contents of the Course:
Crystalline Solids: Lattice structure, point groups, reciprocal lattice
Elementary excitations of a crystal lattice: phonons
Electrons in a lattice; Bloch theorem, band structure
Fermi liquid theory
Magnetism
Symmetries and collective excitations in solids
Superconductivity
Integer and fractional quantum Hall effects

Recommended Literature:
N. W. Ashcroft, N.D. Mermin, Solid State Physics (Saunders College 1976)
P. M. Chaikin, T.C. Lubensky; Principles of Condensed Matter Physics (Cambridge University Press 1997)
W. Nolting; Grundkurs Theoretische Physik Band 7: Vielteilchentheorie (Springer, Heidelberg 2002)
Ch. Kittel; Quantentheorie der Festkörper (Oldenburg Verlag, München 3. Aufl. 1989)

Module: Specialization: Theoretical Physics

Module No.: physics61c

Course: Solid State Theory I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
training in theoretical physics at the B.Sc. level, experimental solid state physics

Form of Testing and Examination:
written or oral examination

Length of Course:
1 semester

Aims of the Course:
this course gives an introduction to the physics of electrons and phonons in solids together with theoretical concepts and techniques as applied to these systems.

Contents of the Course:
The lecture investigates basic concepts to describe solids and their excitations. Various applications are discussed with emphasis on experimental and theoretical research directions of the physics department in Cologne.

Recommended Literature:
Ashcroft/ Mermin: "Solid State Physics"

Module No.: physics62c
Credit Points (CP): 7
Category: Elective
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Specialization: Advanced Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Theoretical Physics						
1.	Advanced Theoretical Particle Physics	physics636	7	Lect. + ex.	210 hrs	ST
2.	Advanced Theoretical Hadron Physics	physics637	7	Lect. + ex.	210 hrs	ST
3.	Advanced Theoretical Condensed Matter Physics	physics638	7	Lect. + ex.	210 hrs	ST

Requirements for Participation:

Form of Examination:
see with the course

Content:
Fundamentals on an advanced level in theoretical physics in Bonn or Cologne

Aims/Skills:
The students will get acquainted with modern research topics

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 Semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 24 CP out of all 6 Specialization Modules

Module: Specialization: Advanced Theoretical Physics

Module No.: physics62c

Course: Advanced Theoretical Particle Physics

Course No.: physics636

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Survey of methods of theoretical high energy physics beyond the standard model, in particular supersymmetry and extra dimensions in regard to current research

Contents of the Course:
Introduction to supersymmetry and supergravity,
Supersymmetric extension of the electroweak standard model,
Supersymmetric grand unification,
Theories of higher dimensional space-time,
Unification in extra dimensions

Recommended Literature:
J. Wess; J. Bagger; Supersymmetry and supergravity (Princeton University Press 1992)
H. P. Nilles, Supersymmetry, Supergravity and Particle Physics, Physics Reports 110 C (1984) 1
D. Bailin; A. Love; Supersymmetric Gauge Field Theory and String Theory (IOP Publishing Ltd. 1994)
M. F. Sohnius; Introducing supersymmtry, (Phys.Res. 128 C (1985) 39)
P. Freund; Introduction to Supersymmetry (Cambridge University Press 1995)

Module: Specialization: Advanced Theoretical Physics

Module No.: physics62c

Course: Advanced Theoretical Hadron Physics

Course No.: physics637

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
physics616 (Theoretical Hadron Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Survey of methods of theoretical hadron physics in regard to current research

Contents of the Course:
Quantum Chromodynamics: Nonperturbative Results, Confinement
Lattice Gauge Theory
Chiral Perturbation Theory
Effective Field Theory for Heavy Quarks

Recommended Literature:
F. E. Close; An Introduction Quarks and Partons (Academic Press 1980)
F. Donoghue, E. Golowich, B. R. Holstein, Dynamics of the Standard Model (Cambridge University Press 1994)
C. Itzykson, J.-B. Zuber; Quantum Field Theory (Dover Publications 2006)
A. V. Manohar, M. B. Wise; Heavy Quark Physics (Cambridge University Press 2000)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Module:	**Specialization: Advanced Theoretical Physics**
Module No.: physics62c	

Course: Advanced Theoretical Condensed Matter Physics

Course No.: physics638

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
physics617 (Theoretical Condensed Matter Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Survey of methods of theoretical condensed matter physics and their application to prominent examples in regard to current research

Contents of the Course:
Bosonic systems:
Bose-Einstein condensation
Photonics

Quantum dynamics of many-electrons systems:
Feynman diagram technique for many-particle systems at finite temperature
Quantum magnetism, Kondo effect, Renormalization group techniques
Disordered systems: Electrons in a random potential
Superconductivity

Recommended Literature:
A. A. Abrikosov, L.P. Gorkov; Methods of Quantum Field Theory in Statistical Physics (Dover, New York 1977)
W. Nolting; Grundkurs Theoretische Physik Band 7: Vielteilchentheorie (Springer, Heidelberg 2002)
A. C. Hewson, The Kondo Problem to Heavy Fermions (Cambridge University Press, 1997)
C. Itzykson, J.-M. Drouffe; Statistical Field Theory (Cambridge University Press 1991)
J. R. Schrieffer; Theory of Superconductivity (Benjamin/Cummings, Reading/Mass, 1983)

Module No.: physics65a
Credit Points (CP): 4
Category: Elective
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Seminar: Experimental Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminars on Current Topics in Experimental Physics		4	seminar	120 hrs	WT/ST

Requirements for Participation:

Form of Examination:
Presentation

Content:
Topics in modern experimental physics covered by the research groups, including current journal literature

Aims/Skills:
The students shall learn to explore a specific scientific topic with the help of libraries and electronic media.
The presentation must be concise and structured

Course achievement/Criteria for awarding cp's:
regular participation and active contribution

Length of Module: 1 semester

Maximum Number of Participants: 20 per seminar

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Physik, Pflicht, Semester: 1-2

Module No.: physics65b
Credit Points (CP): 4
Category: Elective
Semester: 2.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Seminar: Applied Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminars on Current Topics in Applied Physics		4	seminar	120 hrs	WT/ST

Requirements for Participation:

Form of Examination:
Presentation

Content:
Topics in modern applied physics covered by the research groups, including current journal literature

Aims/Skills:
The students shall learn to explore a specific scientific topic with the help of libraries and electronic media.
The presentation must be concise and structured

Course achievement/Criteria for awarding cp's:
regular participation and active contribution

Length of Module: 1 semester

Maximum Number of Participants: 20 per seminar

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Physik, Pflicht, Semester: 1-2

Module No.: physics65c
Credit Points (CP): 4
Category: Elective
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Seminar: Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminars on Current Topics in Theoretical Physics		4	seminar	120 hrs	WT/ST

Requirements for Participation:

Form of Examination:
Presentation

Content:
Topics in modern theoretical physics covered by the research groups, including current journal literature

Aims/Skills:
The students shall learn to explore a specific scientific topic with the help of libraries and electronic media. The presentation must be concise and structured

Course achievement/Criteria for awarding cp's:
regular participation and active contribution

Length of Module: 1 semester

Maximum Number of Participants: 20 per seminar

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Physik, Pflicht, Semester: 1-2

Module No.: physics70a
Credit Points (CP): 3-6
Category: Elective
Semester: 1.-2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures: Experimental Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected courses from catalogue type "E" (Experimental) or "E/A" (E/Applied)	see catalogue	3-6	see catalogue	90-180 hrs	ST/WT
2.	Also possible classes from M.Sc. in Astrophysics					

Requirements for Participation:
none

Form of Examination:
see with the course

Content:
Advanced lectures in experimental physics

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 or 2 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 18 CP out of all 4 Elective Advanced Modules

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Particle Astrophysics and Cosmology (E)

Course No.: physics711

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
physics611 (Particle Physics), useful: Lectures Observational Astronomy

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Basics of particle astrophysics and cosmology

Contents of the Course:
Observational Overview (distribution of galaxies, redshift, Hubble expansion, CMB, cosmic distance latter, comoving distance, cosmic time, comoving distance and redshift, angular size and luminosity distance); Standard Cosmology (cosmological principle, expansion scale factor, curved space-time, horizons, Friedmann-Equations, cosmological constant, cosmic sum rule, present problems); Particle Physics relevant to cosmology (Fundamental Particles and their Interactions, quantum field theory and Lagrange formalism, Gauge Symmetry, spontaneous symmetry breaking and Higgs mechanism, parameters of the Standard Model, Running Coupling Constants, CP Violation and Baryon Asymmetry, Neutrinos); Thermodynamics in the Universe (Equilibrium Thermodynamics and freeze out, First Law and Entropy, Quantum Statistics, neutrino decoupling, reheating, photon decoupling); Nucleosynthesis (Helium abundance, Fusion processes, photon/baryon ratio)
Dark Matter (Galaxy Rotation Curves, Clusters of Galaxies, Hot gas, Gravitational lensing, problems with Cold Dark Matter Models, Dark Matter Candidates); Inflation and Quintessence; Cosmic Microwave Background (origin, intensity spectrum, CMB anisotropies, Temperature correlations, power spectrum, cosmic variance, density and temperature fluctuations, causality and changing horizons, long and short wavelength modes, interpretation of the power spectrum)

Recommended Literature:
A. Liddle; An Introduction to Modern Cosmology (Wiley & Sons 2. Ed. 2003)
E. Kolb, M. Turner; The Early Universe (Addison Wesley 1990)
J. Peacock; Cosmological Physics (Cambridge University Press 1999)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Advanced Electronics and Signal Processing (E/A)

Course No.: physics712

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Electronics laboratory of the B.Sc. in physics programme
Recommended: module nuclear and particle physics of the B.Sc. programme

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Comprehension of the basics of electronics circuits for the processing of (detector) signals, mediation of the basics of experimental techniques regarding electronics and micro electronics as well as signal processing

Contents of the Course:
The physics of electronic devices, junctions, transistors (BJT and FET), standard analog and digital circuits, amplifiers, elements of CMOS technologies, signal processing, ADC, DAC, noise sources and noise filtering, coupling of electronics to sensors/detectors, elements of chip design, VLSI electronics, readout techniques for detectors

Recommended Literature:
P. Horowitz, W. Hill; The Art of Electronics (Cambridge University Press 2. Aufl. 1989)
S. Sze; The Physics of Semiconductor Devices (Wiley & Sons 1981)
H. Spieler, Semiconductor detector system (Oxford University Press 2005))
J. Krenz; Electronics Concepts (Cambridge University Press 2000)

Modules:	physics70a	**Elective Advanced Lectures: Experimental Physics**
	physics70b	**Elective Advanced Lectures: Applied Physics**

Course: Particle Detectors and Instrumentation (E/A)

Course No.: physics713

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with laboratory	English	3+1	6	ST

Requirements for Participation:

Preparation:
Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Designing an experiment in photoproduction on pi-0, selection and building of appropriate detectors, set-up and implementation of an experiment at ELSA

Contents of the Course:
Quark structure of mesons and baryons, nucleon excitation; electromagnetic probes, electron accelerators, photon beams, relativistic kinematics interaction of radiation with matter, detectors for photons, leptons and hadrons; laboratory course: setup of detectors and experiment at ELSA

Recommended Literature:
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
W. R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2. Ed. 1994)
K. Kleinknecht; Detektoren für Teilchenstrahlung (Teubner, Wiesbaden 4. überarb. Aufl. 2005)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Advanced Accelerator Physics (E/A)

Course No.: physics714

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST/WT

Requirements for Participation:

Preparation:
Accelerator Physics (physics612)

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the physics of synchrotron radiation and its influence on beam parameters
Basic knowledge of collective phenomena in particle accelerators
General knowledge of applications of particle accelerators (research, medicine, energy management)

Contents of the Course:
Synchrotron radiation:
radiation power, spatial distribution, spectrum, damping, equilibrium beam emittance, beam lifetime
Space-charge effects:
self-field and wall effects, beam-beam effects, space charge dominated beam transport, neutralization of beams by ionization of the residual gas
Collective phenomena:
wake fields, wake functions and coupling impedances, spectra of a stationary and oscillating bunches, bunch interaction with an impedance, Robinson instability
Applications of particle accelerators:
medical accelerators, neutrino facilities, free electron lasers, nuclear waste transmutation, etc.

Recommended Literature:
F. Hinterberger; Physik der Teilchenbeschleuniger und Ionenoptik (Springer, Heidelberg 1997)
H. Wiedemann; Particle Accelerator Physics (Springer, Heidelberg 2 Aufl. 1999)
K. Wille; Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen (Teubner, Wiesbaden 2. Aufl. 1996)
D. A. Edwards, M.J. Syphers; An Introduction to the Physics of High Energy Accelerators (Wiley & Sons 1993)
A. Chao; Physics of Collective Beam Instabilities in High Energy Accelerators (Wiley & Sons 1993)
Script of the Lecture Particle Accelerators (physics612)
http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Experiments on the Structure of Hadrons (E)

Course No.: physics715

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:

Preparation:
Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the structure of the nucleon, understanding experiments on baryon-spectroscopy, methods of identifying resonance contributions, introduction into current issues in meson-photoproduction

Contents of the Course:
Discoveries in hadron physics, quarks, asymptotic freedom and confinement; multiplets, symmetries, mass generation; quark models, baryon spectroscopy, formation and decay of resonances, meson photoproduction; hadronic molecules and exotic states

Recommended Literature:
Perkins, Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
K. Gottfried, F. Weisskopf; Concepts of Particle Physics (Oxford University Press 1986)
A. Thomas, W. Weise, The Structure of the Nucleon (Wiley-VCH, Weinheim, 2001)

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Statistical Methods of Data Analysis (E)

Course No.: physics716

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Provide a foundation in statistical methods and give some concrete examples of how the methods are applied to data analysis in particle physics experiments

Contents of the Course:
Fundamental concepts of statistics, probability distributions, Monte Carlo methods, fitting of data, statistical and systematic errors, error propagation, upper limits, hypothesis testing, unfolding

Recommended Literature:
R. Barlow: A Guide to the Use of Statistical Methods in the Physical Sciences; J. Wiley Ltd. Wichester 1993
S. Brandt: Datenanalyse (Spektrum Akademischer Verlag, Heidelberg 4. Aufl. 1999)

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: High Energy Physics Lab (E)

Course No.: physics717

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English		4	WT/ST

Requirements for Participation:

Preparation:
Recommended: B.Sc. in physics, physics611 (Particle Physics) or physics618 (Physics of Particle Detectors)

Form of Testing and Examination:
Credit points can be obtained after completion of a written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
This is a research internship in one of the high energy physics research groups which prepare and carry out experiments at external accelerators. The students deepen their understanding of particle and/or detector physics by conducting their own small research project as a part-time member of one of the research groups. The students learn methods of scientific research in particle physics data analysis, in detector development for future colliders or in biomedical imaging (X-FEL) and present their work at the end of the project in a group meeting.

Contents of the Course:
Several different topics are offered among which the students can choose. Available projects can be found at http://heplab.physik.uni-bonn.de. For example:
- Analysis of data from one of the large high energy physics experiments (ATLAS, DØ, ZEUS)
- Investigation of low-noise semiconductor detectors using cosmic rays, laser beams or X-ray tubes
- Study of particle physics processes using simulated events
- Signal extraction and data mining with advanced statistical methods (likelihoods, neural nets or boosted decision trees)

Recommended Literature:
Will be provided by the supervisor

Modules:		
	physics70a	**Elective Advanced Lectures: Experimental Physics**
	physics70b	**Elective Advanced Lectures: Applied Physics**

Course: Programming in Physics and Astronomy with C++ or Python (E/A)

Course No.: physics718

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Basic knowledge of programming and knowledge of simple C/C++ or Python constructs.

Form of Testing and Examination:
C/C++ part: Requirements for the examination (written or oral): successful work with the exercises.
Python part: Requirements for examination: successful implementation of the scientific projects in Python during the semester.

Length of Course:
1 semester

Aims of the Course:
C++ part: In-depth understanding of C++ and its applications in particle physics. Discussion of advanced features of C++ using examples from High Energy Physics. The course is intended for students with some background in C++ or for advanced students who wish to apply C++ in their graduate research.
Python part: Effective and flexible program solving with the easy-to-learn, high level programming language Python. The course addresses master and PhD students with prior Python-programming knowledge as taught in the bachelor course physics131.

Contents of the Course:
C++ part: - Basic ingredients of C++, - Object orientation: classes, inheritance, polymorphism, - How to solve physics problems with C++, - Standard Template Library, - C++ in data analysis, example: the ROOT library, - C++ and large scale calculations, - How to write and maintain complex programs, - Parallel computing and the Grid, - Debugging and profiling
Python part: - In-depth introduction to Python based on prior programming experience, - Introduction to numpy arrays (primary Python data structure for scientific computing), - Introduction to scientific-Python modules (scipy, astropy), - Interactive work / development with Python (ipython), - Web interaction with Python (jupyter notebooks, web and database queries), - Plotting with Python (the matplotlib module)

Recommended Literature:
Eckel: Thinking in C++, Prentice Hall 2000.
Lippman, Lajoie, Moo: C++ Primer, Addison-Wesley 2000.
Deitel and Deitel, C++ how to program, Prentice Hall 2007.
Stroustrup, The C++ Programming Language, Addison-Wesley 2000.

- The course is given in the summer term and alternates between C++ and Python
- The course can only be taken once for credit points.

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Intensive Week: Advanced Topics in High Energy Physics (E)

Course No.: physics719

Category	Type	Language	Teaching hours	CP	Semester
Elective	Combined lecture, seminar, lab course	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of particle physics

Form of Testing and Examination:
Seminar talk

Length of Course:
1 - 2 weeks

Aims of the Course:
This course is about an advanced, current topic in particle physics. The students will gain insights into recent developments in particle physics and participate in lectures, seminars talks and laboratory projects.

Contents of the Course:
As announced in the course catalogue. The main topic will vary from semester to semester.

Recommended Literature:
Will be given in the lecture.

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Physics with Antiprotons (E)

Course No.: physics720

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:
Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Insight in current research topics with antiprotons, understanding experimental methods in particle and nuclear physics, understanding interrelations between different fields of physics such as hadron physics, (astro-)particle physics, atomic physics

Contents of the Course:
Matter-antimatter asymmetry, test of the standard model, anti-hydrogen, anti-protonic atoms, antiproton beams, key issues in hadron physics with antiprotons, planned research facilities (FAIR) and experiments (PANDA)

Recommended Literature:
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 8. Aufl. 2009)
D.H. Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
further literature will be given in the lecture

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Intensive Week: Advanced Topics in Hadron Physics (E)

Course No.: physics721

Category	Type	Language	Teaching hours	CP	Semester
Elective	Combined lecture, seminar, lab course	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of hadron physics

Form of Testing and Examination:
Presentation, working group participation

Length of Course:
1 - 2 weeks

Aims of the Course:
This course will convey recent topics in hadron physics. Guided by lectures, original publications and tutors, the students will prepare a proposal for a planned or recent experiment. The class will not only focus on the experimental aspects, but also on the theoretical motivation for the experiment.

Contents of the Course:
As announced in the course catalogue. The main topics will vary from semester to semester.

Recommended Literature:
Will be given in the lecture

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Advanced Gaseous Detectors - Theory and Practice (E)

Course No.: physics722

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with laboratory	English	3+1	6	ST

Requirements for Participation:

Preparation:
Completed B.Sc. in physics, with experience in electrodynamics, quantum mechanics, nuclear and particle physics, physics618 (Physics of Particle Detectors)

Form of Testing and Examination:
Form of examination: written or oral report

Length of Course:
1 semester

Aims of the Course:
- Design, construction, commissioning and characterization of a modern gaseous particle detector
- Simulations: GARFIELD, GEANT, FE-Methods, etc.
- Signals, Readout electronics and Data Acquisition
- Data analysis: pattern recognition methods, track fitting
- Scientific writing: report

Contents of the Course:
- Signal formation in detectors
- Microscopic processes in gaseous detectors
- Readout electronics
- Tools for detector design and simulation
- Performance criteria
- Laboratory course: commissioning of detector with sources, beam test at accelerator
- Track reconstruction

Recommended Literature:
http://root.cern.ch
http://garfieldpp.web.cern.ch/garfieldpp/
Blum, Rolandi, Riegler: Particle Detection with Drift Chambers
Spieler: Semiconductor Detector Systems

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Hands-on Seminar: Detector Construction (E/A)

Course No.: physics723

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English	2	3	WT/ST

Requirements for Participation:
Basic knowledge of particle physics

Preparation:
physics618 is helpful but not mandatory

Form of Testing and Examination:
Credit points can be obtained after successful construction and operation of the detector and preparing a written and/or oral report on a specific task

Length of Course:
1 semester

Aims of the Course:
Students will design, construct, assemble and operate a particle detector.

Contents of the Course:
Students will construct, assemble and commission a particle detector. They will gain hands-on experience on detector construction. The students organize and execute the tasks of the project in personal responsibility. This includes many tasks common to more complex research or industrial projects. Topics include:

- order the needed detector components
- prepare CAD drawings
- prepare PCB layout
- develop electronic circuits
- produce and assemble detector parts
- vacuum technology
- cooling technology
- organize the work effort in personal responsibility
- communicate with team members and technical staff

Recommended Literature:
H. Kolanoski, N. Wermes, Teilchendetektoren, (Springer, Heidelberg, 2016)
W. R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2. Ed. 1994)
K. Kleinknecht; Detektoren für Teilchenstrahlung (Teubner, Wiesbaden 4. überarb. Aufl. 2005)

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Advanced Methods of Data Analysis (E)

Course No.: physics724

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:
The course builds on the knowledge taught in physics716 Statistical Methods of Data Analysis and is designed as a follow-up course. Participants need to have a working knowledge of the basics of statistical data analysis, including parameter estimation and statistical tests.

Preparation:
Students should have a basic knowledge of either C++ or python programming languages. There will be opportunity during the course to develop programming skills through applications of data analysis.

Form of Testing and Examination:
The examination can be done either through a written exam or by written term papers as communicated at the beginning of the course.

Length of Course:
1 semester

Aims of the Course:
This course teaches advanced techniques of statistical data analysis. Its goal is to enable the participants to contribute to state of the art data analysis projects, for example during their master thesis, and to enable them to conduct their own research into statistical data analysis methods.

Contents of the Course:
Parametric likelihood fits, constraint optimisation, state space models, non-parametric density estimation, unfolding, model validation, introduction to machine learning, classification, adaptive basis function models, ensemble learning, deep generative models

Examples from high energy and hadronic physics.

Recommended Literature:
Elements of statistical learning, 2nd Edition, Hastie, Tibshirani & Friedman, Springer 2017
Data Analysis in High Energy Physics, Behnke et Al. , Wiley-VCH 2013
Statistical Analysis Techniques in Particle Physics, Narsky & Porter, Wiley-VCH 2013
Machine Learning, A Probabilistic Perspective, Murphy, MIT Press 2012

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: universitätbonn Scientific Programming with Python (E/A)

Course No.: physics725

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	6	ST

Requirements for Participation:

Preparation:
Prior knowledge of any programming language (C/C++, Java, Python, ...)

Form of Testing and Examination:
Successful implementation of scientific projects in Python during the semester

Length of Course:
1 semester

Aims of the Course:
Effective and flexible program solving with the easy-to-learn, high-level programming language Python. The course addresses master and PhD students with prior programming knowledge as taught in the bachelor course physics131.

Contents of the Course:
In-depth introduction to the Python programming language; Introduction to numpy arrays (primary Python data structure for scientific computing); Introduction to scientific-Python modules (scipy, astropy);
Interactive work / development with Python (ipython); Web interaction with Python (jupyter notebooks, web and database queries);
Plotting with Python (the matplotlib module), Introduction to writing own scientific Python-modules and Object-oriented programming, Collaborative code development and version control (git, github)

Recommended Literature:
All necessary materials are made available online via the eCampus platform

Credit points can only be earned from one exam out of physics718 and physics725

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Low Temperature Physics (E/A)

Course No.: physics731

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT/ST

Requirements for Participation:

Preparation:
Elementary thermodynamics; principles of quantum mechanics; introductory lecture on solid state physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Experimental methods at low (down to micro Kelvin) temperatures; methods of refrigeration; thermometry; solid state physics at low temperatures

Contents of the Course:
Thermodynamics of different refrigeration processes, liquefaction of gases; methods to reach low (< 1 Kelvin) temperatures: evaporation cooling, He-3-He-4 dilution cooling, Pomeranchuk effect, adiabatic demagnetisation of atoms and nuclei; thermometry at low temperatures (e.g. helium, magnetic thermometry, noise thermometry, thermometry using radioactive nuclei); principles for the construction of cryostats for low temperatures

Recommended Literature:
O.V. Lounasmaa; Experimental Principles and Methods Below 1K (Academic Press, London 1974)
R.C. Richardson, E.N. Smith; Experimental Techniques in Condensed Matter Physics at Low Temperatures (Addison-Wesley 1988)
F. Pobell, Matter and Methods at Low Temperatures (Springer-Verlag, Heidelberg 2. Aufl. 1996)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**

physics70b **Elective Advanced Lectures: Applied Physics**

Course: Optics Lab (E/A)

universitätbonn

Course No.: physics732

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English		4	WT/ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Credit points can be obtained after completion of a written report.

Length of Course:
4-6 weeks

Aims of the Course:
The student learns to handle his/her own research project within one of the optics groups

Available projects and contact information can be found at: http://www.iap.uni-bonn.de/opticslab/

Contents of the Course:
Practical training/internship in a research group, which can have several aspects:
- setting up a small experiment
- testing and understanding the limits of experimental components
- simulating experimental situations

Recommended Literature:
Will be given by the supervisor

Modules:	physics70a	**Elective Advanced Lectures: Experimental Physics**
	physics70b	**Elective Advanced Lectures: Applied Physics**

Course: universitätbonn Holography (E/A)

Course No.: physics734

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to provide in-depth knowledge and to provide practical abilities in the field of holography as an actual topic of applied optics

Contents of the Course:
The course will cover the basic principle of holography, holographic recording materials, and applications of holography. In the first part the idea behind holography will be explained and different hologram types will be discussed (transmission and reflection holograms; thin and thick holograms; amplitude and phase holograms; white-light holograms; computer-generated holograms; printed holograms). A key issue is the holographic recording material, and several material classes will be introduced in the course (photographic emulsions; photochromic materials; photo-polymerization; photo-addressable polymers; photorefractive crystals; photosensitive inorganic glasses). In the third section several fascinating applications of holography will be discussed (art; security-features on credit cards, banknotes, and passports; laser technology; data storage; image processing; filters and switches for optical telecommunication networks; novelty filters; phase conjugation ["time machine"]; femtosecond holography; space-time conversion). Interested students can also participate in practical training. An experimental setup to fabricate own holograms is available

Recommended Literature:
Lecture notes;
P. Hariharan; Optical Holography - Principles, Techniques, and Applications (Cambridge University Press, 2nd Edition, 1996)
P. Hariharan; Basics of Holography (Cambridge University Press 2002)
J. W. Goodman; Introduction to Fourier Optics (McGraw-Hill Education - Europe 2nd Ed. 2000)
A. Yariv; Photonics (Oxford University Press 6th Ed. 2006)

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Laser Cooling and Matter Waves (E)

Course No.: physics735

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Basic thermodynamics: fundamentals of quantum mechanics, fundamentals of solid state physics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The in-depth lecture shows, in theory and experiments, the fundamentals of laser cooling. The application of laser cooling in atom optics, in particular for the preparation of atomic matter waves, is shown. New results in research with degenerated quantum gases enable us to gain insight into atomic many particle physics

Contents of the Course:
Outline: Light-matter interaction; mechanic effects of light; Doppler cooling; polarization gradient cooling, magneto-optical traps; optical molasses; cold atomic gases; atom interferometry; Bose-Einstein condensation of atoms; atom lasers; Mott insulator phase transitions; mixtures of quantum gases; fermionic degenerate gases

Recommended Literature:
P. v. d. Straten, H. Metcalf; Laser Cooling (Springer, Heidelberg 1999)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Crystal Optics (E/A)

Course No.: physics736

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Because of their aesthetic nature crystals are termed "flowers of mineral kingdom". The aesthetic aspect is closely related to the symmetry of the crystals which in turn determines their optical properties. It is the purpose of this course to stimulate the understanding of these relations. The mathematical and tools for describing symmetry and an introduction to polarization optics will be given before the optical properties following from crystal symmetry are discussed. Particular emphasis will be put on the magneto-optical properties of crystals in magnetic internal or external fields. Advanced topics such as the determination of magnetic structures and interactions by nonlinear magneto-optics will conclude the course

Contents of the Course:
Crystal classes and their symmetry; basic group theory; polarized light; optical properties in the absence of fields; electro-optical properties; magneto-optical properties: Faraday effect, Kerr effect, magneto-optical materials and devices, semiconductor magneto-optics, time-resolved magneto-optics, nonlinear magneto-optics

Recommended Literature:
R. R. Birss, Symmetry and Magnetism, North-Holland (1966)
R. E. Newnham: Properties of Materials: Anisotropy, Symmetry, Structure, Oxford University (2005)
A. K. Zvezdin, V. A. Kotov: Modern Magnetooptics & Magnetooptical Materials, Taylor/Francis (1997)
Y. R. Shen: The Principles of Nonlinear Optics, Wiley (2002)
K. H. Bennemann: Nonlinear Optics in Metals, Oxford University (1999)

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Intensive Week: Advanced Topics in Photonics and Quantum Optics (E)

Course No.: physics737

Category	Type	Language	Teaching hours	CP	Semester
Elective	Combined lecture, seminar, lab course	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of optics, fundamentals of quantum mechanics

Form of Testing and Examination:
Seminar or oral examination

Length of Course:
1 - 2 weeks

Aims of the Course:
The intensive course will convey the basics of a recent topic in photonics or quantum optics in theory and experiments. Guided by a combination of lectures, seminar talks (based on original publications) and practical training, the participants will gain insight into recent developments in photonics/quantum optics.

Contents of the Course:
Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:
Will be given in the lecture

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Lecture on Advanced Topics in Quantum Optics (E)

Course No.: physics738

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of Quantum Mechanics, Atomic Physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce the students to a special field of research in quantum optics. New research results will be presented and their relevance is discussed.

Contents of the Course:
Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:
Will be given in the lecture

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Lecture on Advanced Topics in Photonics (E/A)

Course No.: physics739

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:

Preparation:
Optics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce the students to a special field of research in photonics. New research results will be presented and their relevance is discussed.

Contents of the Course:
Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:
Will be given in the lecture

This course may be offered as "Teaching hours (3+1)" with 6 cp, as well

Modules:	physics70a	**Elective Advanced Lectures: Experimental Physics**
	physics70b	**Elective Advanced Lectures: Applied Physics**

Course: Hands-on Seminar: Experimental Optics and Atomic Physics (E/A)

Course No.: physics740

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of optics and quantum mechanics

Form of Testing and Examination:
Credit points can be obtained after successful carrying out the experiments and preparing a written report on selected experiments

Length of Course:
1 semester

Aims of the Course:
The students learn to handle optical setups and carry out optical experiments. This will prepare participants both for the successful completion of research projects in experimental quantum optics/photonics and tasks in the optics industry.

Contents of the Course:
Practical training in the field of optics, where the students start their experiment basically from scratch (i.e. an empty optical table). The training involves the following topics:
- diode lasers
- optical resonators
- acousto-optic modulators
- spectroscopy
- radiofrequency techniques

Recommended Literature:
Will be given by the supervisor

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Modern Spectroscopy (E/A)

Course No.: physics741

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of Optics, Fundamentals of Quantum Mechanics

Form of Testing and Examination:
Requirements for the examination (oral or written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to introduce the students to both fundamental and advanced concepts of spectroscopy and enable them to practically apply their knowledge.

Contents of the Course:
Spectroscopy phenomena - time and frequency domain;
high resolution spectroscopy;
pulsed spectroscopy; frequency combs;
coherent spectroscopy;
nonlinear spectroscopy: Saturation, Raman spectroscopy, Ramsey spectroscopy.
Applications of spectroscopic methods (e.g. Single molecule spectroscopy; spectroscopy at interfaces & surfaces, spectroscopy of cold atoms; atomic clocks; atom interferometry)

Recommended Literature:
W. Demtröder; Laser spectroscopy (Springer 2002)
S. Svanberg; Atomic and molecular spectroscopy basic aspects and practical applications (Springer 2001)
A. Corney; Atomic and laser spectroscopy (Clarendon Press 1988)
N. B. Colthup, L. H. Daly, S. E. Wiberley; Introduction to infrared and Raman spectroscopy (Academic Press 1990)
P. Hannaford; Femtosecond laser spectroscopy (Springer New York 2005)
C. Rulliere; Femtosecond laser pulses: principles and experiments (Springer Berlin 1998)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: Ultracold Atomic Gases (E/T)

Course No.: physics742

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Quantum Mechanics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
This lecture discusses both the experimental and theoretical concepts of ultra-cold atomic gases.

Contents of the Course:
Almost hundred years ago, in 1924, A. Einstein and S.N. Bose predicted the existence of a new state of matter, the so-called Bose-Einstein condensate. It took 70 years to successfully realize this macroscopic quantum state in the lab using ultracold atomic gases (Nobel prize 2001). The main challenge was to achieve cooling to Nanokelvin temperatures, the coolest temperatures ever reached by mankind. Nowadays, ultracold gases are exciting systems to study a broad range of quantum phenomena. These phenomena range from the direct observation of quantum matter waves and superfluidity over the creation of artificial crystal structures as analogous to solids, to the realization of complex quantum phase transitions of interacting atoms, e.g. the formation of a bosonic Mott-insulator or the BCS superconducting state for Fermions. In this lecture we will discuss both the experimental and theoretical concepts of ultra-cold atomic gases.

Outline: Introduction and revision of basic concepts, Fundamentals of atom-laser interaction
Laser cooling & trapping, Bose-Einstein condensation of atomic gases. Dynamics of Bose-Einstein condensates
Optical lattices: strongly interacting atomic gases and quantum phase transitions
The crossover of Fermi-gases between a BCS superconducting state and a Bose-Einstein condensate of molecules.

Recommended Literature:
C. J. Pethick and H. Smith, Bose-Einstein Condensation in Dilute Gases (Cambridge University Press)

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Platforms for Quantum Technologies (E)

Course No.: physics743

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	1 week fulltime	3	WT/ST

Requirements for Participation:

Preparation:
Major courses of the 1st MSc term, for example, "Advanced Atomic, Molecular and Optical Physics", "Quantum Optics", "Advanced Quantum Theory", "Theoretical Condensed Matter Physics"

Form of Testing and Examination:
Homework Sheets

Length of Course:
1 week

Aims of the Course:
Students receive an introduction into quantum technologies both theoretically and experimentally. Focus is on the theoretical foundations of quantum information processing, and experimental platforms primarily used in Bonn (Atomic, molecular and optical systems), Cologne (topological materials) and Aachen (spin & superconducting architectures) in the context of the Excellence Cluster ML4Q.

Contents of the Course:
1. Basics of quantum information processing
2. Atomic, molecular and optical platforms, quantum simulation
3. Solid-state platforms. Focus on quantum computation. Spin qubits, superconducting qubits;
4. Topological platforms, Topological materials, Topological architectures

Recommended Literature:
Nielsen & Chuang "Quantum information processing"
Pethick/Smith "Bose-Einstein condensation"
Lecture notes will be distributed for selected topics

Module: Elective Advanced Lectures: Experimental Physics

Module No.: physics70a

Course: Precision Metrology (E)

Course No.: physics744

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of Quantum Mechanics, Atomic Physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to give the students a deeper insight to the field of precision metrology. Building on prior knowledge from the Bachelor courses it will cover topics from the field of sensing and metrology. The course will focus on work related to atomic physics and laser spectroscopy.

Contents of the Course:
Introduction to precision measurements: the system of SI units, systematic and statistical errors, precision and accuracy, error budgets, Allan deviation; the hydrogen atom and test of QED, including muonic hydrogen; atomic clocks: RF clocks, optical clocks (lattice clocks, ion clocks, nuclear clocks; matter wave interferometry; entanglement and squeezing; search for physics beyond the standard model in atomic physics: isotope shift spectroscopy, drifts in fundamental constants and dark matter, Lorentz violation, parity violation; ring laser gyroscopes for rotation sensing; technology: lasers, frequency combs, resonators. Possible topics outside of atomic physics include tests of special relativity and gravitational wave detection.

Recommended Literature:
Will be given in the lecture

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: universitätbonn Research Project

Course No.: physics799

Category	Type	Language	Teaching hours	CP	Semester
Elective	Research Project	English		4	WT/ST

Requirements for Participation:
Students are asked to contact one of the BCGS lecturers prior to the start of their research project. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have projects available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

registration by written application to the examination office (see homepage)

Module No.: physics70b
Credit Points (CP): 3-6
Category: Elective
Semester: 1.-2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures: Applied Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected courses from catalogue type "A" (Applied) or "E/A" (Experimental/A)	see catalogue	3-6	see catalogue	90-180 hrs	ST/WT
2.	Also possible classes from M.Sc. in Astrophysics					

Requirements for Participation:
none

Form of Examination:
see with the course

Content:
Advanced lectures in applied physics

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 or 2 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 18 CP out of all 4 Elective Advanced Modules

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Advanced Electronics and Signal Processing (E/A)

Course No.: physics712

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Electronics laboratory of the B.Sc. in physics programme
Recommended: module nuclear and particle physics of the B.Sc. programme

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Comprehension of the basics of electronics circuits for the processing of (detector) signals, mediation of the basics of experimental techniques regarding electronics and micro electronics as well as signal processing

Contents of the Course:
The physics of electronic devices, junctions, transistors (BJT and FET), standard analog and digital circuits, amplifiers, elements of CMOS technologies, signal processing, ADC, DAC, noise sources and noise filtering, coupling of electronics to sensors/detectors, elements of chip design, VLSI electronics, readout techniques for detectors

Recommended Literature:
P. Horowitz, W. Hill; The Art of Electronics (Cambridge University Press 2. Aufl. 1989)
S. Sze; The Physics of Semiconductor Devices (Wiley & Sons 1981)
H. Spieler, Semiconductor detector system (Oxford University Press 2005))
J. Krenz; Electronics Concepts (Cambridge University Press 2000)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Particle Detectors and Instrumentation (E/A)

Course No.: physics713

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with laboratory	English	3+1	6	ST

Requirements for Participation:

Preparation:
Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Designing an experiment in photoproduction on pi-0, selection and building of appropriate detectors, set-up and implementation of an experiment at ELSA

Contents of the Course:
Quark structure of mesons and baryons, nucleon excitation; electromagnetic probes, electron accelerators, photon beams, relativistic kinematics interaction of radiation with matter, detectors for photons, leptons and hadrons; laboratory course: setup of detectors and experiment at ELSA

Recommended Literature:
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
W. R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2. Ed. 1994)
K. Kleinknecht; Detektoren für Teilchenstrahlung (Teubner, Wiesbaden 4. überarb. Aufl. 2005)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Advanced Accelerator Physics (E/A)

Course No.: physics714

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST/WT

Requirements for Participation:

Preparation:
Accelerator Physics (physics612)

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the physics of synchrotron radiation and its influence on beam parameters
Basic knowledge of collective phenomena in particle accelerators
General knowledge of applications of particle accelerators (research, medicine, energy management)

Contents of the Course:
Synchrotron radiation:
radiation power, spatial distribution, spectrum, damping, equilibrium beam emittance, beam lifetime
Space-charge effects:
self-field and wall effects, beam-beam effects, space charge dominated beam transport, neutralization of beams by ionization of the residual gas
Collective phenomena:
wake fields, wake functions and coupling impedances, spectra of a stationary and oscillating bunches, bunch interaction with an impedance, Robinson instability
Applications of particle accelerators:
medical accelerators, neutrino facilities, free electron lasers, nuclear waste transmutation, etc.

Recommended Literature:
F. Hinterberger; Physik der Teilchenbeschleuniger und Ionenoptik (Springer, Heidelberg 1997)
H. Wiedemann; Particle Accelerator Physics (Springer, Heidelberg 2 Aufl. 1999)
K. Wille; Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen (Teubner, Wiesbaden 2. Aufl. 1996)
D. A. Edwards, M.J. Syphers; An Introduction to the Physics of High Energy Accelerators (Wiley & Sons 1993)
A. Chao; Physics of Collective Beam Instabilities in High Energy Accelerators (Wiley & Sons 1993)
Script of the Lecture Particle Accelerators (physics612)
http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Scientific Programming with Python (E/A)

Course No.: physics725

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	6	ST

Requirements for Participation:

Preparation:
Prior knowledge of any programming language (C/C++, Java, Python, ...)

Form of Testing and Examination:
Successful implementation of scientific projects in Python during the semester

Length of Course:
1 semester

Aims of the Course:
Effective and flexible program solving with the easy-to-learn, high-level programming language Python. The course addresses master and PhD students with prior programming knowledge as taught in the bachelor course physics131.

Contents of the Course:
In-depth introduction to the Python programming language; Introduction to numpy arrays (primary Python data structure for scientific computing); Introduction to scientific-Python modules (scipy, astropy);
Interactive work / development with Python (ipython); Web interaction with Python (jupyter notebooks, web and database queries);
Plotting with Python (the matplotlib module), Introduction to writing own scientific Python-modules and Object-oriented programming, Collaborative code development and version control (git, github)

Recommended Literature:
All necessary materials are made available online via the eCampus platform

Credit points can only be earned from one exam out of physics718 and physics725

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Programming in Physics and Astronomy with C++ or Python (E/A)

Course No.: physics718

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Basic knowledge of programming and knowledge of simple C/C++ or Python constructs.

Form of Testing and Examination:
C/C++ part: Requirements for the examination (written or oral): successful work with the exercises.
Python part: Requirements for examination: successful implementation of the scientific projects in Python during the semester.

Length of Course:
1 semester

Aims of the Course:
C++ part: In-depth understanding of C++ and its applications in particle physics. Discussion of advanced features of C++ using examples from High Energy Physics. The course is intended for students with some background in C++ or for advanced students who wish to apply C++ in their graduate research.
Python part: Effective and flexible program solving with the easy-to-learn, high level programming language Python. The course addresses master and PhD students with prior Python-programming knowledge as taught in the bachelor course physics131.

Contents of the Course:
C++ part: - Basic ingredients of C++, - Object orientation: classes, inheritance, polymorphism, - How to solve physics problems with C++, - Standard Template Library, - C++ in data analysis, example: the ROOT library, - C++ and large scale calculations, - How to write and maintain complex programs, - Parallel computing and the Grid, - Debugging and profiling
Python part: - In-depth introduction to Python based on prior programming experience, - Introduction to numpy arrays (primary Python data structure for scientific computing), - Introduction to scientific-Python modules (scipy, astropy), - Interactive work / development with Python (ipython), - Web interaction with Python (jupyter notebooks, web and database queries), - Plotting with Python (the matplotlib module)

Recommended Literature:
Eckel: Thinking in C++, Prentice Hall 2000.
Lippman, Lajoie, Moo: C++ Primer, Addison-Wesley 2000.
Deitel and Deitel, C++ how to program, Prentice Hall 2007.
Stroustrup, The C++ Programming Language, Addison-Wesley 2000.

- The course is given in the summer term and alternates between C++ and Python
- The course can only be taken once for credit points.

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Hands-on Seminar: Detector Construction (E/A)

Course No.: physics723

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English	2	3	WT/ST

Requirements for Participation:
Basic knowledge of particle physics

Preparation:
physics618 is helpful but not mandatory

Form of Testing and Examination:
Credit points can be obtained after successful construction and operation of the detector and preparing a written and/or oral report on a specific task

Length of Course:
1 semester

Aims of the Course:
Students will design, construct, assemble and operate a particle detector.

Contents of the Course:
Students will construct, assemble and commission a particle detector. They will gain hands-on experience on detector construction. The students organize and execute the tasks of the project in personal responsibility. This includes many tasks common to more complex research or industrial projects. Topics include:

- order the needed detector components
- prepare CAD drawings
- prepare PCB layout
- develop electronic circuits
- produce and assemble detector parts
- vacuum technology
- cooling technology
- organize the work effort in personal responsibility
- communicate with team members and technical staff

Recommended Literature:
H. Kolanoski, N. Wermes, Teilchendetektoren, (Springer, Heidelberg, 2016)
W. R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2. Ed. 1994)
K. Kleinknecht; Detektoren für Teilchenstrahlung (Teubner, Wiesbaden 4. überarb. Aufl. 2005)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: universitätbonn Low Temperature Physics (E/A)

Course No.: physics731

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT/ST

Requirements for Participation:

Preparation:
Elementary thermodynamics; principles of quantum mechanics; introductory lecture on solid state physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Experimental methods at low (down to micro Kelvin) temperatures; methods of refrigeration; thermometry; solid state physics at low temperatures

Contents of the Course:
Thermodynamics of different refrigeration processes, liquefaction of gases; methods to reach low (< 1 Kelvin) temperatures: evaporation cooling, He-3-He-4 dilution cooling, Pomeranchuk effect, adiabatic demagnetisation of atoms and nuclei; thermometry at low temperatures (e.g. helium, magnetic thermometry, noise thermometry, thermometry using radioactive nuclei); principles for the construction of cryostats for low temperatures

Recommended Literature:
O.V. Lounasmaa; Experimental Principles and Methods Below 1K (Academic Press, London 1974)
R.C. Richardson, E.N. Smith; Experimental Techniques in Condensed Matter Physics at Low Temperatures (Addison-Wesley 1988)
F. Pobell, Matter and Methods at Low Temperatures (Springer-Verlag, Heidelberg 2. Aufl. 1996)

Modules:		
	physics70a	**Elective Advanced Lectures: Experimental Physics**
	physics70b	**Elective Advanced Lectures: Applied Physics**

Course: Optics Lab (E/A)

Course No.: physics732

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English		4	WT/ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Credit points can be obtained after completion of a written report.

Length of Course:
4-6 weeks

Aims of the Course:
The student learns to handle his/her own research project within one of the optics groups

Available projects and contact information can be found at: http://www.iap.uni-bonn.de/opticslab/

Contents of the Course:
Practical training/internship in a research group, which can have several aspects:
- setting up a small experiment
- testing and understanding the limits of experimental components
- simulating experimental situations

Recommended Literature:
Will be given by the supervisor

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: universitätbonn Holography (E/A)

Course No.: physics734

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to provide in-depth knowledge and to provide practical abilities in the field of holography as an actual topic of applied optics

Contents of the Course:
The course will cover the basic principle of holography, holographic recording materials, and applications of holography. In the first part the idea behind holography will be explained and different hologram types will be discussed (transmission and reflection holograms; thin and thick holograms; amplitude and phase holograms; white-light holograms; computer-generated holograms; printed holograms). A key issue is the holographic recording material, and several material classes will be introduced in the course (photographic emulsions; photochromic materials; photo-polymerization; photo-addressable polymers; photorefractive crystals; photosensitive inorganic glasses). In the third section several fascinating applications of holography will be discussed (art; security-features on credit cards, banknotes, and passports; laser technology; data storage; image processing; filters and switches for optical telecommunication networks; novelty filters; phase conjugation ["time machine"]; femtosecond holography; space-time conversion). Interested students can also participate in practical training. An experimental setup to fabricate own holograms is available

Recommended Literature:
Lecture notes;
P. Hariharan; Optical Holography - Principles, Techniques, and Applications (Cambridge University Press, 2nd Edition, 1996)
P. Hariharan; Basics of Holography (Cambridge University Press 2002)
J. W. Goodman; Introduction to Fourier Optics (McGraw-Hill Education - Europe 2nd Ed. 2000)
A. Yariv; Photonics (Oxford University Press 6th Ed. 2006)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Crystal Optics (E/A)

Course No.: physics736

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Because of their aesthetic nature crystals are termed "flowers of mineral kingdom". The aesthetic aspect is closely related to the symmetry of the crystals which in turn determines their optical properties. It is the purpose of this course to stimulate the understanding of these relations. The mathematical and tools for describing symmetry and an introduction to polarization optics will be given before the optical properties following from crystal symmetry are discussed. Particular emphasis will be put on the magneto-optical properties of crystals in magnetic internal or external fields. Advanced topics such as the determination of magnetic structures and interactions by nonlinear magneto-optics will conclude the course

Contents of the Course:
Crystal classes and their symmetry; basic group theory; polarized light; optical properties in the absence of fields; electro-optical properties; magneto-optical properties: Faraday effect, Kerr effect, magneto-optical materials and devices, semiconductor magneto-optics, time-resolved magneto-optics, nonlinear magneto-optics

Recommended Literature:
R. R. Birss, Symmetry and Magnetism, North-Holland (1966)
R. E. Newnham: Properties of Materials: Anisotropy, Symmetry, Structure, Oxford University (2005)
A. K. Zvezdin, V. A. Kotov: Modern Magnetooptics & Magnetooptical Materials, Taylor/Francis (1997)
Y. R. Shen: The Principles of Nonlinear Optics, Wiley (2002)
K. H. Bennemann: Nonlinear Optics in Metals, Oxford University (1999)

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Lecture on Advanced Topics in Photonics (E/A)

Course No.: physics739

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:

Preparation:
Optics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce the students to a special field of research in photonics. New research results will be presented and their relevance is discussed.

Contents of the Course:
Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:
Will be given in the lecture

This course may be offered as "Teaching hours (3+1)" with 6 cp, as well

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Hands-on Seminar: Experimental Optics and Atomic Physics (E/A)

Course No.: physics740

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of optics and quantum mechanics

Form of Testing and Examination:
Credit points can be obtained after successful carrying out the experiments and preparing a written report on selected experiments

Length of Course:
1 semester

Aims of the Course:
The students learn to handle optical setups and carry out optical experiments. This will prepare participants both for the successful completion of research projects in experimental quantum optics/photonics and tasks in the optics industry.

Contents of the Course:
Practical training in the field of optics, where the students start their experiment basically from scratch (i.e. an empty optical table). The training involves the following topics:
- diode lasers
- optical resonators
- acousto-optic modulators
- spectroscopy
- radiofrequency techniques

Recommended Literature:
Will be given by the supervisor

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**

Course: Modern Spectroscopy (E/A)

Course No.: physics741

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:

Preparation:
Fundamentals of Optics, Fundamentals of Quantum Mechanics

Form of Testing and Examination:
Requirements for the examination (oral or written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to introduce the students to both fundamental and advanced concepts of spectroscopy and enable them to practically apply their knowledge.

Contents of the Course:
Spectroscopy phenomena - time and frequency domain;
high resolution spectroscopy;
pulsed spectroscopy; frequency combs;
coherent spectroscopy;
nonlinear spectroscopy: Saturation, Raman spectroscopy, Ramsey spectroscopy.
Applications of spectroscopic methods (e.g. Single molecule spectroscopy; spectroscopy at interfaces & surfaces, spectroscopy of cold atoms; atomic clocks; atom interferometry)

Recommended Literature:
W. Demtröder; Laser spectroscopy (Springer 2002)
S. Svanberg; Atomic and molecular spectroscopy basic aspects and practical applications (Springer 2001)
A. Corney; Atomic and laser spectroscopy (Clarendon Press 1988)
N. B. Colthup, L. H. Daly, S. E. Wiberley; Introduction to infrared and Raman spectroscopy (Academic Press 1990)
P. Hannaford; Femtosecond laser spectroscopy (Springer New York 2005)
C. Rulliere; Femtosecond laser pulses: principles and experiments (Springer Berlin 1998)

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Environmental Physics & Energy Physics (A)

Course No.: physics771

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:
Physik I-V (physik110-physik510)

Form of Testing and Examination:
Active contributions during term and written examination

Length of Course:
1 semester

Aims of the Course:
A deeper understanding of energy & environmental facts and problems from physics (and, if needed, nature or agricultural science) point of view

Contents of the Course:
After introduction into related laws of nature and after a review of supply and use of various resources like energy a detailed description on each field of use, use-improvement strategies and constraints and consequences for environment and/or human health & welfare are given.

Recommended Literature:
Diekmann, B., Heinloth, K.: Physikalische Grundlagen der Energieerzeugung, Teubner 1997
Hensing, I., Pfaffenberger, W., Ströbele, W.: Energiewirtschaft, Oldenbourg1998
Fricke, J., Borst, W., Energie, Oldenbourg 1986
Bobin, J. L.,Huffer,E., Nifenecker,H., L'Energie de Demain ,EDP Sciences 2005
Thorndyke, W., Energy and Environment, Addison Wesley 1976
Schönwiese, C. D., Diekmann, B., Der Treibhauseffekt , DVA 1986
Boeker, E., von Grondelle, R., Physik und Umwelt, Vieweg, 1997

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Physics in Medicine: Fundamentals of Analyzing Biomedical Signals (A)

Course No.: physics772

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Elementary thermodynamics; principles of quantum mechanics, principles of condensed matter

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the principles of physics and the analysis of complex systems

Contents of the Course:
Introduction to the theory of nonlinear dynamical systems; selected phenomena (e.g. noise-induced transition, stochastic resonance, self-organized criticality); Nonlinear time series analysis: state-space reconstruction, dimensions, Lyapunov exponents, entropies, determinism, synchronization, interdependencies, surrogate concepts, measuring non-stationarity.
Applications: nonlinear analysis of biomedical time series (EEG, MEG, EKG)

Recommended Literature:
Lehnertz: Skriptum zur Vorlesung
E. Ott; Chaos in dynamical systems (Cambridge University Press 2. Aufl. 2002)
H. Kantz, T. Schreiber ; Nonlinear time series analysis. (Cambridge University Press 2:Aufl. 2004).
A. Pikovsky, M. Rosenblum, J. Kurths; Synchronization: a universal concept in nonlinear sciences (Cambridge University Press 2003)

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Physics in Medicine: Fundamentals of Medical Imaging (A)

Course No.: physics773

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the principles of physics of modern imaging techniques in medicine

Contents of the Course:
Introduction to physical imaging methods and medical imaging; Physical fundamentals of transmission computer tomography (Röntgen-CT), positron emission computer tomography (PET), magnetic resonance imaging (MRI) and functional MRI
detectors, instrumentation, data acquisition, tracer, image reconstruction, BOLD effect; applications: analysis of structure and function.
Neuromagnetic (MEG) and Neuroelectrical (EEG) Imaging; Basics of neuroelectromagnetic activity, source models
instrumentation, detectors, SQUIDs; signal analysis, source imaging, inverse problems, applications

Recommended Literature:
K. Lehnertz: Scriptum zur Vorlesung
S. Webb; The Physics of Medical Imaging (Adam Hilger, Bristol 1988)
O. Dössel; Bildgebende Verfahren in der Medizin (Springer, Heidelberg 2000)
W. Buckel; Supraleitung (Wiley-VCH Weinheim 6. Aufl. 2004)
E. Niedermeyer/F. H. Lopes da Silva; Electroencephalography (Urban & Schwarzenberg, 1982)

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Electronics for Physicists (E/A)

Course No.: physics774

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Electronics laboratory of the B.Sc. in physics programme

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Comprehension of electronic components, methods to derive the dynamical performance of circuits and mediation that these methods are widely used in various fields of physics

Contents of the Course:
Basics of electrical engineering, RF-electronics I: Telegraph equation, impedance matching for lumped circuits and electromagnetic fields, diodes, transistors, analogue and digital integrated circuits, system analysis via laplace transformation, basic circuits, circuit synthesis, closed loop circuits, oscillators, filters, RF-electronics II: low-noise oscillators and amplifiers

Recommended Literature:
P. Horrowitz, W. Hill; The Art of Electronics (Cambridge University Press)
Murray R. Spiegel; Laplace Transformation (McGraw-Hill Book Company)
A.J. Baden Fuller; Mikrowellen (Vieweg)
Lutz v. Wangenheim; Aktive Filter (Hüthig)

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Nuclear Reactor Physics (A)

Course No.: physics775

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:
Fundamental nuclear physics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Deeper understanding of nuclear power generation (fisson and fusion)

Contents of the Course:
Physics of nuclear fission and fusion, neutron flux in reactors, different reactor types, safety aspects, nuclear waste problem, future aspects
and
Excursion to a nuclear power plant

Recommended Literature:
H. Hübel: Reaktorphysik (Vorlesungsskript, available during the lecture)
M. Borlein: Kerntechnik, Vogel (2009)
W. M. Stacey: Nuclear Reactor Physics, Wiley & Sons (2007)

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Physics in Medicine: Physics of Magnetic Resonance Imaging (A)

Course No.: physics776

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the principles of Magnetic Resonance Imaging Physics

Contents of the Course:
- Theory and origin of nuclear magnetic resonance (QM and semiclassical approach)
- Spin dynamics, T1 and T2 relaxation, Bloch Equations and the Signal Equation
- Gradient echoes and spin echoes and the difference between T2 and T2*
- On- and off-resonant excitation and the slice selection process
- Spatial encoding by means of gradient fields and the k-space formalism
- Basic imaging sequences and their basic contrasts, basic imaging artifacts
- Hardware components of an MRI scanner, accelerated imaging with multiple receiver
- Computation of signal amplitudes in steady state sequences
- The ultra-fast imaging sequence EPI and its application in functional MRI
- Basics theory of diffusion MRI and its application in neuroimaging
- Advanced topics: quantitative MRI, spectroscopic imaging, X-nuclei MRI

Recommended Literature:
- T. Stöcker: Scriptum zur Vorlesung
- E.M. Haacke et al, Magnetic Resonance Imaging: Physical Principles and Sequence Design, John Wiley 1999
- M.T. Vlaardingerbroek, J.A. den Boer, Magnetic Resonance Imaging: Theory and Practice, Springer, 20
- Z.P. Liang, P.C. Lauterbur, Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, SPIE 1999

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Physics in Medicine: Cardiovascular Magnetic Resonance Imaging (CMRI) (A)

Course No.: physics777

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the principles of physics of Cardiovascular Magnetic Resonance Imaging (CMRI)

Contents of the Course:
1. Basic principles of MRI I (Bloch equation, spatial encoding)
2. Basic principles of MRI II (extended Bloch equation)
3. k-space trajectories and reconstruction techniques (Cartesian data: Fast Fourier transform (FFT); Non Cartesian: Nonuniform fast Fourier transform (NUFFT), REGRIDDING, BACK PROJECTION)
4. Basic principles of CMRI (physiology, motion correction, gating strategies)
5. Preclinical MRI systems at high magnetic fields (7T and above) – hardware, advantages and limitations

6. Magnetic resonance contrast agents (from a biophysical point of view, hands-on at MRI)
7. Myocardial relaxometry (T1, T2, T2* mapping, Extracellular Volume mapping, hands-on at MRI)
8. Magnetic resonance angiography (contrast enhanced MR angiography, navigator-based MR angiography)
9. CMRI of moving spins (blood flow velocity: phase contrast MRI, 4D velocity vector fields, velocity-time curves, vorticity, helicity, streamlining, pathfinding, hands-on at MRI)
10. Myocardial perfusion imaging (contrast-enhanced imaging techniques, Arterial Spin Labeling)
11. Myocardial architecture imaging (Diffusion-weighted magnetic resonance imaging (DWI), Diffusion tensor imaging (DTI), quantitative analysis, hands-on at MRI)
12. Myocardial MR Spectroscopy (Point Resolved Spectroscopy (PRESS), Stimulated Echo Acquisition Mode (STEAM), Chemical Shift Imaging (CSI), 31P-Image-Selected In vivo Spectroscopy (ISIS))
13. Novel approaches in metabolic MRI of the heart (Chemical exchange saturation transfer (CEST), Magnetization transfer contrast (MTC), comparison to 1H-MR Spectroscopy, quantitative analysis)
14. Concepts of acceleration in cardiac MRI at preclinical systems (Compressed Sensing (CS), Total Variation (TV), Parallel Imaging)

Recommended Literature:
1. V. Hörr: Scriptum zur Vorlesung

2. MRI: The Basics, Ray H. Hashemi, William G. Bradley, Christopher J. Lisanti, Lippincott Williams & Wilkins.
3. In Vivo NMR Spectroscopy, Robin de Graaf, John Wiley & Sons.
4. Compressed Sensing Magnetic Resonance Image Reconstruction Algorithms, Bhabesh Deka, Sumit Datta, Springer.
5. Magnetic Resonance Imaging: Physical Principles and Sequence Design, Robert W. Brown, Yu-Chung N. Cheng, E. Mark Haacke, Michael R. Thompson, Ramesh Venkatesan, John Wiley & Sons.
6. Cardiovascular Magnetic Resonance, Warren J. Manning, Dudley J. Pennell, Elsevier.

Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: "Energy Production" (A)

Course No.: physics778

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Physik I-V (physik110-physik510)

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The course intends to provide an overview in the field of today's challenges in "energy production" from a physics point of view.

Contents of the Course:
Energy storage & transport

Nuclear power
- Solar (photovoltaics, thermal, wind, water)
- Geothermal
- Reactors (fission / fusion)

Moon power (tidal power plants)

Recommended Literature:
Will be given during the course

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: Research Project

Course No.: physics799

Category	Type	Language	Teaching hours	CP	Semester
Elective	Research Project	English		4	WT/ST

Requirements for Participation:
Students are asked to contact one of the BCGS lecturers prior to the start of their research project. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have projects available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

registration by written application to the examination office (see homepage)

Module No.: physics70c
Credit Points (CP): 3-7
Category: Elective
Semester: 1.-2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures: Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected courses from catalogue type "T" (Theoretical)	see catalogue	5-7	see catalogue	150-210 hrs	WT/ST
2.	Also possible classes from M.Sc. in Astrophysics					

Requirements for Participation:
none

Form of Examination:
see with the course

Content:
Advanced lectures in theoretical physics

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 or 2 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 18 CP out of all 4 Elective Advanced Modules

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: Ultracold Atomic Gases (E/T)

Course No.: physics742

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Quantum Mechanics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
This lecture discusses both the experimental and theoretical concepts of ultra-cold atomic gases.

Contents of the Course:
Almost hundred years ago, in 1924, A. Einstein and S.N. Bose predicted the existence of a new state of matter, the so-called Bose-Einstein condensate. It took 70 years to successfully realize this macroscopic quantum state in the lab using ultracold atomic gases (Nobel prize 2001). The main challenge was to achieve cooling to Nanokelvin temperatures, the coolest temperatures ever reached by mankind. Nowadays, ultracold gases are exciting systems to study a broad range of quantum phenomena. These phenomena range from the direct observation of quantum matter waves and superfluidity over the creation of artificial crystal structures as analogous to solids, to the realization of complex quantum phase transitions of interacting atoms, e.g. the formation of a bosonic Mott-insulator or the BCS superconducting state for Fermions. In this lecture we will discuss both the experimental and theoretical concepts of ultra-cold atomic gases.

Outline: Introduction and revision of basic concepts, Fundamentals of atom-laser interaction
Laser cooling & trapping, Bose-Einstein condensation of atomic gases. Dynamics of Bose-Einstein condensates
Optical lattices: strongly interacting atomic gases and quantum phase transitions
The crossover of Fermi-gases between a BCS superconducting state and a Bose-Einstein condensate of molecules.

Recommended Literature:
C. J. Pethick and H. Smith, Bose-Einstein Condensation in Dilute Gases (Cambridge University Press)

Modules:

ECThPhysics **Elective Courses Theoretical Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: universitätbonn Group Theory (T)

Course No.: physics751

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
physik421 (Quantum Mechanics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Acquisition of mathematical foundations of group theory with regard to applications in theoretical physics

Contents of the Course:
Mathematical foundations:
Finite groups, Lie groups and Lie algebras, highest weight representations, classification of simple Lie algebras, Dynkin diagrams, tensor products and Young tableaux, spinors, Clifford algebras, Lie super algebras

Recommended Literature:
B. G. Wybourne; Classical Groups for Physicists (J. Wiley & Sons 1974)
H. Georgi; Lie Algebras in Particle Physics (Perseus Books 2. Aufl. 1999)
W. Fulton, J. Harris; Representation Theory (Springer, New York 1991)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: universitätbonn Superstring Theory (T)

Course No.: physics752

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Quantum Field Theory (physics755)
Group Theory (physics751)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Survey of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:
Bosonic String Theory, Elementary Conformal Field Theory
Kaluza-Klein Theory
Crash Course in Supersymmetry
Superstring Theory
Heterotic String Theory
Compactification, Duality, D-Branes
M-Theory

Recommended Literature:
D. Lüst, S. Theisen; Lectures on String Theory (Springer, New York 1989)
S. Förste; Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055
C. Johnson, D-Brane Primer (Cambridge University Press 2003)
M. Green, J. Schwarz, E. Witten; Superstring Theory I & II (Cambridge University Press 1988)
H.P. Nilles, Supersymmetry and phenomenology (Phys. Reps. 110 C (1984) 1)
J. Polchinski; String Theory I & II (Cambridge University Press 2005)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Theoretical Particle Astrophysics (T)

Course No.: physics753

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
General Relativity and Cosmology (physics754)
Quantum Field Theory (physics755)
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the current status at the interface of particle physics and cosmology

Contents of the Course:
Topics on the interface of cosmology and particle physics:
Inflation and the cosmic microwave background;
baryogenisis,
Dark Matter,
nucleosynthesis
the cosmology and astrophysics of neutrinos

Recommended Literature:
J. Peacock, Cosmological Physics (Cambridge University Press 1998)
E. Kolb, M. Turner; The Early Universe (Addison Wesley 1990)

Modules:

ECThPhysics **Elective Courses Theoretical Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: General Relativity and Cosmology (T)

Course No.: physics754

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
physik221 and physik321 (Theoretical Physics I and II)
Differential geometry

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the general theory of relativity and its cosmological implications

Contents of the Course:
Relativity principle
Gravitation in relativistic mechanics
Curvilineal coordinates
Curvature and energy-momentum tensor
Einstein-Hilbert action and the equations of the gravitational field
Black holes
Gravitational waves
Time evolution of the universe
Friedmann-Robertson-Walker solutions

Recommended Literature:
S.Weinberg; Gravitation and Cosmology (J. Wiley & Sons 1972)
R. Sexl: Gravitation und Kosmologie, Eine Einführung in die Allgemeine Relativitätstheorie (Spektrum Akadem. Verlag 5. Aufl 2002)
L.D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.2: Classical field theory (Butterworth-Heinemann 1995), also available in German from publisher Harry Deutsch

Modules:

ECThPhysics **Elective Courses Theoretical Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: Quantum Field Theory (T)

Course No.: physics755

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
Advanced quantum theory (physics606)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding quantum field theoretical methods, ability to compute processes in quantum electrodynamics (QED) and many particle systems

Contents of the Course:
Classical field theory
Quantization of free fields
Path integral formalism
Perturbation theory
Methods of regularization: Pauli-Villars, dimensional
Renormalizability
Computation of Feynman diagrams
Transition amplitudes in QED
Applications in many particle systems

Recommended Literature:
N. N. Bogoliubov, D.V. Shirkov; Introduction to the theory of quantized fields (J. Wiley & Sons 1959)
M. Kaku, Quantum Field Theory (Oxford University Press 1993)
M. E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Harper Collins Publ. 1995)
L. H. Ryder; Quantum Field Theory (Cambridge University Press 1996)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Critical Phenomena (T)

Course No.: physics756

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
Advanced quantum theory (physics606)
Theoretical condensed matter physics (physics617)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Acquisition of important methods to treat critical phenomena

Contents of the Course:
Mean Field Approximation and its Improvements
Critical Behaviour at Surfaces
Statistics of Polymers
Concept of a Tomonaga-Luttinger Fluid
Random Systems
Phase Transitions, Critical Exponents
Scale Behaviour, Conformal Field Theory
Special Topics of Nanoscopic Physics

Recommended Literature:
J. Cardy, Scaling and Renormalization in Statistical Physics (Cambridge University Press, 1996)
A. O. Gogolin, A. A. Nersesyan, A.N.Tsvelik; Bosonisation and strongly correlated systems (Cambridge University Press, 1998)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Effective Field Theory (T)

Course No.: physics757

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements for Participation:

Preparation:
Advanced quantum theory (physics606)
Quantum Field Theory (physics755)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding basic properties and construction of Effective Field Theories, ability to perform calculations in Effective Field Theories

Contents of the Course:
Scales in physical systems, naturalness
Effective Quantum Field Theories
Renormalization Group, Universality
Construction of Effective Field Theories
Applications: effective field theories for physics beyond the Standard Model, heavy quarks, chiral dynamics, low-energy nuclear physics, ultracold atoms

Recommended Literature:
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)
J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)
A.V. Manohar, M.B. Wise; Heavy Quark Physics (Cambridge University Press 2007)
P. Ramond, Journeys Beyond The Standard Model (Westview Press 2003)
D.B. Kaplan, Effective Field Theories (arXiv:nucl-th/9506035)
E. Braaten, H.-W. Hammer; Universality in Few-Body Systems with Large Scattering Length (Phys. Rep. 428 (2006) 259)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Quantum Chromodynamics (T)

Course No.: physics758

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements for Participation:

Preparation:
Advanced quantum theory (physics606)
Quantum Field Theory (physics755)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding basic properties of Quantum Chromodynamics, ability to compute strong interaction processes

Contents of the Course:
Quantum Chromodynamics as a Quantum Field Theory
Perturbative Quantum Chromodynamics
Topological objects: instantons etc.
Large N expansion
Lattice Quantum Chromodynamics
Effective Field Theories of Quantum Chromodynamics
Flavor physics (light and heavy quarks)

Recommended Literature:
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)
M.E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Westview Press 1995)
F.J. Yndurain; The Theory of Quark and Gluon Interactions (Springer 2006)
J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)
E. Leader and E. Predazzi; An Introduction to Gauge Theories and Modern Particle Physics (Cambridge University Press 1996)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Quantum Field Theory for Condensed Matter Physics (T)

Course No.: physics759a

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:
Quantum Mechanics (physik421)
Thermodynamics and Statistical Physics (physik521)

Preparation:
Elementary condensed matter physics (physik411 or similar)

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Knowledge of quantum field theory of interacting many-body systems at finite temperature
Knowledge of quantum field theory for non-equilibrium systems
Ability to construct and evaluate perturbation theory using Feynman diagrams
Basic understanding of problems of open quantum systems

Contents of the Course:
Fock space and occupation-number representation for bosons and fermions (if not yet familiar)
Elementary linear response theory
Quantum field theory at finite temperature: functional integral fomulation
Green's functions: analytical properties and their relation to observable quantities
Perturbation theory in thermodynamic equilibrium: Feynman diagrams, Matsubara technique
Kondo effect and renormalization group
Quantum field theory away from thermodynamic equilibrium: Schwinger-Keldysh functional integral
Perturbation theory away from equilibrium: Keldysh technique
Open and driven-dissipative quantum systems: Lindblad formalism

Recommended Literature:
A. Kamenev, Field Theory of Non-Equilibrium Systems, 2nd edition, Cambridge University Press (2023).
G. Stefanucci, R. van Leeuwen, Nonequilibrium Many-Body Theory of Quantum Systems, A Modern Introduction, Cambridge University Press (2013).
H.-P. Breuer, F. Petruccione, The Theory of Open Quantum Systems, Oxford University Press (2002, reprinted 2010).
P. Coleman, Introduction to Many-Body Physics, Cambridge University Press (2015, reprinted 2017).

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Advanced Quantum Field Theory for Condensed Matter Physics (T)

Course No.: physics759b

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:
Quantum Field Theory for Condensed Matter Physics (physics759a)

Preparation:
Special interest in theoretical condensed matter physics and mathematical physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Knowledge of advanced methods for evaluating quantum field theories
Knowledge of advanced models of quantum many-body systems

Contents of the Course:
Selected topics of modern theoretical condensed matter field theory, for example:
Formalism of generating functionals
Luttinger-Ward identities and conserving approximations
Bosonization
Dynamical Mean-Field Theory (DMFT)
Disordered systems and Anderson localization
Applications of field-theoretic methods to specific models

Recommended Literature:
A. Kamenev, Field Theory of Non-Equilibrium Systems, 2nd edition, Cambridge University Press (2023).
G. Stefanucci, R. van Leeuwen, Nonequilibrium Many-Body Theory of Quantum Systems, A Modern Introduction, Cambridge University Press (2013).
P. Coleman, Introduction to Many-Body Physics, Cambridge University Press (2015, reprinted 2017).
Th. Giamarchi, Quantum Physics in One Dimension, Oxford University Press (2004).

Modules:

ECThPhysics **Elective Courses Theoretical Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: universitätbonn Computational Physics (T)

Course No.: physics760

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises and project work	English	2+2+1	7	WT/ST

Requirements for Participation:
Knowledge of a modern programming language (like C, C++)

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
successful participation in exercises,
presentation of an independently completed project

Length of Course:
1 semester

Aims of the Course:
ability to apply modern computational methods for solving physics problems

Contents of the Course:
Statistical Models, Likelihood, Bayesian and Bootstrap Methods
Random Variable Generation
Stochastic Processes
Monte-Carlo methods
Markov-Chain Monte-Carlo

Recommended Literature:
W.H. Press et al.: Numerical Recipes in C (Cambridge University Press)
http://library.lanl.gov/numerical/index.html
C.P. Robert and G. Casella: Monte Carlo Statistical Methods (Springer 2004)
Tao Pang: An Introduction to Computational Physics (Cambridge University Press)
Vesely, Franz J.: Computational Physics: An Introduction (Springer)
Binder, Kurt and Heermann, Dieter W.: Monte Carlo Simulation in Statistical Physics (Springer)
Fehske, H.; Schneider, R.; Weisse, A.: Computational Many-Particle Physics (Springer)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Supersymmetry (T)

universitätbonn

Course No.: physics761

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT/ST

Requirements for Participation:
Quantum Field Theory I

Preparation:

Form of Testing and Examination:
Individual Oral Examinations

Length of Course:
1 semester

Aims of the Course:
Teach the students the basics of supersymmetric field theory and how it can be tested at the LHC.

Contents of the Course:
Superfields; Supersymmetric Lagrangians; MSSM; Testing the MSSM at the LHC

Recommended Literature:

Theory and phenomenology of sparticles: An account of four-dimensional N=1 supersymmetry in high energy physics.
M. Drees, (Bonn U.) , R. Godbole, (Bangalore, Indian Inst. Sci.) , P. Roy, (Tata Inst.) . 2004. 555pp.
Hackensack, USA: World Scientific (2004) 555 p.

Weak scale supersymmetry: From superfields to scattering events.
H. Baer, (Florida State U.) , X. Tata, (Hawaii U.) . 2006. 537pp.
Cambridge, UK: Univ. Pr. (2006) 537 p.

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Transport in mesoscopic systems (T)

Course No.: physics762

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements for Participation:

Preparation:
Classical mechanics
Elementary thermodynamics and statistical physics (physik521)
Advanced quantum theory (physics606)
Introductory theoretical condensed matter physics (physics617)

Form of Testing and Examination:
Requirements for the examination (written or oral); successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding essential transport phenomena in solids and mesoscopic systems
Acquisition of important methods for treating transport problems

Contents of the Course:
Linear response theory
Disordered and ballistic systems
Semiclassical approximation
Introduction to quantum chaos theory, chaos and integrability in classical and quantum mechanics
Elements of random matrix theory
Specific problems of mesoscopic transport (weak localization, universal conductance fluctuations, shot noise, spin-dependent transport, etc.)
Quantum field theory away from thermodynamic equilibrium

Recommended Literature:
K. Richter, Semiclassical Theory of Mesoscopic Quantum Systems, Springer, 2000
(http://www.physik.uni-regensburg.de/forschung/richter/richter/pages/research/springer-tracts-161.pdf)
M. Brack, R. K. Bhaduri, Semiclassical Physics, Westview Press, 2003
S. Datta, Electronic Transport in Mesoscopic Systems, Cambrige University Press, 1995
M. C. Gutzwiller, Chaos in Classical and Quantum Mechanics, Springer, New York, 1990
F. Haake, Quantum signatures of chaos, Springer, 2001
M. L. Mehta, Random matrices, Elsevier, 2004
J. Imry, Introduction to mesoscopic physics, Oxford University Press
Th. Giamarchi, The physics of one-dimensional systems, Oxford University Press

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Advanced Topics in String Theory (T)

universitätbonn

Course No.: physics763

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:

Preparation:
Quantum Field Theory (physics755)
Group Theory (physics751)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Theoretical Particle Physics (physics615)
Superstring Theory (physics752)

Form of Testing and Examination:
active participation in exercises, written examination

Length of Course:
1 semester

Aims of the Course:
Detailed discussion of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:
Realistic compactifications
Interactions
Effective actions
Heterotic strings in four dimensions
Intersecting D-branes

Recommended Literature:
D. Lüst, S. Theisen: Lectures on String Theory (Springer, New York 1989)
S. Förste: Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055
C. Johnson: D-Brane Primer (Cambridge University Press 2003)
M. Green, J. Schwarz, E. Witten: Superstring Theory I & II (Cambridge University Press 1988)
H.P. Nilles: Supersymmetry and Phenomenology (Phys. Reps. 110C (1984)1)
J. Polchinski: String Theory I & II (Cambridge University Press 2005)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Advanced Topics in Field and String Theory (T)

Course No.: physics764

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:
Prerequisite knowledge of Quantum Field Theory, Superstring Theory, and General Relativity is helpful.

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Superstring Theory (physics752)

Form of Testing and Examination:
active participation in exercises, oral or written examination

Length of Course:
1 semester

Aims of the Course:
An introduction into modern topics in Mathematical High Energy Physics in regard to current research areas

Contents of the Course:
String and Supergravity Theories in various dimensions
Dualities in Field Theory and String Theory
Topological Field Theories and Topological Strings
Large N dualities and integrability

Recommended Literature:
Selected review articles an arXiv.org [hep-th]
J. Polchinski: String Theory I & II
S. Weinberg: Quantum Theory of Fields

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Advanced Topics in Quantum Field Theory (T)

Course No.: physics765

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements for Participation:
Prerequisite knowledge of Quantum Field Theory

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Form of Testing and Examination:
active participation in exercises, oral or written examination

Length of Course:
1 semester

Aims of the Course:
Covers advanced topics in Quantum Field Theory that are relevant for current developments in the field.

Contents of the Course:
TBA

Recommended Literature:
Selected articles on arXiv.org [hep-th]
TBA

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Physics of Higgs Bosons (T)

Course No.: physics766

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirement for the examination (written or oral): successful participation in the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the physics of electroweak symmetry breaking, and the interpretations of the recently discovered signals for the existence of a Higgs boson

Contents of the Course:
Spontaneous symmetry breaking
The Higgs mechanism
The Higgs boson of the Standard Model
Experimental situation
Extended Higgs sectors
Precision calculations

Recommended Literature:
J. Gunion, H.E. Haber, G.L. Kane and S. Dawson: The Higgs Hunter's Guide (Frontiers of Physics, 2000)
A. Djouadi: Anatomy of Electroweak Symmetry Breaking I (Phys. Rep. 457 (2008) 1, hep-ph/0503173)
A. Djouadi: Anatomy of Electroweak Symmetry Breaking II (Phys. Rep. 459 (2008) 1, hep-ph/0504090)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Computational Methods in Condensed Matter Theory (T)

Course No.: physics767

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements for Participation:

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Advanced Theoretical Condensed Matter Physics (physics638)

Form of Testing and Examination:
Active participation in exercises, written examination

Length of Course:
1 semester

Aims of the Course:
Detailed discussion of computational tools in modern condensed matter theory

Contents of the Course:
Exact Diagonalization (ED)
Quantum Monte Carlo (QMC)
(Stochastic) Series expansion (SSE)
Density Matrix Renormalization (DMRG)
Dynamical Mean Field theory (DMFT)

Recommended Literature:
will be given in the lecture

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: General Relativity for Experimentalists (T)

Course No.: physics768

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements for Participation:

Preparation:
Theoretische Physik I & II, Analysis I & II

Form of Testing and Examination:
Weekly homework sets (50% required), Final exam

Length of Course:
1 semester

Aims of the Course:
The students shall learn the basics of general relativity and be able to apply it to applications such as experimental tests of GR, GPS, astrophysical objects and simple issues in cosmology.

Contents of the Course:
Review of special relativity
Curved spacetime of GR
Experimental tests of GR
GPS
Black holes
Gravitational waves
Introductory cosmology

Recommended Literature:
GRAVITY, by James Hartle
A FIRST COURSE IN GENERAL RELATIVITY, by Bernard Schutz
EXPLORING BLACK HOLES, by Taylor and Wheeler

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Lattice QCD (T)

Course No.: physics769

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST/WT

Requirements for Participation:

Preparation:
Quantum Mechanics 1+2, Quantum Field Theory 1

Form of Testing and Examination:
Written / oral examination

Length of Course:
1 semester

Aims of the Course:
To give an introduction to the quantum field theory on the lattice

Contents of the Course:
- Introduction: Quantum mechanics on the lattice
- Numerical algorithms
- Spin systems on the lattice: The Ising model
- Scalar field theory on the lattice: Discretization; Perturbation theory; Continuum limit
- Gauge fields: Link variables; Plaquette action; Wilson loop and confinement
- Fermions on the lattice: Fermion doubling; Different formulations for lattice fermions; Axial anomaly; Chiral fermions
- Use of Effective Field Theory methods: Extrapolation in the quark masses; Resonances in a finite volume

Recommended Literature:
J. Smit, Introduction to quantum fields on a lattice: A robust mate, Cambridge Lect. Notes Phys. (2002)

I. Montvay and G. Münster, Quantum Fields on a Lattice, Cambridge Monographs on Mathematical Physics, Cambridge University Press 1994

C. Gattringer and Ch. Lang, Quantum Chromodynamics on the Lattice: An Introductory Presentation Series: Lecture Notes in Physics, Vol. 788

H.J. Rothe, Lattice Gauge Theories: An Introduction, World Scientific, (2005)

Modules:

ECThPhysics	**Elective Courses Theoretical Physics**
physics70c	**Elective Advanced Lectures: Theoretical Physics**

Course: universitätbonn Advanced Quantum Field Theory (T)

Course No.: physics7501

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
3-year theoretical physics course with extended interest in theoretical physics and mathematics

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to modern methods and developments in Theoretical Physics in regard to current research

Contents of the Course:
Selected Topics in Modern Theoretical Physics for example:
Anomalies
Solitons and Instantons
Quantum Fluids
Bosonization
Renormalization Group
Bethe Ansatz
Elementary Supersymmetry
Gauge Theories and Differential Forms
Applications of Group Theory

Recommended Literature:
M. Nakahara; Geometry, Topology and Physics (Institute of Physics Publishing, London 2nd Ed. 2003)
R. Rajaraman; Solitons and Instantons, An Introduction to Solitons and Instantons in Quantum Field Theory (North Holland Personal Library, Amsterdam 3rd reprint 2003)
A. M. Tsvelik; Quantum Field Theory in Condensed Matter Physics (Cambridge University Press 2nd Ed. 2003)
A. Zee; Quantum Field Theory in a Nutshell (Princeton University Press 2003)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Random Walks and Diffusion (T)

Course No.: physics7502

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	1+1	3	ST

Requirements for Participation:

Preparation:
Quantum mechanics and Thermodynamics

Form of Testing and Examination:
Requirements for the (written or oral) examination: Successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to introduce the student to random processes and their application to diffusion phenomena

Contents of the Course:
Basics of probability theory, Master equation and Langevin equation, Law of large numbers and Central Limit Theorem, First passage problems, Large scale dynamics, Dynamical scaling.

Recommended Literature:
Will be announced in the first lecture

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Selected Topics in Modern Condensed Matter Theory (T)

Course No.: physics7503

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
+ Introductory Condensed Matter Theory
+ Quantum Mechanics
+ Statistical Physics

Form of Testing and Examination:
oral or written examination

Length of Course:
1 semester

Aims of the Course:
Knowledge of topics of contemporary condensed matter research
Knowledge of theoretical methods of condensed matter physics

Contents of the Course:
Covers topics and methods of contemporary research, such as
+ Feynman diagram technique
+ Phase transitions and critical phenomena
+ Topological aspects of phenomena in condensed matter physic

Recommended Literature:
R. D. Mattuck, A Guide to Feynman Diagrams in the Many-Body Problem
N. Goldenfeld, Lectures on Phase Transitions and the Renormalization Group
B. A. Bernevig, Topological Insulators and Topological Superconductors

The course can be taken in parallel to physics617 Theoretical Condensed Matter Physics.

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Theory of Superconductivity and Superfluidity (T)

Course No.: physics7504

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements for Participation:

Preparation:
Quantum Mechanics, Thermodynamics and Statistics, Quantum Field Theory

Form of Testing and Examination:
Requirements for the (written or oral) examination: Successful participation in the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce students to the theory of superconductivity and superfluidity.

Contents of the Course:
Phenomenological theory of basic superconductivity, type I and type II superconductivity, vortices and their dynamics, Meissner-Ochsenfeld Effekt, microscopic theory of superconductivity: Gor'kov equation, BCS theory, Migdal theorem, strong coupling theory of superconductivity: Eliashberg equation, Andreev scattering, Josephson effect, Anderson theorem: impurity scattering, Collective excitations in superconductors and superfluids, Anderson (Higgs) mechanism for the mass generation. Superfluidity in 3He, superconductivity in heavy fermion compounds, high temperature superconductivity and open questions.

Recommended Literature:
Will be announced in the first lecture

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: High performance computing: Modern computer architectures and applications in the physical science (T)

universitätbonn

Course No.: physics7505

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT/ST

Requirements for Participation:
Knowledge of a modern programming language like C/C++

Preparation:

Form of Testing and Examination:
oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding principles of modern computer architectures and their usage and programming for scientific problems

Contents of the Course:
Computer architectures and system components (CPU, memory, network)
Software environment
Parallel architectures and parallel programming paradigms (MPI, OpenMP/threads)
High Performance Computing

Recommended Literature:
John L. Hennessy, David A. Patterson: Computer Architecture - A Quantitative Approach. Morgan Kaufmann Publishers, 2012
David A. Patterson, John L. Hennessy: Computer Organization and Design - The Hardware / Software Interface. Morgan Kaufmann Publishers, 2013
W.H. Press et al.: Numerical Recipes in C (Cambridge University Press)
Message Passing Interface Forum: MPI: A Message-Passing Interface Standard, Version 3.1
OpenMP Application Programming Interface, Version 4.5, November 2015

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Quark Distributions Functions (T)

Course No.: physics7506

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:
Quantum Field Theory (physics755 or equivalent)

Form of Testing and Examination:
oral examination

Length of Course:
1 semester

Aims of the Course:
By the end of the course, the student should be able to understand the formal parton model, renormalization of parton distributions, and current attempts to compute them on the lattice.

Contents of the Course:
Deep Inelastic Scattering; The Operator Product Expansion; Basics of the parton model; The formal parton model; Quark distributions and quasi-quark distributions; One loop corrections and renormalization; Lattice attempts to compute PDF

Recommended Literature:
Elliot Leader, Enrico Predazzi: An introduction to gauge theories and modern particle physics. Cambridge Monographs on Particle physics, Nuclear Physics and Cosmology 1996.

John Collins: Foundations of Perturbative QCD.
Cambridge Monographs on Particle physics, Nuclear Physics and Cosmology 2011.

Anthony W. Thomas, Wolfram Weise: The Structure of the Nucleon. Wiley-VCH Verlag Berlin 2001.

R. K. Ellis, W. J. Stirling, B. R. Webber: QCD and Collider Physics.
Cambridge Monographs on Particle physics, Nuclear Physics and Cosmology 2003.

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Theory of Quantum Magnetism (T)

Course No.: physics7507

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Quantum mechanics, Thermodynamics and Statistics, Quantum Field Theory

Form of Testing and Examination:
(1) form of examination: written or oral
(2) requirement for participation in examination: successful participation in exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce students to advanced concepts in the theory of magnetism.

Contents of the Course:
Phenomenological theory of magnetism, spin exchange, ferro and anti-ferro magnetism, classically frustrated systems (Kagome lattice). Representations of spin algebras: Dyson-Maleev, Holstein, Primakov, Schwinger bosons, spin coherent states, spin path integral, non-linear sigma models, quantum phase transition, Bereshinski-Kosterlitz-Thouless transition, Haldane gap, frustrated magnets, valence bond states, spin liquids, quantum Heisenberg model (two dimensional, Kagome, pyrochlore lattice) Exactly solvable models (transfer matrix) Ising model. Exactly solvable models (Bethe Ansatz): XXZ model, Kondo model. Open problems in quantum magnetism.

Recommended Literature:
Will be announced in the first lecture

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Quantum Computing (T)

Course No.: physics7508

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements for Participation:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
written / oral examination

Length of Course:
1 semester

Aims of the Course:
Understand the theory of quantum computing and apply it to existing hardware.

Contents of the Course:
- Quantum circuits
- Quantum algorithms
- Quantum computers
- Quantum noise and quantum operations
- Quantum error correction

Recommended Literature:
M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information, Cambridge

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Advanced Topics in Particle and Astroparticle Physics (T)

Course No.: physics7509

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements for Participation:

Preparation:
physics615 and physics711 strongly recommended, a course on General Relativity (e.g. physics754) would also be helpful.

Form of Testing and Examination:
Biweekly Homework Sheets + Final Written Exam

Length of Course:
1 semester

Aims of the Course:
To gain knowledge in Cosmological Perturbations, Axion physics, Dark Messenger physics/dark photons.

Contents of the Course:
1) Cosmological perturbations and effect on the CMB
2) Axions: Theory and Detection
3) Dark Photons: Theory and Detection

Recommended Literature:
1) Introduction to the Theory of the Early Universe, Vol. II (Cosmological perturbations and Inflationary Theory) by Gorbunov and Rubakov [World Scientic]on, Modern Cosmoless (Elsevier) 2
2) Modern Cosmology, Scott Dodelson (1st edition, 2003)
3) Various reviews on axions and dark photons.

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: QCD at colliders (T)

Course No.: physics7510

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Quantum Field Theory (physics755)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises.

Length of Course:
1 semester

Aims of the Course:
Understanding how to use perturbative quantum chromodynamics to perform calculations for collider experiments in modern high-energy physics.

Contents of the Course:
Quantum chromodynamics (QCD): quarks, gluons and the strong coupling constant
Tree-level scattering amplitudes: Feynman rules, modern methods for scattering amplitudes (BCFW recursion, scattering equations, ...)
Infrared divergences (collinear and soft singularities).
Loop corrections in QCD.
Cancellation of infrared divergences.
Parton model and parton distribution functions.
Modern methods for multi-loop computations.

Recommended Literature:
B. Webber, J. Stirling, R. K. Ellis; QCD and Collider Physics (Cambridge University Press 1996).
J. Campbell, J. Houston, F. Krauss; The Black Book of Quantum Chromodynamics: A Primer for the LHC Era (Oxford University Press 2017).
M. Peskin, D. V. Schroeder: An introduction to Quantum Field Theory (CRC Press 1995).
J. C. Plefka, J. M. Henn, Scattering Amplitudes in Gauge Theories (Springer 2014).
H. Elvang, Y.-T. Huang, Scattering Amplitudes in Gauge Theory and Gravity (Cambridge University Press 2015).

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Introduction to Integrability (T)

Course No.: physics7511

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT

Requirements for Participation:

Preparation:
Quantum Mechanics
(Quantum Field Theory/Statistical Physics useful but not necessary)

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Integrability is a property of special models or setups, which connects different physical and mathematical fields. The range of applications extends from classical mechanics to quantum field theory. The goal of this course is to gain an overview over the different facets and applications of integrability and to get to know interesting physical problems.

Contents of the Course:
Integrability and hidden symmetries of physical models, exactly solvable systems, classical and quantum integrability

Concepts & Methods:
Lax pairs, inverse scattering method, R-matrix, Yang-Baxter equation, factorized scattering, Bethe ansatz, nonlocal symmetries, quantum groups, Yangian symmetry

Models:
Elementary mechanical models, spin chains, field theories, AdS/CFT duality

Recommended Literature:
B. Sutherland. Beautiful Models: 70 Years of Exactly Solved Quantum Many-Body Problems
O. Babelon, D. Bernard, M. Talon. Introduction to Classical Integrable Systems.
P. Dorey. Exact S-matrices. http://arxiv.org/abs/hep-th/9810026
L. Faddeev. How algebraic Bethe ansatz works for integrable Model. http://arxiv.org/abs/hep-th/9605187.

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Introduction to Random Matrix Theory (T)

Course No.: physics7512

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST/WT

Requirements for Participation:

Preparation:
Complex Analysis, Theory I-IV is strongly recommended

Form of Testing and Examination:
Examination (written)

Length of Course:
1 semester

Aims of the Course:
Basic understanding of RMT and ist application

Contents of the Course:
Random matrix theory is a tool for understanding a wide variety of phenomena in physics and mathematics. It started with the idea of Wigner in the 1950's to describe the spectra of heavy nuclei with a random Hamiltonian. Surprisingly this idea worked and yielded some important physical information about this complicated system and lead to the notion of universality. RMT has wide range of applications in atomic physics, mesoscopic physics, QCD, quantum chaos, biophysics, number theory, finance and many others. The main topics of this course will be universality, symmetry classfication of RMTs, the logarithmic Coulomb gas,finite size effects, asymptotic analysis of the Riemann-Hilbert problem and applications to problems in quantum physics and statistical mechanics.

Recommended Literature:
Mehta M.L. Random matrices (3ed., Elsevier, 2004)
Potters M., Bouchaud J.P., A First Course in Random Matrix Theory (Cambridge University Press, 2020)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Introduction to Conformal Field Theory (T)

Course No.: physics7513

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements for Participation:

Preparation:
Quantum Field Theory

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Conformal symmetry represents a natural extension of Poincaré symmetry and plays an important role in many areas of theoretical physics. The aim of this course is to become acquainted with the basics of Conformal Field Theory (CFT) and to get an idea of applications in different contexts.

Contents of the Course:
CFT in two and higher dimensions, example CFTs, conformal bootstrap

Recommended Literature:
- Joshua D. Qualls, "Lectures on Conformal Field Theory", https://arxiv.org/abs/1511. 04074
- Marc Gillioz, "Conformal Field Theory for Particle Physicists", https://arxiv.org/abs/ 2207.09474
- Slava Rychkov, "EPFL Lectures on Conformal Field Theory in D >= 3 Dimensions", SpringerBriefs in Physics (2016), https://arxiv.org/abs/1601.05000
- Giuseppe Mussardo, "Statistical Field Theory", Oxford University Press (2020)
- P. Di Francesco, and P. Mathieu, and D. Senechal, "Conformal Field Theory", Graduate Texts in Contemporary Physics, Springer (1997)
- Ralph Blumenhagen, and Erik Plauschinn, "Introduction to Conformal Field Theory", Lect.Notes Phys. 779 (2009)

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Introduction to Quantum Computing (T)

Course No.: physics7514

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+2	5	ST

Requirements for Participation:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Written / oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the theory and applications of quantum computing.

Contents of the Course:
- Quantum versus classical computing
- Quantum circuits and algorithms
- Quantum error correction and mitigation
- Applications in physics and chemistry

Recommended Literature:
M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press.
A. Yu. Kitaev, A. H. Shen, and M. N. Vyalyi, Classical and Quantum Computation, American Mathematical Society.
J. Watrous, The Theory of Quantum Information, Cambridge University Press.

within the Transdisciplinary Research Area "Building Blocks of Matter and Fundamental Interactions"

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Introduction to the AdS/CFT Correspondence (T)

Course No.: physics7515

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements for Participation:

Preparation:
Quantum Field Theory, General Relativity

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The correspondence between string theory on Anti-de-Sitter spacetime and conformal quantum field theory on its boundary represents one of the most active and inspiring research areas of theoretical physics in the last decades. The aim of this course is to review the basic concepts to understand this duality between two a priory very different theories and to study some of ist implications and applications.

Contents of the Course:
basics of conformal field theory, supersymmetry and string theory, N=4 Super Yang-Mills theory, statement and selected applications of the AdS/CFT correspondence, integrable structures in planar AdS/CFT

Recommended Literature:

* Horatio Nastase, Lecture Notes "Introduction to AdS/CFT", https://arxiv.org/abs/0712.0689 or the book "Introduction to the AdS/CFT Correspondence", Cambridge University Press
* Makoto Natsuume, "AdS/CFT Duality User Guide", Lect.Notes Phys. 903 (2015) pp.1-294, https://arxiv.org/abs/1409.3575
* Joao Penedones, "TASI lectures on AdS/CFT", https://arxiv.org/abs/1608.04948
* Niklas Beisert et al, "Review of AdS/CFT Integrability: An Overview", Lett.Math.Phys. 99 (2012), https://arxiv.org/abs/1012.3982
* Diego Bombardelliet al, "An integrability primer for the gauge-gravity correspondence", J.Phys.A 49 (2016) 32, https://arxiv.org/abs/1606.02945

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Machine Learning for Quantum Scientists (T)

Course No.: physics7516

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+2	5	WT/ST

Requirements for Participation:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Written / oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the basics of machine learning and applications in quantum sciences

Contents of the Course:
- Basic structure, training, and analysis of artificial neural networks
- Standard architectures for machine learning, including convolutional neural networks, Boltzmann machines, and deep generative models
- Applications of machine learning in theoretical physics and chemistry

Recommended Literature:
C. M. Bishop, "Pattern Recognition and Machine Learning", Springer.
I. Goodfellow, Y. Bengio, A. Courville, "Deep Learning", MIT Press.
A. Dawid, et al., "Modern Applications of Machine Learning in Quantum Sciences", Cambridge University Press

within the Transdisciplinary Research Area "Building Blocks of Matter and Fundamental Interactions"

Module: Elective Advanced Lectures: Theoretical Physics

Module No.: physics70c

Course: Quantum chaos: tools and applications (T)

Course No.: physics7517

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT

Requirements for Participation:

Preparation:
Classical mechanics, Quantum mechanics, Statistical mechanics (recommended). Special interest in quantum dynamics and nonlinear systems.

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Knowledge on the theory of chaos, tools to analyze it in quantum systems with examples, as well as its manifestation in many-body systems that can be realized on the experimental platforms.

Contents of the Course:
1. Introduction and classification of dynamical systems
- From macroscopic, mesoscopic to microscopic systems, Different dynamics: simple to complex.

2. Chaos in classical systems
- Discrete dynamical system: One dimensional maps
- Hamiltonian systems: Phase space and Hamilton’s equation
- Poincare map
- Stroboscopic Maps of Periodically Driven Systems: Kicked rotor
- KAM theorem
- Lyapunov exponent, Kolmogorov-Sinai entropy

3. Aspects of quantum chaos
- Quantum classical correspondence
- EBK quantization
- Gutzwiller’s Trace formula
- Phase space densities and Wigner function
- Anderson and dynamical localization

4. Level statistics: Application of Random Matrix Theory
- Gaussian Ensembles of Hermitian Matrices
- Level Spacing Distributions
- Unfolding Spectra
- Eigenvector statistics
- Dyson’s Brownian-Motion Model

5. Quantum chaos and ergodicity in many-body systems
- Quantum butterfly effect
- Out-of-time-ordered correlator (OTOC)
- Ergodicity and quantum scar
- Example from collective quantum systems: Dicke model, Josephson junction

Recommended Literature:
- F. Haake, Quantum Signatures of Chaos, Springer Science and Business Media (Springer, 2013).
- S. Wimberger, Nonlinear Dynamics and Quantum Chaos: An Introduction (Springer, 2014).
- H.-J. Stöckmann, Quantum Chaos, An Introduction (Cambridge University Press, 1999).

Modules:

physics70a **Elective Advanced Lectures: Experimental Physics**
physics70b **Elective Advanced Lectures: Applied Physics**
physics70c **Elective Advanced Lectures: Theoretical Physics**

Course: Research Project

Course No.: physics799

Category	Type	Language	Teaching hours	CP	Semester
Elective	Research Project	English		4	WT/ST

Requirements for Participation:
Students are asked to contact one of the BCGS lecturers prior to the start of their research project. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have projects available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

registration by written application to the examination office (see homepage)

Module No.: physics70d
Credit Points (CP): 3-8
Category: Elective
Semester: 1.-2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures: BCGS Courses

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected courses from catalogue	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST

Requirements for Participation:
none

Form of Examination:
see with the course

Content:
Advanced lectures within the Bonn Cologne Graduate School of Physics and Astronomy (BCGS).

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 or 2 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve at least 18 CP out of all 4 Elective Advanced Modules

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Relativity and Cosmology I (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	WT

Requirements for Participation:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Introduction into Einstein's theory of general relativity and its major applications

Contents of the Course:
Gravity as a manifestation of geometry
Introduction to differential geometry
Einstein field equations
The Schwarzschild solution
Experimental tests
Gravitational waves

Recommended Literature:
T. Padmanabhan, Gravitation: Foundation and Frontiers
J. B. Hartle, Gravity: An introduction to Einstein's general relativity

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Relativity and Cosmology II (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Application of Einstein's theory of general relativity to black holes and cosmology

Contents of the Course:
Black holes
Introduction to cosmology
The early Universe

Recommended Literature:
V. Mukhanov, Physical Foundations of Cosmology
T. Padmanabhan, Gravitation: Foundation and Frontiers
J. B. Hartle, Gravity: An introduction to Einstein's general relativity

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Quantum Field Theory I (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Methods of quantum field theory are in use in almost all areas of modern physics. Strongly oriented towards applications, this course offers an introduction based on examples and phenomena taken from the area of solid state physics.

Contents of the Course:
Second quantization and applications
Functional integrals
Perturbation theory
Mean-field methods

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Quantum Field Theory II (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Quantum Field Theory I

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Quantum field theory is one of the main tools of modern physics with many applications ranging from high-energy physics to solid state physics. A central topic of this course is the concept of spontaneous symmetry breaking and its relevance for phenomena like superconductivity, magnetism or mass generation in particle physics.

Contents of the Course:
Correlation functions: formalism, and their role as a bridge between theory and experiment
Renormalization
Topological concepts

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Geometry in Physics (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The course introduces the background in differential geometry necessary to understand the geometrically oriented languages of modern theoretical physics. Applications include the coordinate invariant formulation of electrodynamics, phase space and symplectic mechanics, and a brief introduction to the foundations of general relativity.

Contents of the Course:
exterior calculus
manifolds
Lie groups
fibre bundles

Recommended Literature:
M. Göckeler & T. Schücker, Differential geometry, gauge theory, and gravity, Cambridge University Press, 1987.

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Topology for Physicists (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Bachelor of physics or mathematics; the basics of exterior calculus are assumed

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
This course gives an introduction to various topological concepts and results that play an important role in modern theoretical physics.

Contents of the Course:
Elements of homotopy theory: homeomorphic spaces, homotopic maps, fundamental group, covering spaces, homotopy groups, long exact homotopy sequence of a fibration
Homology and cohomology: Poincare lemma, Mayer-Vietoris sequence, Cech-deRham complex, Hurewicz isomorphism theorem, spectral sequences
Vector bundles and characteristic classes: Euler form, Thom isomorphism, Chern classes
Applications: Berry phase; Dirac monopole problem; visualization of closed differential forms by Poincare duality; cohomology of electrical conductance; supersymmetry and Morse theory; index theorems; homotopy classification of topological insulators

Recommended Literature:
R. Bott and L.W. Tu: Differential forms in algebraic topology (Springer, 1982)
A.S. Schwarz, Topology for physicists (Springer, 1994)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Nuclear physics II (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	5	WT

Requirements for Participation:

Preparation:
Nuclear Physics I, Quantum Mechanics

Form of Testing and Examination:
Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Study of nuclear reactions, fission and fusion.

Contents of the Course:
- Kinematics in nuclear reactions
- Cross section
- Rutherford scattering
- Scattering in quantum mechanics
- The Born approximation
- Partial wave analysis
- Inelastic scattering, resonances
- Optical model
- Direct, compound, spallation and fragmentation reactions
- Neutron sources and detectors
- Neutron cross sections
- Fission
- Nuclear reactors
- Fusion
- Solar fusion
- Man-made thermonuclear fusion
- Controlled thermonuclear fusion

Recommended Literature:
A script for parts of the course will be distributed during the course.
K.S. Krane, Introductory nuclear physics, chapters 11-14

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Physics of Detectors (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

Requirements for Participation:

Preparation:
Nuclear Physics I, Quantum Mechanics

Form of Testing and Examination:
Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Study detection methods of experimental techniques in nuclear and particle physics.

Contents of the Course:
- Interaction of electrons and charged heavy particles in matter
- Coherent effects: Cherenkov and transition radiation
- Interaction of gamma-radiation in matter
- Detection of neutal particles: neutrons and neutrinos
- Measurement of 4-momentum in particle physics
- Ionisation detectors: Bragg chamber, avalanche detectors
- Position sensitive detectors: drift chambers, time-procjection chamber
- Anorganic and organic scintillators
- Energy detection, calorimeter and shower detectors
- Semiconductor detectors
- Position sensitive Si detectors (strip-, pixel-detectors)
- Ge detectors
- Low background measurements
- Lifetime measurements
- Mössbauer Spectroscopy
- Basic principles of analoge and digital signal processing

Recommended Literature:
A script or slides of the course will be distributed during the course.
R. Leo, Techniques for Nuclear and Particle Physics Experiments
K Kleinknecht, Detektoren für Teilchenstrahlung
G.F. Knoll, Radiation Detection and Measurement

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Particle physics (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

Requirements for Participation:

Preparation:
Quantum Mechanics

Form of Testing and Examination:
Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Introduction into particle physics, accelerators and detectors

Contents of the Course:
- Relativistic kinematics
- Interaction of radiation with matter
- Particle accelerators
- Targets and detectors
- Symmetries in particle physics
- QED
- Weak interaction, neutrinos
- Quark model
- QCD
- Standard model
- Cosmology

Recommended Literature:
A script for course will be available on-line

D.H. Perkins: Introduction to High Energy Physics, Cambridge University Press, ISBN 0521621968
H. Frauenfelder, E.M. Henley: Subatomic Physics, Prentice Hall, ISBN 0138594309
F. Halzen: A.D. Martin: Quarks and Leptons, John Wiley and Sons, ISBN 0471887412
D. Griffiths: Introduction to Elementary Particles, John Wiley and Sons ISBN: 0471603864
B. Povh, K. Rith, C. Scholz, F. Zetsche: Teilchen und Kerne, Springer-Verlag, ISBN 3540659285
C. Berger: Elementarteilchenphysik, Springer-Verlag, ISBN 3-540-41515-7

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Groundbreaking experiments in nuclear physics (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:
Basic knowledge in Nuclear Physics

Form of Testing and Examination:
Part of courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Study of original publications of fundamental experiments in nuclear physics. The students should participate actively in the course.

Contents of the Course:
- Discovery of radioactivity
- Rutherford and his many discoveries using alpha sources
- The discovery of the neutron and deuteron
- Determination of magnetic moments
- Hofstadters electron scattering experiments
- The use of cosmic rays to discover mesons
- Fermi work in neutron physics
- Properties of neutrinos
- Mößbauereffekt

Recommended Literature:
Will be distributed during the course.

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Condensed Matter Physics II (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
2 semesters

Aims of the Course:
Advanced topics in condensed matter physics with examples of current research.

Contents of the Course:
The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:
Crystal structure and binding
Reciprocal space
Lattice dynamics and thermal properties
Electronic structure (free-electron gas, Fermi surface, band structure)
Semiconductors and metals
Transport properties
Dielectric function and screening
Superconductivity
Magnetism

Recommended Literature:
Skriptum (available during the course)
Ashcroft/Mermin: Solid State Physics
Kittel: Introduction to Solid State Physics
Ibach/Lüth: Festkörperphysik

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Semiconductor Physics and Nanoscience (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
No examination

Length of Course:
1 semester

Aims of the Course:
Understanding of theoretical and experimental concepts of semiconductor physics, nanotechnology as well as aspects of future information technology.
Knowledge of basic fields and important applications of information technology.

Contents of the Course:
Semiconducting material and nanostructures represent the backbone of modern electronics and information technology. At the same time they are fundamental to the research of problems of modern solid state physics, information technology and biophysics. This lecture will provide an introduction to semiconductor physics and its applications.
Topics covered are
introduction to semiconductor physics, crystalline structure, band structure, electronic and optical properties,
heterostructures, junction and interfaces,
basic semiconductor device concepts,
up to date techniques and strategies of information technology ranging from nowadays preparation technologies and nanoscience to concepts of molecular electronic and bioelectronics.

Recommended Literature:
Skriptum (available during the course)
Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)
Ibach/Lüth, Festkörperphysik

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Superconductivity (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of the fundamental aspects of superconductivity.

Contents of the Course:
The lecture provides an overview of the fundamental aspects of superconductivity, theoretical description and technological applications, including the following topics:

Basic experimental facts and critical parameters
Phenomenological description: London equations
Ginzburg-Landau theory
Magnetic flux quantization
Type I and type II superconductors, characteristic length scales, vortices
Microscopic description: BSC theory
Electron-phonon interaction, Cooper pairs
Josephson effects
Applications of superconductivity in science, transport, and medicine
Brief introduction to unconventional superconductivity with recent examples

Recommended Literature:
J. F. Annett: Superconductivity, Superfluids and Condensates (2004)
M. Tinkham: Introduction to Superconductivity (1996)
V. V. Schmidt: The Physics of Superconductors (1997)
J. R. Waldram: Superconductivity of Metals and Cuprates (1996)
D. R. Tilley and J. Tilley: Superfluidity and Superconductivity (1990)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Magnetism (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of magnetism in condensed matter systems

Contents of the Course:
The lecture introduces to the magnetism in condensed matter systems. Starting from basic concepts of the magnetic properties of free atoms it is aimed to illustrate the extremely rich field of collective magnetism that arises from the mutual interaction of an extremely large number of interacting particles.
Topics covered are
Magnetism of free atoms
Magnetism of ions in the crystal electric field
Magnetic interactions and ordering phenomena
Magnetic ground states and excitations
Itinerant magnetism
Magnetic frustration and low dimensionality
Magnetic order vs. competing ordering phenomena

Recommended Literature:
Skriptum (available during the course)
S. Blundell, Magnetism in Condensed Matter
Ashcroft/Mermin, Solid State Physics
Kittel, Festkörperphysik

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Experimental methods in condensed matter physics (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of experimental concepts in condensed matter science
Knowledge of basic fields and important applications

Contents of the Course:
The lecture introduces to modern experimental approaches in solid state physics. Basic concepts are illustrated with examples of physical problems investigated employing different methods.
Topics covered are
Introduction on sample preparation
X-ray powder diffraction
Specific heat, Thermal expansion
Magnetization and magnetic susceptibility
DC-Transport
Dielectric spectroscopy
Photo-emission spectroscopy
Inelastic scattering (neutrons, light)
THz spectroscopy / Optical spectroscopy
Scanning probe microscopy/spectroscopy (AFM, STM)

Recommended Literature:
Skriptum (available during the course)
Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)
Ibach/Lüth, Festkörperphysik
Ashcroft/Mermin, solid state physics

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Physics of Surfaces and Nanostructures (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:
Basic knowledge of solid state physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts in surface and nanostructure science
Knowledge of basic fields and important applications

Contents of the Course:
The lecture introduces to modern topics of surface and nanostructure physics. Basic concepts are illustrated with examples and the link to technical applications is emphazised. Topics covered are
- surface structure and defects,
- adsorption and heterogeneous catalysis,
- surface thermodynamics and energetics
- surface electronic structure and quantum dots,
- magnetism at surfaces
- epitaxy and thin film processes,
- oxide films
- ion beam processes at surfaces,
- clusters,
- graphene

Recommended Literature:
Michely: Skriptum (available during the course)
H. Ibach: Physics of Surfaces and Interfaces (Springer, Berlin 2006)
K. Oura et al: Surface Science - an introduction (Springer, Berlin 2003)
M. Prutton: Introduction to Surface Physics (Oxford University Press, 1994)
H. Lüth: Solid Surfaces, Interfaces and Thin Films, (Springer, Berlin 2001)
M. Henzler/ W. Göpel: Oberflächenphysik des Festkörpers (Teubner, Stuttgart 1994)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Introduction to neutron scattering (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of the basic concepts and techniques of elastic and inelastic neutron scattering experiments.

Contents of the Course:
The lecture introduces to the techniques of elastic and inelastic neutron scattering that can be used to determine the crystal or magnetic structure as well as the dispersion of nuclear or magnetic excitations.
Topics covered are
Crystal structures and reciprocal space
Neutron powder diffraction
Single-crystal diffraction
Structure refinements
Inelastic neutron scattering
Phonon dispersion
Magnetic excitations
Examples of current research (high-temperature superconductors, manganates with colossal magnetoresistivity, multiferroics)
Polarized neutron scattering

Recommended Literature:
Skriptum (available during the course)
S. W. Lovesey, Theory of Neutron Scattering from Condensed Matter, Oxford (1981)
G. E. Bacon, Neutron Diffraction, Oxford (1979)
Shirane, Shapiro and, Tranquada, Neutr. Scattering with a triple-axis spectrometer, Cambridge (2002)
Izyumov, Ozerov, Magnetic Neutron Diffraction Plenum (1970)
Marshall and Lovesey, Theory of thermal neutron scattering,Oxford (1971)
Squires, Introduction to the theory of Thermal Neutron scattering, Cambridge (1978)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Optical Spectroscopy (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT/ST

Requirements for Participation:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of the basic concepts and techniques of optical spectroscopy on solid-state samples.

Contents of the Course:
Topics covered are:
Electromagnetic waves in matter, dielectric function
Electromagnetic response of metals and insulators, Drude-Lorentz model
Kramers-Kronig relations
THz spectroscopy (time domain and cw)
Fourier-transform spectroscopy
Ellipsometry
Examples of current research (phonons, magnons, orbital excitations, superconductors, …)

Recommended Literature:
Skriptum (available during the course)
Dressel/Grüner: Electrodynamics of Solids: Optical Properties of Electrons in Matter (Cambridge, 2002)
Klingshirn: Semiconductor Optics (Springer, 1997)
Kuzmany: Solid-State Spectroscopy: An Introduction (Springer, 2009)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Astrochemistry (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	4	ST

Requirements for Participation:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
The lecture introduces to astrochemistry of various astrophysical environments. Fundamental processes, such as molecular collisions, fragmentations, and chemical reactions, are explained, and implications for astrophysical observations by means of high resolution spectroscopy are treated.

Contents of the Course:
- Detection of Molecules in Space
- Elementary Chemical Processes
- Chemical Networks
- Grain Formation (Condensation)
- Properties of Grains and Ice
- Grain Chemistry
- Diffuse Clouds, Shocks, Dark Clouds, Star Forming Regions

Recommended Literature:
A.Tielens "The Physics and Chemistry of the Interstellar Medium" Cambridge University Press, 2005
S. Kwok "Physics and Chemistry of the Interstellar Medium" University Science Books, 2006
D. Rehder "Chemistry in Space, From Interstellar Matter to the Origin of Life" Wiley-VCCH, Weinheim, 2010
J. Lequeux "The interstellar Medium" Spinger, 2004
A. Shaw "Astrochemistry" Wiley, 2006
D. Whittet "Dust in the Galactic Environment", Taylor and Francis, 2nd edition, 2002

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Fundamentals of Molecular Symmetry (E/A/T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	4	ST

Requirements for Participation:

Preparation:
Basic knowledge of quantum mechanics

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
Understanding the fundamental concepts of representation theory and its application to describe the symmetry of molecules

Contents of the Course:
The lecture introduces to group theory with special emphasis on representations and their use to describe the symmetry of molecules in high-resolution spectroscopy and in molecular physics generally. The theory is accompanied by a series of "prototypical" examples Topics covered are
- symmetry in general and symmetry of a molecule.
- groups and point groups.
- irreducible representations, characters.
- vanishing integral rule
- the Complete Nuclear Permutation-Inversion (CNPI) group.
- the Molecular Symmetry (MS) group).
- the molecular point group.
- classification of molecular states: electronic, vibrational, rotational, and nuclear spin states
- nuclear spin statistical weights
- hyperfine structure
- non-rigid molecules (inversion, internal rotation)

Recommended Literature:
Jensen: Script (text of powerpoint presentation files; available during the course)
P. Jensen and P. R. Bunker: The Symmetry of Molecules, in: "Encyclopedia of Chemical Physics and Physical Chemistry" (J. H. Moore and N. D. Spencer, Eds.), IOP Publishing, Bristol, 2001.
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition," NRC Research Press, Ottawa, 1998 (ISBN 0-660-17519-3).
P. R. Bunker and P. Jensen: "Fundamentals of Molecular Symmetry", IOP Publishing, Bristol, 2004 (ISBN 0-7503-0941-5).

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Physical biology (T/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Acquaintance with basic concepts of molecular and evolutionary biology; understanding of statistical issues arising in the analysis of sequence data and the application of methods from statistical physics addressing them.

Contents of the Course:
Statistics of the genome
Sequence analysis and sequence alignement
Evolutionary theory and population genetics
Theory of bio-molecular networks

Recommended Literature:
J.H. Gillespie, Population Genetics: A concise guide (Johns Hopkins University Press, 2004)
R. Durbin, S.R. Eddy, A. Krogh, G. Mitchison, Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids (Cambridge University Press, 1998)
F. Kepes, Biological Networks (World Scientific, Singapore 2007)
D.J. Wilkinson, Stochastic Modelling for Systems Biology (Chapman&Hall, 2006)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Statistical physics of soft matter and biomolecules (T/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the molecular structure and mesoscopic properties of various types of soft matter systems, in particular with regard to their role in living cells.

Contents of the Course:
Colloids, polymers and amphiphiles
Biopolymers and proteins
Membranes
Physics of the cell

Recommended Literature:
J. K. G. Dhont, An Introduction to Dynamics of Colloids (Elsevier, Amsterdam, 1996).
M. Doi and S. F. Edwards, The Theory of Polymer Dynamics (Clarendon Press, Oxford, 1986).
S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes (Addison-Wesley, Reading, MA, 1994).
G. Gompper, U. B. Kaupp, J. K. G. Dhont, D. Richter, and R. G. Winkler, eds., Physics meets Biology — From Soft Matter to Cell Biology, vol. 19 of Matter and Materials (FZ Jülich, Jülich, 2004).
D. H. Boal, Mechanics of the Cell (Cambridge University Press, Cambridge, 2002).

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Statistical physics far from equilibrium (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the generic behavior of fluctuation-dominated systems far from equilibrium, and acquaintance with the basic mathematical tools used for their description.

Contents of the Course:
Stochastic methods
Transport processes
Scale-invariant growth
Pattern formation far from equilibrium

Recommended Literature:
P.L. Krapivsky, S. Redner and E. Ben-Naim: A kinetic view of statistical physics (Cambridge University Press, 2010)
M. Kardar, Statistical Physics of Fields (Cambridge University Press, 2007)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Disordered systems (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements for Participation:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the novel types of behaviour that arise in systems with quenched disorder, as well as the specific mathematical challenges associated with their theoretical description.

Contents of the Course:
Disorder average
Replica methods
Percolation
Phase transitions in disordered systems
Localization
Glassy dynamics

Recommended Literature:
D. Stauffer and A..Aharony, Introduction to Percolation Theory (Taylor & Francis, London 1994)
K.H. Fischer and J.A. Hertz, Spin Glasses (Cambridge University Press, Cambridge 1991)
K. Binder and W. Kob, Glassy Materials and Disordered Solids (World Scientific, Singapore 2005)
T. Nattermann, lecture notes

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Nonequilibrium physics with interdisciplinary applications (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Statistical mechanics

Form of Testing and Examination:
Oral examination or term paper

Length of Course:
1 semester

Aims of the Course:
Acquaintance with basic concepts of nonequilibrium physics; ability to apply the basic methods for the investigation of nonequilibrium problems; application of physics-based models to interdisciplinary problems.

Contents of the Course:
Principles of nonequilibrium physics
Stochastic systems and their desription (master equation, Fokker-Planck equation,..)
Analytical and numerical methods
Nonequilibrium phase transitions
Applications to traffic, pedestrian dynamics, economic systems, biology, pattern formation,..

Recommended Literature:
A. Schadschneider, D. Chowdhury, K. Nishinari: Stochastic Transport in Complex Systems (Elsevier, 2010)
P.L. Krapivsky, S. Redner, E. Ben-Naim: A Kinetic View of Statistical Physics (Cambridge University Press, 2010)
V. Privman (Ed.): Nonequilibrium Statistical Mechanics in One Dimension (Cambridge University Press, 1997)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course: Probability theory and stochastic processes for physicists (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	WT

Requirements for Participation:

Preparation:
Statistical mechanics on the bachelor level

Form of Testing and Examination:
Oral examination or term paper

Length of Course:
1 semester

Aims of the Course:
Acquaintance with probabilistic concepts and stochastic methods commonly used in the theory of disordered systems and nonequilibrium phenomena, as well as in interdisciplinary applications of statistical physics.

Contents of the Course:
Limit laws and extremal statistics
Point processes
Markov chains and birth-death processes
Stochastic differential equations and path integrals
Large deviations and rare events

Recommended Literature:
D. Sornette: Critical Phenomena in Natural Sciences (Springer, 2004)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

Module No.:	physics910
Credit Points (CP):	15
Category:	Required
Semester:	3.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Scientific Exploration of the Master Thesis Topic

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Scientific Exploration of the Master Thesis Topic	physics911	15		450 hrs	WT

Requirements for Participation:
Successful completion of 60 credit points from the first year of the Master phase, including 7 cp from the Module physics601, 7 cp from the Elective Course Theoretical Physics and 24 cp from the Specialization Modules

Form of Examination:
Presentation

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall explore the science field, read the relevant recent literature, and perhaps participate in further specialised classes and in seminars. The student shall write an essay about the acquired knowledge, which may serve as the introduction part of the M.Sc. Thesis

Aims/Skills:
The student shall demonstrate to have understood the scientific question to be studied in the Master Thesis

Course achievement/Criteria for awarding cp's:
none

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Physik, Pflicht, Semester: 3

Module No.: physics920
Credit Points (CP): 15
Category: Required
Semester: 3.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Methods and Project Planning

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Methods and Project Planning	physics921	15		450 hrs	WT

Requirements for Participation:
Successful completion of 60 credit points from the first year of the Master phase, including 7 cp from the Module physics601, 7 cp from the Elective Course Theoretical Physics and 24 cp from the Specialization Modules

Form of Examination:
Written proposal

Content:
Under guidance of the supervisor of the planned Master Thesis topic, the student shall acquire knowledge about the methods required to carry out the Master Thesis project. This may include the participation in specialised seminars or specialised classes for the master programme. The student shall plan the steps needed to successfully complete the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the methods to be used in the Master Thesis research. The project plan has to be presented

Course achievement/Criteria for awarding cp's:
none

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Physik, Pflicht, Semester: 3

Module No.: physics930
Credit Points (CP): 30
Category: Required
Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Master Thesis

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Master Thesis	physics931	30		900 hrs	ST

Requirements for Participation:
Successful completion of 60 credit points from the first year of the Master phase, including 7 cp from the Module physics601, 7 cp from the Elective Course Theoretical Physics and 24 cp from the Specialization Modules

Form of Examination:
Master Thesis

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall carry out the research of the Master Thesis project

Aims/Skills:
The student shall demonstrate to be able to do research

Course achievement/Criteria for awarding cp's:
Oral presentation

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Physik, Pflicht, Semester: 4

Modul-Nr.: add. Courses
Leistungspunkte:
Kategorie:
Semester:

Modul: additional courses

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physics in the Private Sector	PhysPrivSec	0		90 hrs	

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Inhalt:

Lernziele/Kompetenzen:

Prüfungsmodalitäten:

Dauer des Moduls:

Max. Teilnehmerzahl:

Anmeldeformalitäten:

Modul: additional courses

Modul-Nr.: add. Courses

Lehrveranstaltung: Physics in the Private Sector

LV-Nr.: PhysPrivSec

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Elective	Lecture with exercises	English	2+1	0	

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematical, theoretical and experimental foundations in physics

Studien- und Prüfungsmodalitäten:
Requirements for the module examination (written examination): successful work with exercises

Dauer der Lehrveranstaltung:
1 semester

Lernziele der LV:
The vast majority of graduates with a physics degree or a doctorate in physics work in the private sector in very different areas, ranging from industrial research and software development to management consultancies, financial institutions and patent attorneys. In this lecture, the basics of these different fields are explained, deepened in the exercises and supplemented by guest lectures by physicists from the private sector.

Successful participants will receive a document about their attendance and the course contents.

Inhalte der LV:
- Management Consulting
- Financial Physics
- Professional Software Development
- Patent Law
- Physics in Insurances
- Simulations in Physics
- Entrepreneurship

Literaturhinweise:
- Grundprinzipien der Finanz- und Versicherungsmathematik: Grundlagen und Anwendungen der Bewertung von Zahlungsströmen, Peter Albrecht
- Patentrecht für Studierende der Naturwissenschaften: Eine kompakte Einführung in die Grundlagen, Gernot Krobath
- A Friendly Guide to Software Development: What You Should Know Without Being a Developer (Friendly Guides to Technology) (English Edition), Leticia Portella
- Cracked it!: How to solve big problems and sell solutions like top strategy consultants, Bernard Garrette , Corey Phelps

Module-Handbook
Master in Astrophysics
PO von 2014

SS 2024

February 2024

We don’t offer each of these modules regularly.

For any update please see:

https://www.physik-astro.uni-bonn.de/de/studium/

lehrveranstaltungen/termine-und-lehrveranstaltungen

Master of Astrophysics

Rheinische Friedrich-Wilhelms-Universität Bonn

(valid from WS 2014/2015)

Course Phase

		Compulsory					Elective
1. Sem.	Oct, Nov, Dec, Jan, Feb, Mar		astro608: Theoretical Astrophysics 7 cp	astro810/811: Stars and Stellar Evolution 6 cp	astro810/812: Cosmology 6 cp		Elective Advanced Lectures (at least 18 cp out of astro84 and astro85) 18 cp
1./2. Sem.	Feb, Mar, Apr, May	physics601: Advanced Laboratory Course 7 cp					
2. Sem.	Apr, May, June, July, Aug, Sep		astro830: Seminar 4 cp	astro820/821: Astrophysics of Galaxies 6 cp	astro820/822: Physics of the Interstellar Medium 6 cp		

Research Phase

3. Sem.	Oct, Nov, Dec, Jan, Feb, Mar	astro940: Scientific Exploration of the Master thesis topic 15 cp	astro950: Methods and Project Planning 15 cp
4. Sem.	Apr, May, June, July, Aug, Sep	astro960: Master Thesis 30 cp	

Table of Contents: M.Sc. in Astrophysics (PO von 2014)

physics601 Advanced Laboratory Course 1
physics601 Advanced Laboratory Course 2
astro608 Theoretical Astrophysics 4
astro608 Theoretical Astrophysics 5
astro810 Compulsory Astrophysics I 6
astro811 Stars and Stellar Evolution or specific: Stellar Structure and Evolution 7
astro812 Cosmology 8
astro820 Compulsory Astrophysics II 9
astro821 Astrophysics of Galaxies 10
astro822 Physics of the Interstellar Medium 11
astro830 Seminar: Astrophysics 12
astro840 Elective Advanced Lectures: Observational Astronomy 13
astro831 Research Project 14
astro841 Radio Astronomy: Tools, Applications, Impacts 15
astro842 Submillimeter Astronomy 16
astro843 Astronomical Interferometry and Digital Image Processing 17
astro845 Observational Cosmology 18
astro846 Wave Optics and Astronomical Applications 19
astro847 Optical Observations 20
astro848 Galactic and Intergalactic Magnetic Fields 21
astro849 Multiwavelength Observations of Galaxy Clusters 22
astro8401 Introduction to Hydro- and Magnetohydrodynamics 23
astro8402 X-Ray Astronomy 24
astro8403 Hydrodynamics and astrophysical magnetohydrodynamics 25
astro8404 Radiointerferometry: Methods and Science 26
astro8405 The Cosmic Microwave Background 27
Active Galactic Nuclei (OA) 28
Methods of Experimental Astrophysics (OA) 29
The Fourier-Transform and its Applications (OA) 30
astro850 Elective Advanced Lectures: Modern Astrophysics 31
astro831 Research Project 32
astro851 Stellar and Solar Coronae 33
astro852 Gravitational Lensing 34
astro8531 The Physics of Dense Stellar Systems as the Building Blocks of Galaxies 35
astro854 Numerical Dynamics 37
astro856 Quasars and Microquasars 38
astro857 Star Formation 39
astro858 Nucleosynthesis 40
astro859 The cosmic history of the intergalactic medium 41
astro8501 Binary Stars 42
astro8502 Physics of Supernovae and Gamma-Ray Bursts 43
astro8503 Radio and X-Ray Observations of Dark Matter and Dark Energy 44
astro8504 Lecture on Advanced Topics in Modern Astrophysics 45
astro8505 Introduction to MoND 46
astro8506 Statistical Methods in Cosmology & Astrophysics 47
astro8507 Advanced Topics in Cosmology 48
Astrophysics II (MA) 49
Star Formation (MA) 50

Galaxy Dynamics (MA) 51
astro940 Scientific Exploration of the Master Thesis Topic 52
astro950 Methods and Project Planning 53
astro960 Master Thesis 54

Module No.: physics601
Credit Points (CP): 7
Category: Required
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Advanced Laboratory Course

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Laboratory Course	physics601	7	Laboratory	210 hrs	WT/ST

Requirements for Participation:

Form of Examination:
written report for every laboratory

Content:
Every student has to complete this Laboratory Course. The course consists of advanced experiments introducing into important subfields of contemporary experimental physics and astrophysics. The lab-course is accompanied by a seminar.

Aims/Skills:
The students shall gain insight in the conceptual and complex properties of relevant contemporary experiments. The students gain experience in setting up an experiment, data logging and data analysis. They experience the intricacies of forefront experimental research

Course achievement/Criteria for awarding cp's:
Before carrying out an experiment, the students shall demonstrate to have acquired the necessary preparatory knowledge. Experiments are selected from the catalogue of laboratory set-ups offered. Cumulative lab-units of >= 9 are required.
Requirements for the examination (written report for every laboratory): successful completion of the experiment and initial oral questioning plus seminar talk

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Advanced Laboratory Course

Module No.: physics601

Course: Advanced Laboratory Course

Course No.: physics601

Category	Type	Language	Teaching hours	CP	Semester
Required	Laboratory	English	3+2	7	WT/ST

Requirements for Participation:
Lab course physik661 "Praktikum Kerne und Teilchen" or successful completion of the experiment "Nuclear electronics and lifetime measurement" of physik661.

Preparation:
An appropriate knowledge of the physics background and the experimental environment of the laboratories is required. Recommended lectures are specified in the catalogue of laboratories.

Form of Testing and Examination:
Experiments are selected from the catalogue of laboratory setups offered. Five experiments are required. One of the experiments 1-3 is compulsory for physics students. Two of the experiments 14-17 are compulsory for astrophysics students. Requirements for the module examination (written report for every laboratory): successful completion of the experiment and initial oral questioning

Length of Course:
1 semester

Aims of the Course:
The student shall gain insight in the intricate workings of physics in relevant advanced experiments. The student gains experience in the setting up of a proper experimental environment and experiences the intricacies of forefront experimental research and presenting his/her results.

Contents of the Course:
Advanced experiments are carried out. Experimenting time ~8 to 16 hrs, preparation time and report writing each ~15 hrs. The experiments are chosen among those being offered and after consultation with the head of the course.
In the accompanying seminar the students report about one experiment. This experiment will be selected after consultation with the head of the course.

Recommended Literature:
Hand outs and literature will be distributed with the registration for an experiment

Catalogue of laboratories: (subject to change, for an up-to-date catalogue see https://www.physik-astro.uni-bonn.de/praktika/en/modules/physics601)

1. Analysis of decays of heavy vector boson Z0
2. ATLAS
3. Investigation of particle-antiparticle oscillations at BELLE-II
4. Radiofrequency cavities for particle acceleration
5. Lab course accelerator Bonn (LAB)
6. Properties of elementary particles
7. STYX
8. Positron lifetime in metals and insulators
9. Nuclear y-y angular correlations
10. Optical frequency doubling
11. Laser spectroscopy
12. Magneto-optic trap

13. Laser Gyroscope
14. Optical astronomy (Recommended: astro800 Introduction to Astrophysics or an equivalent basic knowledge in astrophysics)
15. Setting up a Radio-astronomical receiver / Setting up a Radio Interferometer (Recommended: lecture astro123 "Einführung in die Radioastronomie" or lecture astro841 Radio Astronomy: tools, application, impacts)
16. Photometry of star clusters
17. Radio astronomical observing course (Recommended: lecture astro123 "Einführung in die Radioastronomie" or lecture astro841 Radio Astronomy: tools, application, impacts

Module No.: astro608
Credit Points (CP): 7
Category: Required
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Theoretical Astrophysics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Theoretical Astrophysics	astro608	7	Lect. + ex.	210 hrs	WT

Requirements for Participation:

Form of Examination:
written examination

Content:
Introduction into Theoretical Astrophysics

Aims/Skills:
To provide the students with sound theoretical bases on a number of topics that have wide applications in astrophysics. They include general relativity, kinetic theory, plasma and fluid dynamics, stochastic and radiative processes, and radiative transfer.

Course achievement/Criteria for awarding cp's:
successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Theoretical Astrophysics

Module No.: astro608

Course: Theoretical Astrophysics

Course No.: astro608

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+2	7	WT

Requirements for Participation:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of this course is to provide the students with sound theoretical bases on a number of topics that have wide applications in astrophysics. They include general relativity, kinetic theory, plasma and fluid dynamics, stochastic and radiative processes, and radiative transfer.

Contents of the Course:
Introduction to General Relativity, Schwarzschild metric and gravitational waves.
Kinetic theory, Klimontovich equation, BBGKY hierarchy, Boltzmann and Vlasov equations, fluid limit, transport coefficients.
Basics of hydrodynamics, spherical flows, shock waves, Bondi accretion.
Random fields and stochastic processes, correlation and structure functions, power spectrum and multispectra, Langevin and Fokker-Planck equations.
Continuum radiation processes, synchrotron radiation, free-free radiation, Compton scattering.
Radiation from bound-free and bound-bound transitions.
Radiative transfer.
Concepts of plasma physics, Langmuir waves, Alfven waves, Faraday rotation, dispersion relations.

Recommended Literature:
Lecture notes
S. Carroll, Spacetime and Geometry (Addison Wesley 2004)
F.F. Chen, Introduction to Plasma Physics and Controlled Fusion (Springer 1984)
K. Huang, Statistical Physics (John Wiley & Sons 1987)
C.W. Misner, K.S. Thorne, J.A. Wheeler, Gravitation (Freeman 1973)
H. Risken, The Fokker-Planck Equation (Springer 1996)
G.R. Rybicky, A.P. Lightman; Radiative Processes in Astrophysics (John Wiley & Sons 1991)
F.H. Shu, The Physics of Astrophysics, Vol I & II (University Science Books 2010)

Module No.: astro810
Credit Points (CP): 12
Category: Required
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Compulsory Astrophysics I

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Stars and Stellar Evolution or specific: Stellar Structure and Evolution	astro811	6	Lect. + ex.	180 hrs	WT
2.	Cosmology	astro812	6	Lect. + ex.	180 hrs	WT

Requirements for Participation:

Form of Examination:
written examination

Content:
The module represents the fundamentals of the phases of stars and stellar evolution and the knowledge about our cosmological model

Aims/Skills:
The student shall acquire deeper understanding of the workings of stars and their evolution, in particular of important transitory phases of evolution, and shall be able to understand the origin of stars related with the location of their parameters in the HRD.
The student shall acquire deep understanding of the foundation of our world models and of their consequences, with special emphasis on the formation of structures in the universe and its physical and observational consequences

Course achievement/Criteria for awarding cp's:
successful work with the exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Compulsory Astrophysics I

Module No.: astro810

Course: Stars and Stellar Evolution or specific: Stellar Structure and Evolution

Course No.: astro811

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Students will acquire sufficient knowledge to understand stars and their evolution. Study of radiation transport, energy production, nucleosynthesis and the various end phases of stellar evolution shall lead to appreciation for the effects these processes have on the structure and evolution of galaxies and of the universe

Contents of the Course:
Historical introduction, measuring quantities, the HRD. Continuum and line radiation (emission and absorption) and effects on the stellar spectral energy distribution. Basic equations of stellar structure. Nuclear fusion. Making stellar models. Star formation and protostars. Brown Dwarfs. Evolution from the main-sequence state to the red giant phase. Evolution of lower mass stars: the RG, AGB, HB, OH/IR, pAGB, WD phases. Stellar pulsation. Evolution of higher mass stars: supergiants, mass loss, Wolf-Rayet stars, P-Cyg stars. Degenerate stars: White Dwarfs, Neutron Stars, Black Holes. Supernovae and their mechanisms. Binary stars and their diverse evolution (massive X-ray binaries, low-mass X-ray binaries, Cataclysmic variables, etc.). Luminosity and mass functions, isochrones. Stars and their influence on evolution in the universe

Recommended Literature:
Lecture notes on "Stars and Stellar Evolution" (de Boer & Seggewiss)

Module: Compulsory Astrophysics I

Module No.: astro810

Course: Cosmology

Course No.: astro812

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Introductory astronomy

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The student shall acquire deep understanding of the foundation of our world models and of their consequences, with special emphasis on the formation of structures in the universe and its physical and observational consequences. The lecture shall enable the student to read and understand original literature in astrophysical cosmology, but also to see the direct connection between the fundamental problems in cosmology and particle physics, such as the nature of dark matter and dark energy

Contents of the Course:
Kinematics and dynamics of cosmic expansion, introduction to General relativity, Friedmann equations and classification of world models, flatness and horizon problem; thermal history of the big bang, decoupling, WIMPS, nucleosynthesis, recombination and the CMB; gravitational light deflection, principles and applications of strong and weak gravitational lensing; structure formation in the Universe, perturbation theory, structure growth and transfer function, power spectrum of cosmic fluctuations, spherical collapse model, Press-Schechter theory and generalizations, cosmological simulations, cosmic velocity fields; principles of inflation; lensing by the large-scale structure, cosmic shear; anisotropies of the CMB, determination of cosmological parameters

Recommended Literature:
J. A. Peacock; Cosmological Physics (Cambridge University Press 1998)
P. J. E. Peebles; Principles of Physical Cosmology (Princeton University Press 1993)
Handout of the Transparencies

Module No.: astro820
Credit Points (CP): 12
Category: Required
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Compulsory Astrophysics II

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Astrophysics of Galaxies	astro821	6	Lect. + ex.	180 hrs	ST
2.	Physics of the Interstellar Medium	astro822	6	Lect. + ex.	180 hrs	ST

Requirements for Participation:

Form of Examination:
written examination

Content:
This module presents both, theoretical aspects, as well as the detailed properties of the major building blocks of cosmic structure, viz. galaxies. The fundamentals of the physics of the interstellar medium are conveyed, along with the tools used to study its properties

Aims/Skills:
The student shall acquire knowledge about the properties of galaxies, including their formation and their evolution, based on knowledge of the constituent matter (stars, gas, dark matter). The fundamentals of stellar dynamics are also conveyed. Physical processes relevant for the study of the interstellar medium have to be understood including the basic methods of measurements and their interpretation of the fundamental phases of the ISM

Course achievement/Criteria for awarding cp's:
successful work with the exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Compulsory Astrophysics II

Module No.: astro820

Course: Astrophysics of Galaxies

Course No.: astro821

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Introductory astronomy as well as a good understanding of stars and their evolution as well as of the interstellar medium

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
The student shall acquire deep knowledge of the structure of the Milky Way and of other galaxies including their evolution.
This must enable them to understand and evaluate new publications in the field. It should provide the student a quick entry into the research phase of the study programme

Contents of the Course:
Review of stars and stellar evolution, review of the interstellar medium. Solar neighbourhood: observables, differential galactic rotation, Hyades, Goulds Belt, Local Bubble. The Galaxy: size, dynamics of objects, rotation curve, disk and z-distribution. Stellar dynamics: Boltzmann, Jeans drift, Schwarzschild ellipsoid, scale length and height, density wave, mass distribution, age of populations, dark matter concept, evolution. Satellites: the Magellanic Clouds, their structure and evolution, Magellanic Stream, Dwarf spheroidals, Local Group galaxies. Star clusters: stellar dynamics, binary and multiple stars, energy exchange, star-cluster birth and death, origin of galactic field population. Active galactic nuclei: observables, jets, accretion, black holes. Structure and shape of spirals and ellipticals, surface brightness, globular cluster systems. Galaxy clusters: distances, statistics, luminosity function, X-ray halos, virial theorem. Galaxy evolution: chemical enrichment, galactic winds, infall, observables. Galaxy collisions: relaxation, mergers, birth of dwarf galaxies

Recommended Literature:
J. Binney; B. Merrifield; Galactic Astronomy (Princeton University Press 1998)
J. Binney, S. Tremaine; Galactic Dynamics (Princeton University Press 1988)
L. S. Sparke; J. S. Gallagher; Galaxies in the Universe (Cambridge University Press, 2000)
Write-up of the class

Module: Compulsory Astrophysics II

Module No.: astro820

Course: Physics of the Interstellar Medium

Course No.: astro822

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Introductory astronomy

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The student shall acquire a good understanding of the physics and of the phases of the ISM. The importance for star formation and the effects on the structure and evolution of galaxies is discussed.

Contents of the Course:
Constitutens of the interstellar medium, physical processes, radiative transfer, recombination, HI 21cm line, absorption lines, Stroemgren spheres, HII regions, interstellar dust, molecular gas and clouds, shocks, photodissociation regions, energy balances, the multi-phase ISM, gravitational stability and star formation.

Recommended Literature:
B. Draine; The Physics of the Interstellar and Intergalactic Medium (Princeton Univ. Press 2010)
J. Lequeux; The Interstellar Medium (Springer 2005)

Module No.: astro830
Credit Points (CP): 4
Category: Elective
Semester: 2.

Module: Seminar: Astrophysics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminar on Modern Topics in Astrophysics		4		120 hrs	WT/ST

Requirements for Participation:

Form of Examination:
Presentation

Content:
Modern developments in astrophysics are discussed using recent literature

Aims/Skills:
These seminars will introduce the student for the first time into professional research in astrophysics.
Active participation will furnish the student with the skill to read and present modern research topics

Course achievement/Criteria for awarding cp's:
regular participation and active contribution

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Astrophysik, Pflicht, Semester: 1-2

former astro890

Module No.: astro840
Credit Points (CP):
Category: Elective
Semester: 1.-2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures: Observational Astronomy

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 84* courses from catalogue	astro84*	3-6	see catalogue	90-120 hrs	WT/ST
2.	Astrophysics Courses from Cologne marked "OA"	see catalogue	4	see catalogue	120 hrs	WT/ST
3.	Also possible classes from M.Sc. in Physics					

Requirements for Participation:

Form of Examination:
written examination

Content:
This module covers all observational tools used in modern astronomy, over a wide range of the electromagnetic spectrum

Aims/Skills:
Observational astronomy shall be conveyed to the students by teaching the fundamentals of observational astronomical tools, along with relevant applications. These tools cover essentially the entire electro-magnetic spectrum, from radio wavelengths through X-ray energies. They naturally also encompass a wide range of astrophysical phenomena, including condensed matter (stars, neutron stars), the interstellar and intergalactic medium, galaxies and active galactic nuclei, and clusters of galaxies. Emphasis is also on observational cosmology

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

The students must obtain 18 CP in all out of the modules astro840 and astro850.

Modules:

astro840 **Elective Advanced Lectures: Observational Astronomy**
astro850 **Elective Advanced Lectures: Modern Astrophysics**

Course: universitätbonn Research Project

Course No.: astro831

Category	Type	Language	Teaching hours	CP	Semester
Elective	Research Project	English		4	WT/ST

Requirements for Participation:
Students are asked to contact one of the BCGS lecturers prior to the start of their project. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have projects available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

registration by written application to the examination office (see homepage)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Radio Astronomy: Tools, Applications, Impacts

Course No.: astro841

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements for Participation:

Preparation:
Good knowledge of electrodynamics, atomic physics, and astronomy

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
An introduction to modern radio astronomy, its history, methods, and research potentials is given. The goals are to equip the student with the background and know-how to analyze and interpret data from modern single-dish and interferometer radio telescopes, and to enable them to motivate and write radioastronomical observing proposals. Aperture synthesis techniques are explained at some depth. The lecture is furnished with numerous examples demonstrating the versatility and power of radioastronomical tools

Contents of the Course:
Radiation: processes, propagation; Signal detection; Radio telescopes: properties, types; Receivers: heterodyne, bolometers; Backends: continuum, spectroscopy, pulsars; Interferometers: Fourier optics, aperture synthesis; imaging; Future: APEX, ALMA, LOFAR.

Recommended Literature:
B. F. Burke; F. Graham-Smith, An Introduction to Radio Astronomy (Cambridge University Press 2002)
T. L. Wilson; C. Rohlfs; Tools of Radio Astronomy (Springer, Heidelberg 4. rev. und erw. Ed. 2006)
J. D. Kraus; Radio Astronomy (Cygnus-Quasar Books, Durham 2. Aufl. 1986)
R.A. Perley; F. R. Schwab, A.H. Bridle; Synthesis Imaging in Radio Astronomy, 3rd NRAO Summer School 1988 (Astronomical Society of the Pacific Conference Series, 1989)
A. R. Thompson, J. M. Moran, G.W. Swenson, Interferometry and Synthesis in Radio Astronomy (Wiley & Sons, Weinheim 2. Aufl. 2001)
Lecture Notes (U. Klein)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Submillimeter Astronomy

Course No.: astro842

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:

Preparation:
Basic astronomy knowledge

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Students with B.Sc. in Physics will be introduced to astronomy in the submillimeter wavelength range, one of the last spectral regions to be explored with new high-altitude ground-based or airborne telescopes, and from space

Contents of the Course:
The basic concepts of emission/excitation mechanisms from interstellar dust and molecules are discussed as well as the properties of the observed objects: the dense interstellar medium, star forming regions, circumstellar environments. Star formation near and far is a central focus of submillimeter astronomy and will thus be introduced in depth. Telescopes, instrumentation, and observational techniques will be described in the course

Recommended Literature:
Contemporary review articles

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Astronomical Interferometry and Digital Image Processing

Course No.: astro843

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Students learn the basics required to carry out research projects in the field of wave optics and astronomical infrared interferometry

Contents of the Course:
Statistical optics; Wave optics; image detectors; resolution enhancement by digital deconvolution; interferometric imaging methods in optical astronomy; Theory of photon noise; iterative image reconstruction methods; astronomical applications

Recommended Literature:
J. W. Goodman; Introduction to Fourier Optics (Roberts & Company Publishers 3. Aufl. 2004)
Lecture Notes

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Observational Cosmology

Course No.: astro845

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Students with B.Sc. in Physics will be introduced to past and current experiments in cosmology, with some bias toward radio- and submillimeter astronomy

Contents of the Course:
Brief history of cosmology and its initial discoveries: cosmic expansion, cosmic microwave background. Overview of modern cosmological experiments, their major aims and technology. Aims: constraints on Big Bang and dark energy, CMB power spectrum and polarization, Sunyaev-Zeldovich effect, Supernova Ia distance measures, structure /cluster /galaxy formation, epoch of reionization, high-redshift galaxies and quasars. Experiments: APEX, LOFAR, Planck, Herschel, ALMA, SKA. Techniques: bolometer, HEMT

Recommended Literature:
B. F. Burke; F. Graham-Smith, An Introduction to Radio Astronomy (Cambridge University Press 2002)
J. A. Peacock; Cosmological Physics (Cambridge University Press 1998)
Contemporary Review Articles

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Wave Optics and Astronomical Applications

Course No.: astro846

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Acquire the fundamentals necessary to carry out research projects in the field of wave optics and astronomical infrared interferometry

Contents of the Course:
Fundamentals of wave optics; Fourier mathematics; digital image processing; Michelson interferometry; speckle interferometry; speckle holography; Knox-Thompson method; bispectrum-speckle interferometry; interferometric spectroscopy; infrared-long-baseline interferometry; optical phase-closure method; infrared interferometry of young stars and stars in late evolutionary stages and in nuclei of galaxies

Recommended Literature:
Lecture Notes
J. W. Goodman; Introduction to Fourier Optics (Roberts & Company Publishers 3rd edition, 2004)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Optical Observations

Course No.: astro847

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Astronomy introduction classes

Form of Testing and Examination:
Requirements for the examination (written or oral exam): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
The students should get familiar with major aspects of optical astronomical observations, data reduction, and image analysis.

Contents of the Course:
Optical CCD and near infrared imaging, data reduction, catalogue handling, astrometry, coordinate systems, photometry, spectroscopy, photometric redshifts, basic weak lensing data analysis, current surveys, how to write observing proposals.
Practical experience is gained by obtaining and analysing multi-filter CCD imaging observations using the 50cm telescope on the AIfA rooftop, as well as the analysis of professional data from the archive.

Recommended Literature:
Provided upon registration

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Galactic and Intergalactic Magnetic Fields

Course No.: astro848

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Good knowledge of electrodynamics and astronomy

Form of Testing and Examination:
Requirements for examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The students shall become familiar with relativistic plasmas in astrophysics. They shall comprehend the origin and significance of magnetic fields in diffuse astrophysical media. The potential role of magnetic fields in the evolution of the universe will be discussed. The detection and quantitative measurements of magnetic fields in the ISM and IGM shall be conveyed, along with a description of the current and future observational facilities.

Contents of the Course:
Introduction: magnetism, physical quantities, history, observational evidence; radiation processes: radiation transport, free-free radiation, synchrotron radiation, inverse-Compton radiation, propagation effects; diagnostics: optical polarisation, synchrotron radiation, Faraday rotation, Zeeman effect; radio continuum observations: total and polarised intensity, rotation measure, RM synthesis, telescopes; Milky Way: diffuse ISM, molecular clouds and star-forming regions, supernova remnants, diffusive shock acceleration, cosmic rays, origin and maintenance of magnetic fields, galactic dynamo; external galaxies: spiral galaxies, dwarf irregular galaxies, elliptical galaxies, origin of magnetic fields; active galactic nuclei: radio galaxies, quasars, Seyfert galaxies, origin of magnetic fields; intergalactic magnetic fields: clusters of galaxies, radio halos, radio relics, mini-halos, magnetisation of the IGM, cosmological shocks; cosmological magnetic fields

Recommended Literature:
M.S. Longair: High Energy Astrophysics, Vol. 1+2 (Cambridge University Press, 2008)
S. Rosswog, M. Brüggen: Introduction to High-Energy Astrophysics (Cambr. Univ. Press 2009)
L. Spitzer: Physics of Fully Ionized Gases (Dover Publications , 2006)
Lecture Notes (U. Klein)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Multiwavelength Observations of Galaxy Clusters

Course No.: astro849

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Introductory Astronomy lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
To introduce the students into the largest clearly defined structures in the Universe, clusters of galaxies. In modern astronomy, it has been realized that a full understanding of objects cannot be achieved by looking at just one waveband. Different phenomena become apparent only in certain wavebands, e.g., the most massive visible component of galaxy clusters - the intracluster gas - cannot be detected with optical telescopes. Moreover, some phenomena, e.g., radio outbursts from supermassive black holes, influence others like the X-ray emission from the intracluster gas. In this course, the students will acquire a synoptic, mulitwavelength view of galaxy groups and galaxy clusters.

Contents of the Course:
The lecture covers galaxy cluster observations from all wavebands, radio through gamma-ray, and provides a comprehensive overview of the physical mechanisms at work. Specifically, the following topics will be covered: galaxies and their evolution, physics and chemistry of the hot intracluster gas, relativistic gas, and active supermassive black holes; cluster weighing methods, Sunyaev-Zeldovich effect, gravitational lensing, radio halos and relics, and the most energetic events in the Universe since the big bang: cluster mergers.

Recommended Literature:
Lecture script and references therein

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Introduction to Hydro- and Magnetohydrodynamics

Course No.: astro8401

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements for Participation:

Preparation:
Revision of vectors and vector calculus, electromagnetism, basic thermodynamics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The students will become familiar with the basic laws of hydrodynamics and magnetohydrodynamics and will understand their universal applicability and importance in many varied contexts. As well as learning about the basic phenomena such as waves and compressible flow, several particular contexts (mainly in astrophysics and atmospheric physics) will be examined in detail using analytical tools which the students will then learn to apply in other, new situations and contexts. By doing this the students will develop abilities to tackle and interpret any hydrodynamical phenomenon they encounter.

Contents of the Course:
The fluid approximation, Euler equations, ideal fluids, viscous fluids, diffusion of heat, sound waves, hydrostatics, flow around an object, the Bernoulli equation, the Reynolds number and other dimensionless parameters used to describe a flow, compressible and incompressible flow, supersonic and subsonic flow, shock waves (with example: supernovae), surface gravity waves, internal gravity waves, waves in a rotating body of fluid (example: earth's atmosphere), stability analysis (examples: convection, salt fingers in ocean), the magnetohydrodynamics equations, Alfven waves, flux conservation, flux freezing, magnetic pressure and tension, force-free fields, reconnection (with example: solar corona), angular momentum transport and the magneto-rotational instability (example: astrophysical discs).

Recommended Literature:
E.Landau & E.Lifshitz, Fluid mechanics (Pergamon Press 1987)
S.Shore; Astrophysical hydrodynamics: an introduction (Wiley-VCH, 2007)
Lecture notes at http://www.astro.uni-bonn.de/~jonathan/misc/astroMHDnotes.pdf

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: X-Ray Astronomy

universitätbonn

Course No.: astro8402

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Introductory astronomy lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The student shall be familiarized with X-ray observations as a powerful tool to study almost all astrophysical objects in ways not possible in other wavebands.

Contents of the Course:
History, space-based instruments, radiation processes, solar system objects, isolated compact objects, binaries with compact objects, supernova remnants, interstellar medium, Galactic center, normal galaxies, galaxy clusters, superclusters, intergalactic medium, active galactic nuclei.

Recommended Literature:
Lecture notes will be provided

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Hydrodynamics and astrophysical magnetohydrodynamics

Course No.: astro8403

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Revision of elementary thermodynamics, vector calculus and electromagnetism. Please note that although this course is designed mainly with astrophysics in mind, no knowledge of astrophysics is assumed. Students of other branches of physics are welcome.

Form of Testing and Examination:
Exercises throughout the semester, and an oral examination at the end of the course.

Length of Course:
1 semester

Aims of the Course:
Almost the entire universe is fluid and so an understanding of many phenomena is impossible without a proper grasp of fluid dynamics. This course introduces the field, drawing on examples from astrophysics as well as atmospheric physics to illustrate the principles. The aim is for the students to develop an intuitive understanding of underlying principles. Roughly the last quarter of the course is an introduction to magnetohydrodynamics; here the emphasis is on astrophysical applications (rather than laboratory/plasma physics).

Contents of the Course:
The fluid approximation, Euler equations, ideal fluids, viscous fluids, diffusion of heat, sound waves, hydrostatics, flow around a solid body, the Bernoulli equation, the Reynolds number and other dimensionless parameters used to describe a flow, compressible and incompressible flow, supersonic and subsonic flow, shocks (with example: supernovae), surface & internal gravity waves, vortices and vorticity, waves in a rotating body of fluid (example: earth's atmosphere), stability analysis (examples: convection, shear instability), the magnetohydrodynamics equations, Alfven waves, flux conservation, flux freezing, magnetic pressure and tension, force-free fields, reconnection (with example: solar corona), angular momentum transport and the magneto-rotational instability (example: astrophysical discs).

Recommended Literature:
E.Landau & E.Lifshitz, "Fluid mechanics" Pergamon Press 1987
S.Shore, "Astrophysical hydrodynamics: an introduction", Wiley-VCH 2007
A. Choudhuri, "The physics of fluids and plasmas", Cambridge 1998
Lecture notes at http://www.astro.uni-bonn.de/~jonathan/misc/Hydro_astroMHD.pdf

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Radiointerferometry: Methods and Science

Course No.: astro8404

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+2	4	ST

Requirements for Participation:

Preparation:
Einführung in die Radioastronomie (astro123), Radio Astronomy (astro841)

Form of Testing and Examination:
Requirements for the examination (written or oral): Successful participation in the exercise sessions

Length of Course:
1 semester

Aims of the Course:
Basics of radiointerferometric observations and techniques; review of science highlights; use of common data analysis packages.

Contents of the Course:
Principles of interferometry, aperture synthesis, calibration, continuum and spectral line imaging, zero spacing, VLBI, use of AIPS and CASA, ALMA and VLA proposal writing, LOFAR and SKA, science highlights.

Recommended Literature:
"Synthesis Imaging in Radio Astronomy II" (ASP Conference Series, V. 180, 1998), Editors: Taylor, Carilli, Perley
Interferometry and Synthesis in Radio Astronomy (Wiley 2001), by Thompson, Moran, Swenson

On-line material

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: The Cosmic Microwave Background

Course No.: astro8405

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:
Some basic knowledge of electrodynamics and thermal physics, and some experience with Python programming. No prior course-work on cosmology is necessary.

Preparation:

Form of Testing and Examination:
Weekly exercise classes, after successful evaluation of which a final oral exam at the end of the semester

Length of Course:
1 semester

Aims of the Course:
This course intends to give the students a modern and up-to-date introduction to the science and experimental techniques relating to the Cosmic Microwave Background (CMB). No prior knowledge of cosmology is assumed; rather, the course introduces the necessary concepts in the class, and partly depends on the mandatory cosmology course that is taught in parallel. The aim is to make the students interested in the vast field of CMB research, which continues to be one of the richest source of information about our Universe.

Contents of the Course:
Roughly 14 lectures, covering the four main topics of (i) CMB thermal spectrum, (ii) CMB temperature anisotropies and their cosmological significance, (iii) CMB polarization and the search for primordial gravitational waves, and (iv) CMB foregrounds and component separation techniques. There will be weekly exercise classes, some of which involve simple programming and plotting.

Recommended Literature:
Appropriate references are provided during the lectures.

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Active Galactic Nuclei (OA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts and physical radiation mechanisms for active galactic nuclei
Like Seyfert-galaxies, QSOs, quasars, and violently variable objects.

Contents of the Course:
The lecture introduces to basic aspects of active galactic nuclei:
Types of sources HII-galaxies, LINERs, Seyfert I, Seyfert II, QSO I , QSO II, BLLac /OVV-sources
Structure of an active nucleus: Broad line region (BLR), Narrow line region (NLR) and extended narrow line region (ionization cone).
Forbidden and permitted line transitions as density and temperature probes
Continuum emission processes: free-free and synchrotron radiation
Radio galaxies, jets and lobes as well as super luminal motion in jets.

Recommended Literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: Methods of Experimental Astrophysics (OA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Elementary Physics (Bachelor level); Astrophysics I (and II)

Form of Testing and Examination:
Exercise and written test; or oral examination

Length of Course:
1 semester

Aims of the Course:
Gain insight into which type of instrumentation, based on which principles, is employed for particular astronomical and astrophysical applications; and learn about their practical and fundamental limitations in resolution and sensitivity

Contents of the Course:
- detection of radiation: direct and coherent detection
- Signal/Noise ratio: fundamental and practical limits
- principles of optical instruments: imaging
- principles of optical instruments: spectroscopy
- radio receivers: Local Oscillator, Mixer and Backend-Spectrometers
- calibration: theory and measurement startegies

Recommended Literature:
Rieke: Detection of Light
Kraus: Radioastronomy
Bracewell: The Fourier Transform and its Applications

Module: Elective Advanced Lectures: Observational Astronomy

Module No.: astro840

Course: The Fourier-Transform and its Applications (OA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Elementary Physics (Bachelor level); Elementary QM

Form of Testing and Examination:
Exercise and written test; or oral examination

Length of Course:
1 semester

Aims of the Course:
Strengthen insight into how the mathematical principles of Fourier Theory as a common principle affect many areas of physics (optics: diffraction/interference; QM: Heisenberg principle; statistics of noise and drifts; data acquisition: sampling) and other applications (data compression, signal processing).

Contents of the Course:
- introduction to the principles of Fourier Transform mathematics
- Delta-function and more general distributions
- diffraction optics and interferometry
- uncertainty principle in QM as application of FT
- theory of noise, drifts and their statistics
- intro to wavelet analysis and data compression

Recommended Literature:
Bracewell: The Fourier Transform and its Applications

Module No.: astro850
Credit Points (CP):
Category: Elective
Semester: 1.-2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures: Modern Astrophysics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 85* courses from catalogue	astro85*	3-6	see catalogue	90-180 hrs	WT/ST
2.	Astrophysics Courses from Cologne marked "MA"	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
3.	Also possible classes from M.Sc. in Physics					

Requirements for Participation:

Form of Examination:
written examination

Content:
This module contains a number of lectures on various astrophysical phenomena, from stars to the largescale structure of the universe

Aims/Skills:
The student shall acquire deeper knowledge of a variety of astrophysical phenomena, from stars through large-scale structure to cosmological aspects. The physical mechanisms and mathematical tools required to understand these phenomena shall be conveyed, complementing what is being treated in the compulsory astrophysics courses

Course achievement/Criteria for awarding cp's:
see with the course

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

The students must obtain 18 CP in all out of the modules astro840 and astro850.

Modules:

astro840 **Elective Advanced Lectures: Observational Astronomy**
astro850 **Elective Advanced Lectures: Modern Astrophysics**

Course: Research Project

Course No.: astro831

Category	Type	Language	Teaching hours	CP	Semester
Elective	Research Project	English		4	WT/ST

Requirements for Participation:
Students are asked to contact one of the BCGS lecturers prior to the start of their project. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have projects available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

registration by written application to the examination office (see homepage)

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Stellar and Solar Coronae

Course No.: astro851

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The student shall gain thorough knowledge of activity phenomena exhibited by the sun and other stars

Contents of the Course:
Sunspots and solar corona; Solar cycle; The Dynamo theory; Emission mechanism; Coronal loops; Magnetic reconnection; Flares; Magnetic stellar activity; Mapping star-spots: Doppler imaging; Radio coronae

Recommended Literature:
Literature references will be provided during the course

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Gravitational Lensing

Course No.: astro852

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
After learning the basics of gravitational lensing followed by the main applications of strong and weak lensing, the students will acquire knowledge about the theoretical and observational tools and methods, as well as about the current state of the art in lensing research. Strong emphasis lies on weak lensing as a primary tool to study the properties of the dark-matter distribution and the equation of state of dark energy

Contents of the Course:
The detection of the deflection of light in a gravitational field was not only one of the crucial tests of Einstein's Theory of General Relativity, but has become in the past two decades a highly valuable tool for astronomers and cosmologists. It is ideally suited for studying the mass distribution of distant objects, search for compact objects as a potential constituent of the Galactic dark matter, provide powerful (and cheap) 'natural telescopes' to take a deeper look into the distant Universe, to measure the mass distribution in clusters and on larger spatial scales, and to study the relation between luminous and dark matter in the Universe. Principles and methods are described in detail and the applications will be presented

Recommended Literature:
P. Schneider, C. Kochanek, J. Wambsganss; Gravitational Lensing: Strong, Weak and Micro: Saas-Fee Advanced Course 33. Swiss Society f Astrophysics and Astronomy (Springer, Heidelberg 2006)
P. Schneider, J. Ehlers, E. F. Falco; Gravitational Lenses (Springer, Heidelberg 1992)

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: The Physics of Dense Stellar Systems as the Building Blocks of Galaxies

Course No.: astro8531

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	6	WT

Requirements for Participation:

Preparation:
Participation in the lecture course and in the exercise classes and reading

Form of Testing and Examination:
A final two hour written exam on the contents of the course

Length of Course:
1 semester

Aims of the Course:
The students are taught the fundamentals of collisional stellar dynamics and of the emergence of stellar populations from galactic building blocks

Contents of the Course:
Fundamentals of stellar dynamics: distribution functions, generating functions, collisionless Boltzmann equation, Jeans equations, Fokker-Planck equation, dynamical states, collisional dynamics and relaxation, formal differentiation between star clusters and galaxies, mass segregation, evaporation, ejection, star-cluster evolution, the form, variation and origin of the stellar initial mass function, stellar populations, their evolution and their properties, binary stars as energy sinks and sources, the distribution functions of binary stars and the evolution of these distribution functions, star-cluster birth, violent relaxation, birth of dwarf galaxies.

The lecture course covers a broad range of topics related to the emergence of stellar populations from their molecular cloud cores. It provides a Bonn-unique synthesis on the one hand side between observationally and theoretically derived distribution functions, which describe stellar populations, and on the other hand side the temporal evolution of these distribution functions, such that a comprehensive mathematical formulation of stellar populations in galaxies becomes possible with this knowledge.

Recommended Literature:
Lecture notes
Galactic Dynamics by J.Binney and S.Tremaine (1987, Princeton University Press)
Dynamics and Evolution of Galactic Nuclei by D.Merritt (2013, Princeton University Press)
Dynamical Evolution of Globular Clusters by Lyman Spitzer, Jr. (1987, Princeton University Press)
The Gravitational Million-Body Problem by Douglas Heggie and Piet Hut (2003, Cambridge University Press)
Gravitational N-body Simulations: Tools and Algorithms by Sverre Aarseth (2003, Cambridge University Press)
Initial Conditions for Star Clusters by Pavel Kroupa (2008, Lecture Notes in Physics, Springer)

The stellar and sub-stellar IMF of simple and composite populations by Pavel Kroupa (2013, Stars and Stellar Systems Vol.5, Springer)
The universality hypothesis: binary and stellar populations in star clusters and galaxies by Pavel Kroupa (2011, IAUS 270, p.141)

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: universitätbonn Numerical Dynamics

Course No.: astro854

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with exercises and programming tasks

Length of Course:
1 semester

Aims of the Course:
The students will have to familiarize themselves with the various numerical recipes to solve the coupled 2nd-order differential equations as well as with the limitations of these methods

Contents of the Course:
The two-body problem and its analytical solution. Ordered dynamics: integration of planetary motion, solar system, extra-solar planets. Collisional dynamics: integration of stellar orbits in star clusters, star-cluster evolution. Collisionless dynamics: integration of stellar orbits in galaxies, cosmological aspects

Recommended Literature:
Write-up of the class;
S. J. Aarseth; Gravitational N-body simulations: Tools and Algorithms (Cambridge University Press, 2003)

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Quasars and Microquasars

Course No.: astro856

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The phenomenon of quasars and their energy production shall be studied from the smallest (stellar binaries) to the largest (active galactic nuclei) scales

Contents of the Course:
Microquasars and Quasars; X-ray binaries; Accretion; Neutron stars; Black holes; X-ray observations; Spectral states; Radio observations; Doppler boosting; Energy losses; Magneto-hydrodynamic production of jets; Gamma-ray observations; Review of Microquasars; Quasi periodic oscillations (QPO)

Recommended Literature:
Literature references will be provided during the course

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Star Formation

Course No.: astro857

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
An introduction to basic concepts, modern theories, and the current observational basis of star formation.

Contents of the Course:
The structure and evolution of the interstellar medium in relation to Star Formation: molecular excitation, interstellar chemistry; the star formation process: conditions, cloud collapse, protostellar evolution; low mass vs. massive star formation; related phenomena: jets and outflows, protostellar disks, shocks, photodissociation regions; the initial mass function, global star formation, starbursts, the star formation history of the Universe, the very first stars.

Recommended Literature:
Stahler, Palla: The Formation of Stars (Wiley-VCH, 2004)
Additional literature will be given during the course

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Nucleosynthesis

Course No.: astro858

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Introduction to Astronomy, Stars and Stellar Evolution

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Obtain an overview of the different nucleosynthesis processes in the universe, an understanding of how they work, and where they work.

Contents of the Course:
Basic: Thermonuclear reactions
Big Bang nucleosynthesis
Overview of stellar evolution
Hydrostatic Nucleosynthesis I: Hydrogen burning
Hydrostatic Nucleosynthesis II: Helium burning and beyond
Hydrostatic Nucleosynthesis III: The s-process
Hydrostatic Nucleosynthesis IV: s-process components
Explosive Nucleosynthesis I: Core-collapse supernovae
Explosive Nucleosynthesis II: r-process and p-process
Explosive Nucleosynthesis III: Thermonuclear supernovae
Cosmic ray nucleosynthesis
Chemical Evolution of galaxies

Recommended Literature:
Lecture script
C.E.Rolfs, W.S.Rodney: Cauldrons in the Cosmos (ISBN 0-226-45033-3), not compulsary
D.D. Clayton: Physics of Stellar Evolution and Nucleosynthesis (ISBN 0-226-10953-4), not compulsary

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: The cosmic history of the intergalactic medium

Course No.: astro859

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:

Preparation:
Basic atomic physics (hydrogen atom) and basic thermodynamics. No previous knowledge of astrophysics is required.

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The aim of this course is to familiarize students with the physics of the intergalactic medium (the material that pervades the vast regions between galaxies) and with its significance for cosmology and the astrophysics of galaxies. Thanks to progress in observations, theoretical modeling, and computational power, our knowledge in this field is growing rapidly. The main questions driving current research will be discussed and new results introduced as they occur.

Contents of the Course:
Basic: Transport of continuum and line radiation, photo-ionizations and radiative recombinations, the cooling function, the expanding universe.

Advanced: Cosmic recombination, the dark ages, hydrogen and helium reionization, 21cm-probes of the dark ages and reionization, quasar absorption systems, the UV background, the warm-hot intergalactic medium, intracluster gas, Lyman-alpha fluorescence.

Recommended Literature:
The study of the intergalactic medium is a young subject. No textbook exists for this topic. Lecture notes will be distributed.

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Binary Stars

Course No.: astro8501

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Introductory astronomy and cosmology lectures, stars and stellar evolution

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The course will provide the necessary understanding of the basic physics of binary stars, in particular orbits, mass-transfer, chemistry and the importance of binary stars and populations of binaries to modern astrophysics.

Contents of the Course:
Most stars are not alone, they orbit a companion in a binary star system. This course will address the evolution of such binary stars and their impact on the Universe. It will start by considering orbital dynamics and observations of binaries, followed by stellar interaction in the form of mass transfer by Roche-lobe overflow and wind mass transfer. The effect of duplicity on chemistry, rotation rates and orbital parameters will be studied with the emphasis on uniquely binary-star phenomena such as type Ia supernovae, thermonuclear novae and gamma-ray bursts. It will conclude with quantitative studies of populations of binary stars.

Recommended Literature:
An Introduction to Close Binary Stars - Hildtich - Cambridge University Press ISBN 0-421-79800-0
Interacting Binary Stars - Pringle and Wade - CUP (Out of print but you can find cheap second-hand copies on www.amazon.com) ISBN 0-521-26608-4
Evolutionary Processes in Binary and Multiple Stars - Eggleton - CUP ISBN 0-521-85557-8

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Physics of Supernovae and Gamma-Ray Bursts

universitätbonn

Course No.: astro8502

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:

Preparation:
Introductory astronomy and cosmology lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The student will learn basic physics on supernova and gamma-ray burst, and will have an overview on their applications to various fields of astrophysics.

Contents of the Course:
Basic physics on stellar hydrodynamics, radiation processes, and stellar death.
Type Ia supernova: observations and theory. Application to cosmology
Core collapse supernova: observations and theory
Gamma-ray bursts: observations and theory.
Implications for massive star population and star-formation history
Supernova nucleosynthesis and chemical evolution of galaxies
Explosions of the first generations of stars
Some related issues: supernova remnants, neutrinos, shock break-out, etc.

Recommended Literature:
Lecture notes with key references for each topic will be provided.

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Radio and X-Ray Observations of Dark Matter and Dark Energy

Course No.: astro8503

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:

Preparation:
Introductory astronomy and cosmology lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The student will learn how the phenomena of dark matter and dark energy are explored using radio and X-ray observations, from the largest down to galaxy scales.

Contents of the Course:
Introduction into the evolution of the Universe and the theoretical background of dark matter and dark energy tests, dark matter associated with galaxies, dark matter associated with galaxy clusters and superclusters, the cosmic microwave background (CMB), epoch of re-ionization, low-frequency radio astronomy, high-z supernovae, cosmic infrared background (CIB), precise distance measurements at cosmological distances, observational evidence for hierarchical structure formation, MOND vs. dark matter cosmology.

Recommended Literature:
Lecture notes will be provided

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Lecture on Advanced Topics in Modern Astrophysics

Course No.: astro8504

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements for Participation:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
This course is to allow the students to have deeper insight into a specialised subject of astrophysics that is not covered in the astrophysics curriculum otherwise. The content of the course depends on the lecturer's expertise and may vary from time to time.

Contents of the Course:
See detailed announcements ("kommentiertes Vorlesungsverzeichnis")

Recommended Literature:

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Introduction to MoND

Course No.: astro8505

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	0	ST

Requirements for Participation:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
The aim of this course is to provide an introduction to Modified Newtonian Dynamics (MoND) as a successful alternative for dark matter.

Contents of the Course:
1) Observational basis: baryonic Tully-Fisher relation (BTFR), radial acceleration relation (RAR), dynamical friction, planes of satellites, rotation curves of galaxies, pattern speed of spiral galaxies, tidal dwarf galaxies, stability of galactic disks, asymmetries of stellar tidal tails, galaxy and structure formation, wide-binary evolution

2) Theoretical framework: classical field theory, generalised Poisson equation, aquadratic MoND formulation (AQUAL), quasi-linear MoND formulation (QUMOND), pressure and rotationally supported systems, external field effect (EFE), modified gravity vs. modified inertia, discrete N-body systems in MoND, inverse Lagrangian problem, higher order Lagrangian theory, general relativistic embedding

3) Numerical treatment: Solving the PDEs of AQUAL and QUMOND numerically, overview and usage of existing software packages for MOND simulations, first steps in MoNDian direct N-body dynamics

4) Open questions and current research status

Recommended Literature:
No textbook exists for this topic at the moment. Lecture notes and access to original research literature will be provided.

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Statistical Methods in Cosmology & Astrophysics

Course No.: astro8506

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:
None. Ideally some experience with programming, preferably in python.

Preparation:

Form of Testing and Examination:
Written or oral examination, successful exercise work.

Length of Course:
1 semester

Aims of the Course:
Statistical methods are an integral part of cosmology and astrophysics studies. This course will give an overview of the statistical principles and tools that are used in these fields. Topics covered will include basic probability theory, estimators, hypothesis testing, Bayesian inference, sampling, and an introduction to Machine Learning. We will discuss these concepts during the lectures, while the exercise classes will focus on practical implementations of these methods to astrophysical problems using python and jupyter notebooks.

Contents of the Course:
Introduction to Python
Probabilities
Point Estimation
Maximum Likelihood
Hypothesis Testing
Regression Methods
Bayesian Inference
Error Estimation
Monte Carlo Markov Chain methods
Introduction to Machine Learning

Recommended Literature:
Notes presented in the lectures will come from a diverse set of sources and will form the main material for the course.
Additional literature:
- Statistics in Theory and Practice - Robert Lupton
- Statistics, Data Mining, and Machine Learning in Astronomy - Zeljko Ivezic, Andrew J. Connolly, Jacob T. VanderPlas, and Alexander Gray
- Modern Statistical Methods for Astronomy - Eric D. Feigelson and G. Jogesh Babu

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Advanced Topics in Cosmology

Course No.: astro8507

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
General Relativity and Cosmology at the level of the Theoretical Astrophysics & Cosmology courses of the first semester.

Form of Testing and Examination:
Oral examination, successful exercise work.

Length of Course:
1 semester

Aims of the Course:
This course will build on Theoretical Astrophysics and Cosmology and introduce students to advanced concepts in cosmology with a focus on the understanding of galaxy redshift surveys. The aim of the course will be to cover the basics needed to understand the current literature and start research work in the field.

Contents of the Course:
The course consists of two parts: (1) A theoretical discussion of the evolution of matter perturbations from Inflation to the present day, (2) An introduction to observational techniques in galaxy surveys.

Recommended Literature:
Notes presented in the lectures will come from a diverse set of sources and will form the main material for the course.

Additional literature:
Modern Cosmology - Scott Dodelson (Fabian Schmidt)
Cosmological Physics - John Peacock
Cosmology - Steven Weinberg

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Astrophysics II (MA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+1	8	WT

Requirements for Participation:

Preparation:
Astrophysics I

Form of Testing and Examination:
written test

Length of Course:
1 semester

Aims of the Course:
The student will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable him to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepares the students towards their own research activity within the master thesis.

Contents of the Course:
Based on the introductory course 'Astrophysics I' in the Bachelor program this course deepens the understanding in selected topical areas of relevance. These are:
Interstellar medium: molecular clouds, HII regions, photon dominated regions, shock waves, radiation processes, radiative transfer, astrochemistry
Star formation (low mass and high mass), planetary system formation
Galaxies: galactic structure, morphology, dynamics, chemical evolution, nuclei of active galaxies
Large scale structure of the universe: intergalactic distance ladder, galaxy clusters, dark matter, gravitational lenses, experimental cosmology

Recommended Literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einfhrung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Star Formation (MA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2	3	WT

Requirements for Participation:

Preparation:
Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts of star formation in a variety of environments.

Contents of the Course:
The lecture introduces the basic aspects of Star Formation:
Physical Processes in the ISM, Interstellar Chemistry, ISM and Molecular Clouds, Equilibrium Configurations and Collapse, Protostars, Formation of High Mass Stars, Jets, Outflows, Disks, Pre-main sequence stars, Initial Mass Function, Structure of the Galaxy, Starburst Galaxies, Star Formation in the early Universe

Recommended Literature:
Palla and Stahler, Formation of Stars (Wiley)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Spitzer, Physical Processes in the Interstellar Medium (Wiley)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)

Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Galaxy Dynamics (MA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements for Participation:

Preparation:
Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts of stellar and galaxy dynamics.

Contents of the Course:
The lecture introduces to basic aspects of stellar and galaxy dynamics: Multiple stellar systems, dynamics of open and compact stellar clusters, elliptical, disk and barred spiral galaxies, gas kinematics, galaxy evolution in galaxy clusters, gravitational friction, violent relaxation, the Hubble fork, galaxy collisions and mergers, cosmological evolution of stellar systems.

Recommended Literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Module No.: astro940
Credit Points (CP): 15
Category: Required
Semester: 3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Scientific Exploration of the Master Thesis Topic

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Scientific Exploration of the Master Thesis Topic	astro941	15		450 hrs	WT

Requirements for Participation:
Successful completion of 60 credit points from the first year of the Master phase, including the modules physics601, astro608, astro 810, and astro820

Form of Examination:
Presentation

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall explore the science field, read the relevant recent literature, and perhaps participate in further specialised classes and in seminars. The student shall write an essay about the acquired knowledge, which may serve as the introduction part of the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the scientific question to be studied in the Master Thesis

Course achievement/Criteria for awarding cp's:

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Astrophysik, Pflicht, Semester: 3

Module No.: astro950
Credit Points (CP): 15
Category: Required
Semester: 3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Methods and Project Planning

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Methods and Project Planning	astro951	15		450 hrs	WT/ST

Requirements for Participation:
Successful completion of 60 credit points from the first year of the Master phase, including the modules physics601, astro608, astro 810, and astro820

Form of Examination:
written proposal

Content:
Under guidance of the supervisor of the planned Master Thesis topic, the student shall acquire knowledge about the methods required to carry out the Master Thesis project. This may include the participation in specialised seminars or specialised classes for the Master programme. The student shall plan the steps needed to successfully complete the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the methods to be used in the Master Thesis research. The project plan has to be presented

Course achievement/Criteria for awarding cp's:

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Useable for:
Masterstudiengang Astrophysik, Pflicht, Semester: 3

Module No.: astro960
Credit Points (CP): 30
Category: Required
Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Master Thesis

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Master Thesis	astro960	30	Thesis	900 hrs	WT/ST

Requirements for Participation:
Successful completion of 60 credit points from the first year of the Master phase, including the modules physics601, astro608, astro 810, and astro820

Form of Examination:
Master Thesis

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall carry out the research of the Master Thesis project

Aims/Skills:
The student shall identify and work out the science question to be tackled in the Master Thesis

Course achievement/Criteria for awarding cp's:
oral presentation

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

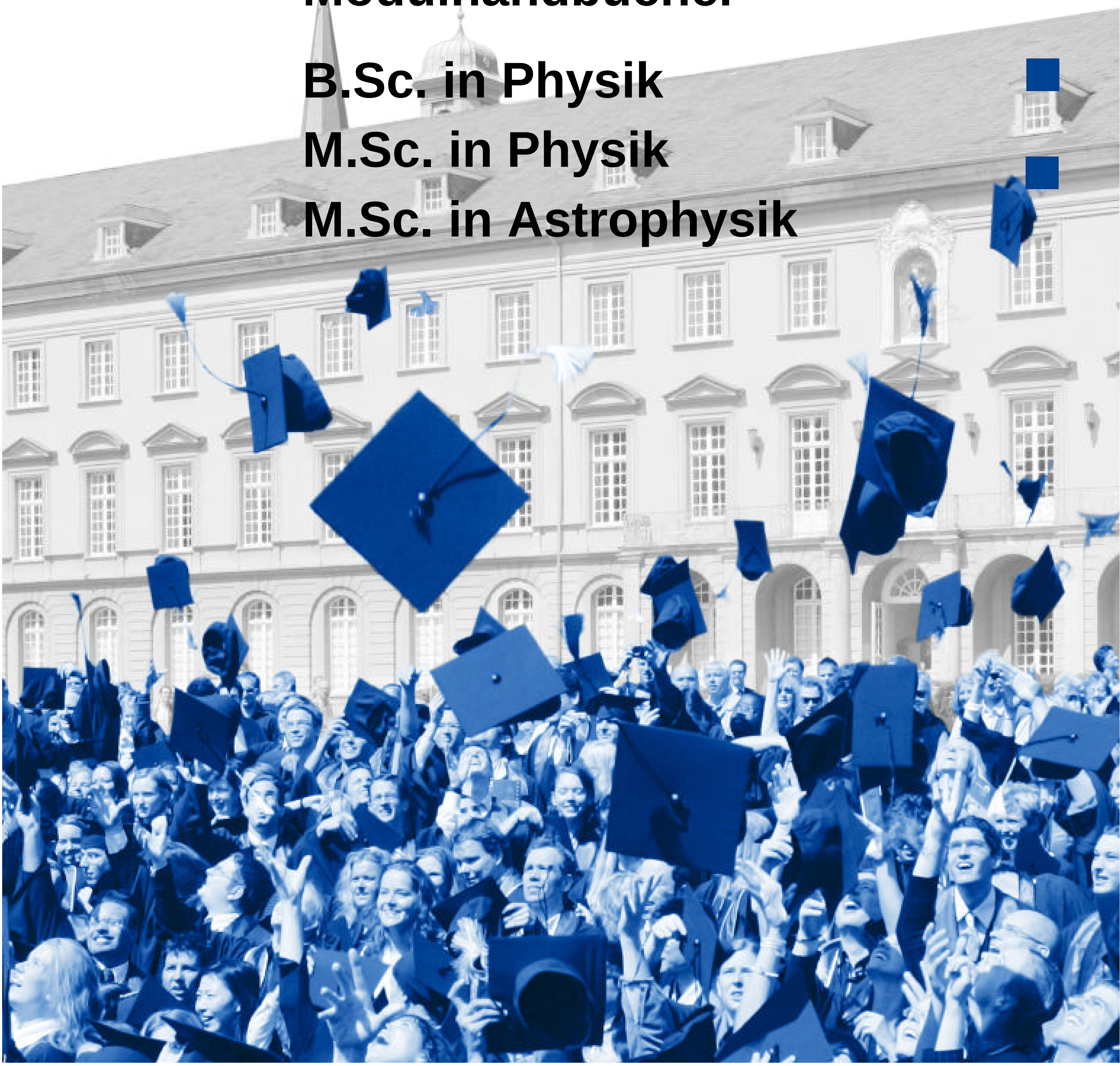
Useable for:
Masterstudiengang Astrophysik, Pflicht, Semester: 4

universitätbonn

Fachgruppe Physik/Astronomie

Modulhandbücher

B.Sc. in Physik
M.Sc. in Physik
M.Sc. in Astrophysik



Modulhandbuch
Bachelor in Physik
PO von 2006

SS 2024

Bachelor in Physik, Universität Bonn

180 LP*	Experimental-physik	Labor	Mathematik	Theoretische Physik	Wahlpflicht	Prüfungs-module	Zusatzmodule	Schriftliche Arbeit
1. Sem.	physik110/111 **Physik I Mechanik, Wärmelehre** 4+2 SWS, 7 LP		math140/141 **Mathematik I für Physiker und Physikerinnen** 6+3 SWS, 13 LP		physik120 **Lehrveranstal-tungen aus Astronomie / Chemie / Informatik / Meteorologie / BWL / VWL, Philosophie** 8 LP		physik130/131 **Einführung in die EDV** 1+2 SWS, 4 LP	
2. Sem.	physik210/211 **Physik II Elektromagnetismus** 4+2 SWS, 7 LP	physik110/112 **Praktikum Mechanik, Wärmelehre** 3 SWS, 3 LP	math240/241 **Mathematik II für Physiker und Physikerinnen** 4+3 SWS, 11 LP	physik220/221 **Theoretische Physik I Mechanik** 4+3 SWS, 9 LP				
3. Sem.	physik310/311 **Physik III Optik und Wellenmechanik** 4+2 SWS, 7 LP	physik210/212 **Praktikum Elektromagnetismus** 3 SWS, 3 LP physik310/312 **Praktikum Optik, Wellenmechanik** 3 SWS, 3 LP	math340/341 **Mathematik III für Physiker und Physikerinnen** 4+3 SWS, 11 LP	physik320/321 **Theoretische Physik II Elektrodynamik** 4+3 SWS, 9 LP				
4. Sem.	physik410/411 **Physik IV Atome, Moleküle, Kondensierte Materie** 4+2 SWS, 7 LP	physik310/313 **Elektronikpraktikum + Blockvorlesung** 4 SWS, 4 LP	physik440/441 **Numerische Methoden der Physik** 2+2 SWS, 6 LP	physik420/421 **Theoretische Physik III Quantenmechanik** 4+3 SWS, 11 LP	physik450 **Wahlpflichtmodul** 6 LP			
5. Sem.	physik510/511 **Physik V Kerne und Teilchen** 4+2 SWS, 7 LP	physik 410/412 **Praktikum Atome, Moleküle, Kondensierte Materie** 5 SWS, 5 LP		physik520/521 **Theoretische Physik IV Statistische Physik** 4+3 SWS, 9 LP		physik530/531 **Prüfung Experimentalphysik** 4 LP	physik540/541 **Proseminar Präsentation** 3 SWS, 3 LP	physik590 **Bachelorarbeit** 12 LP
6. Sem.		physik510/512 **Praktikum Kern- und Teilchenphysik** 5 SWS, 5 LP				physik530/532 **Prüfung Theoretische Physik** 4 LP	physik540/542 **Seminar zur Bachelorarbeit** 2 SWS, 2 LP	

* Die im Diagramm dargestellten Leistungspunkte (LP) sind im Studium zu erbringen (insgesamt 180 LP); *SWS (x+y)* gibt die Anzahl der Semesterwochenstunden für Vorlesung (*x*) und Übungen (*y*) an.

Verwendete Abkürzungen:

LP	Leistungspunkte
LV	Lehrveranstaltung
n.a.	nicht anwendbar
n.V.	nach Vereinbarung
PO	Prüfungsordnung
s.	siehe
Sem.	Semester
SS	Sommersemester
Std.	Stunden
Üb.	Übungen
Vorl.	Vorlesung
WS	Wintersemester
SWS	*(x+y)* gibt die Anzahl der Semesterwochenstunden für Vorlesung(*x*) und Übungen (y) an

Anmerkung zu math140, math240 und math340:
Studierende mit starker Neigung zur theoretischen Physik können alternativ die entsprechenden Vorlesungen für Mathematiker besuchen. Studierende, die diese Option wahrnehmen, werden typischerweise mehr als die im Bachelorstudiengang Physik vorgesehenen 35 LP erwerben.

Aus allen Modulen der Mathematik (math140, 240, 340 und alternativen Modulen aus dem Bachelorstudium der Mathematik) werden maximal 35 LP für den Erwerb des Bachelorgrades in Physik angerechnet. Bei der Berechnung der Gesamtnote werden die Ergebnisse aus der Mathematik mit 35 LP gewichtet. Überzählige Prüfungsleistungen/Kreditpunkte werden auf dem Zeugnis ausgewiesen (§ 20, Abs. 1a Bachelor PO).

Anmerkung zu Modul(teil)prüfungen:
Die Einzelheiten der Modul(teil)prüfungen werden vor Beginn der Lehrveranstaltung von den Dozentinnen und Dozenten festgelegt.

Anmerkung zu den Gliederungspunkten "Zulassungsvoraussetzungen" und "Empfohlene Vorkenntnisse:
Unter dem Gliederungspunkt "Empfohlene Vorkenntnisse" werden LV'S aufgeführt, deren Inhalt wesentlich zum Verständnis der beschriebenen LV beiträgt. Unter dem Gliederungspunkt "Zulassungsvoraussetzungen" werden nur Studienleistungen aufgeführt, die für die Zulassung für das beschriebene Modul zwingend erforderlich sind.

Inhaltsverzeichnis: B.Sc. in Physik (PO von 2006)

physik110 Physik I (Mechanik, Wärmelehre) ... 1
physik111 Physik I (Mechanik, Wärmelehre) ... 2
physik112 Praktikum Mechanik, Wärmelehre ... 3
physik120 Einführungsveranstaltungen anderer Fächer ... 4
Liste der Einführungsveranstaltungen anderer Fächer ... 5
astro121 Einführung in die Astronomie ... 6
astro122 Einführung in die extragalaktische Astronomie ... 7
astro123 Einführung in die Radioastronomie ... 8
physik130 Einführung in die EDV ... 9
physik131 EDV für Physiker und Physikerinnen ... 10
math140 Mathematik I für Physiker und Physikerinnen ... 11
math141 Mathematik I (für Physiker und Physikerinnen) ... 12
physik210 Physik II (Elektromagnetismus) ... 13
physik211 Physik II (Elektromagnetismus) ... 14
physik212 Praktikum Elektromagnetismus ... 15
physik220 Theoretische Physik I (Mechanik) ... 16
physik221 Theoretische Physik I (Mechanik) ... 17
math240 Mathematik II für Physiker und Physikerinnen ... 18
math241 Mathematik II (für Physiker und Physikerinnen) ... 19
physik310 Physik III (Optik und Wellenmechanik) ... 20
physik311 Physik III (Optik und Wellenmechanik) ... 21
physik312 Praktikum Optik, Wellenmechanik ... 22
physik313 Elektronikpraktikum ... 23
physik320 Theoretische Physik II (Elektrodynamik) ... 24
physik321 Theoretische Physik II (Elektrodynamik) ... 25
math340 Mathematik III für Physiker und Physikerinnen ... 26
math341 Mathematik III (für Physiker und Physikerinnen) ... 27
physik410 Physik IV (Atome, Moleküle, Kondensierte Materie) ... 28
physik411 Physik IV (Atome, Moleküle, Kondensierte Materie) ... 29
physik412 Praktikum Atome, Moleküle, Kondensierte Materie ... 30
physik420 Theoretische Physik III (Quantenmechanik) ... 31
physik421 Theoretische Physik III (Quantenmechanik) ... 32
physik440 Numerische Methoden der Physik ... 33
physik441 Numerische Methoden der Physik ... 34
physik450 Wahlpflichtmodul ... 35
Veranstaltungen aus Master Physik und Master Astrophysik ... 36
physik458 Projektpraktikum Physik ... 37
physik459 Betriebspraktikum ... 38
physik510 Physik V (Kerne und Teilchen) ... 39
physik511 Physik V (Kern- und Teilchenphysik) ... 40
physik512 Praktikum Kern- und Teilchenphysik ... 41
physik520 Theoretische Physik IV (Statistische Physik) ... 42
physik521 Theoretische Physik IV (Statistische Physik) ... 43
physik530 Mündliche Prüfungen ... 44
physik531 Prüfung Experimentalphysik ... 45
physik532 Prüfung Theoretische Physik ... 46
physik540 Präsentation ... 47
physik541 Proseminar Präsentationstechnik ... 48

physik542 Seminar zur Bachelorarbeit 49
physik590 Bachelorarbeit 50
Lehrveranstaltungen Variante "FV" 51
physik591 Bachelorarbeit 52

Modul-Nr.: physik110
Leistungspunkte: 10
Kategorie: Pflicht
Semester: 1.-2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik I (Mechanik, Wärmelehre)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik I (Mechanik, Wärmelehre)	physik111	7	Vorl. + Üb.	210 Std.	WS
2.	Praktikum Mechanik, Wärmelehre	physik112	3	Praktikum	90 Std.	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Inhalt:
Mechanik-Grundlagen mit Demonstrationsversuchen, Mechanik des Massenpunktes, deformierbare Medien, Vielteilchensysteme, Wärmelehre, Relativistische Aspekte. Dazu 6 Praktikumsversuche

Lernziele/Kompetenzen:
Einarbeitung in die Mechanik und die Wärmelehre; Erarbeitung der Phänomenologie in Vorbereitung auf den theoretischen Unterbau

Prüfungsmodalitäten:
physik111: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen.
physik112: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Bearbeitung der Versuchsprotokolle, mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer des Moduls: 2 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Physik I (Mechanik, Wärmelehre)

Modul-Nr.: physik110

Lehrveranstaltung: Physik I (Mechanik, Wärmelehre)

LV-Nr.: physik111

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Einarbeitung in die Mechanik und die Wärmelehre; Erarbeitung der Phänomenologie in Vorbereitung auf den theoretischen Unterbau

Inhalte der LV:
Grundlagen (Größen, Einheiten; Skalare, Vektoren, trigonometrische Funktionen, differenzieren, partielle und totale Ableitungen, integrieren, komplexe Zahlen, Gradient, Divergenz, Rotation);
Mechanik des Massenpunktes (Kinematik, Dynamik, Relativbewegung; beschleunigte Bezugssysteme, Impuls, Drehimpuls, Arbeit, Energie, Massenmittelpunkt);
Relativistische Kinematik (Lorentz-Transformationen, Längenkontraktion, Zeitdilatation).
Gravitation und Keplerbewegung
Mechanik des Starren Körpers (Kraft, Drehmoment, Statik, Dynamik, Starrer Rotator, freie Achsen, Trägheitsmoment, Kreisel, Schwingungen, Festkörperwellen);
Mechanik deformierbarer Medien (Aggregatzustände, Verformungseigenschaften fester Körper, ruhende Medien, statischer Auftrieb, Oberflächenspannung, bewegte Medien, Wellen und Akustik, dynamischer Auftrieb);
Mechanik der Vielteilchensysteme (Gaskinetik, Temperatur, Zustandsgrößen, Hauptsätze der Wärmelehre, Wärmekraftmaschinen, Entropie und Wahrscheinlichkeit, Diffusion, Transportphänomene)

Literaturhinweise:
W. Demtröder; Experimentalphysik 1 (Springer, Heidelberg 4. Aufl. 2006)
D. Meschede; Gerthsen Physik (Springer, Heidelberg 23. Aufl. 2006)

Modul: Physik I (Mechanik, Wärmelehre)

Modul-Nr.: physik110

Lehrveranstaltung: Praktikum Mechanik, Wärmelehre

LV-Nr.: physik112

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	3	3	SS

Zulassungsvoraussetzungen:
Teilnahme an Physik I (physik111). Das heißt: erfolgreiche Teilnahme an den Übungen plus Anmeldung zur Modulteilprüfung physik111

Empfohlene Vorkenntnisse:
Grundlagen der statistischen Datenauswertung

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Bearbeitung der Versuchsprotokolle, mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit)

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten. Erarbeitung von Versuchsprotokollen.

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.

6 Versuche im Praktikum zur Mechanik und Wärmelehre/Zeitaufwand pro Versuch: Vorbereitung ~8 Std., Durchführung ~ 4 Std., Protokollanfertigung ~ 2 Std.
Auswahl: Einführungsversuch "Was ist ein Praktikum"; Elastizitätskonstanten; Biegung und Knickung; Schwingungen; freie und erzwungene Schwingungen (Pohlsches Drehpendel);Trägheitsmoment und physisches Pendel; spezifische Wärmekapazität; Adiabatenkoeffizient; statistische Schwankungen;

Literaturhinweise:
Versuchsanleitungen: http://pi.physik.uni-bonn.de/~aprakt/
W. Walcher; Praktikum der Physik (Teubner, Wiesbaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel; E. Lohrmann; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999)
S. Brandt; Datenanalyse (Spektrum Akademischer Vlg., Heidelberg 4. Aufl. 1999)
E.W. Otten: Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Westphal; Physikalisches Praktikum (Vieweg); Titel vergriffen, aber in der ULB vorhanden
Kohlrausch; Praktische Physik Bd. 1-3 (Teubner, Wiesbaden) Titel vergriffen, aber in der ULB vorhanden

Modul-Nr.: physik120
Leistungspunkte: 8*
Kategorie: Wahlpflicht
Semester: 1.-4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Einführungsveranstaltungen anderer Fächer

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Veranstaltungen in Astronomie	astro121-123	4+4	s. Katalog	240 Std.	WS+SS
2.	Veranstaltungen in Informatik	siehe Liste	8	s. Liste	240 Std.	WS
3.	Veranstaltungen in Meteorologie	siehe Liste	6+2	s. Liste	240 Std.	WS+SS
4.	Veranstaltungen in Chemie	siehe Liste	8	s. Liste	240 Std.	WS
5.	Veranstaltungen in VWL/BWL	siehe Liste	7,5 **	s. Liste	240 Std.	WS/SS
6.	Veranstaltungen in Philosophie	siehe Liste	8	s. Liste	240 Std.	WS

Zulassungsvoraussetzungen:
gemäß gewähltem Modul

Empfohlene Vorkenntnisse:
gemäß gewähltem Modul

Inhalt:
Einführende Lehrveranstaltungen aus anderen Fächern ermöglichen es den Studierenden, Grundlagenwissen in anderen wissenschaftlichen Bereichen zu erwerben. Inhalt und Umfang des Moduls werden durch das jeweilige Fach definiert

Lernziele/Kompetenzen:
Die Studierenden sollen elementare Grundlagen aus anderen Wissensbereichen erarbeiten, um Verständnis für interdisziplinäre Fragestellungen zu erwerben. Sie sollen mit Sachverstand über die Bereiche berichten können

Prüfungsmodalitäten:
gemäß gewähltem Modul

Dauer des Moduls: 1 oder 2 Semester

Max. Teilnehmerzahl:

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

* Die Leistungspunkte müssen in einem Fach erworben werden
** Wird für B.Sc. als 8 LP angerechnet

Liste der „Einführungslehrveranstaltungen anderer Fächer“:

Astronomie:
(1) Einführung in die Astronomie, (Vorlesung, Übung)
(2) Einführung in die extragalaktische Astronomie, (Vorlesung, Übung)
(3) Einführung in die Radioastronomie, (Vorlesung, Übung, Praktikum)

Informatik:
(1) Informationssysteme, (Vorlesung, Übung)
(2) Technische Informatik, (Vorlesung, Übung)
(3) Algorithmen und Programmierung, (Vorlesung, Übung)

Meteorologie:
(1) Einführung in die Meteorologie 1, (Vorlesung, Übung)
(2) Einführung in die Meteorologie 2, (Vorlesung, Übung)

Chemie:
(1) Experimentelle Einführung in die Anorganische und Allgemeine Chemie, (Vorlesung, Seminar)

Volkswirtschaftslehre/ Betriebswirtschaftslehre:
(1) Grundzüge der Volkswirtschaftslehre (Vorlesung, Übung, 7,5 LP)
(2) Grundzüge der BWL: Einführung in die Theorie der Unternehmung, (Vorlesung, Übung, 7,5 LP)
(3) Grundzüge der BWL: Investition und Finanzierung, (Vorlesung, Übung, 7,5 LP)
(4) Finanzmärkte und -institutionen, (Vorlesung, Übung, 7,5 LP)

Philosophie:
(1) Logik und Grundlagen ZF, (eine Vorlesung, ein Tutorium, Klausur, 8 LP)
(2) Erkenntnistheorie ZF, (eine Vorlesung, ein Tutorium, Klausur, 8 LP)
(3) Wissenschaftsphilosophie ZF, (eine Vorlesung, ein Tutorium, Klausur, 8 LP)

Modul: Einführungsveranstaltungen anderer Fächer

Modul-Nr.: physik120

Lehrveranstaltung: Einführung in die Astronomie

LV-Nr.: astro121

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Vorlesung mit Übungen	deutsch	2+1	4	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden werden an die stellare Astronomie herangeführt. Sie lernen die Probleme der Entfernungsbestimmung in der Astronomie kennen und erwerben Kenntnisse über Sterne und Sternentwicklung, einschließlich Phänomene in den Endphasen, wie Planetarische Nebel, Supernovaexplosionen und Schwarze Löcher. Man wird in die Lage versetzt, die Grundlagen der stellaren Astronomie einem Laien zu erklären

Inhalte der LV:
Teleskope, Instrumente, Detektoren; Himmelsmechanik; Himmel, Planetensystem, Kometen, Meteore; Sonne und Erdklima; Planck-Funktion, Photometrie, Sterne, Entfernungsbestimmung der Sterne, Hertzsprung-Russell-Diagramm; Sternatmosphäre; Sternaufbau und Sternentwicklung, Kernfusionsprozesse; Variable Sterne; Doppelsterne; Sternhaufen und Altersbestimmung; Endstadien der Sterne; Messgeräte der anderen Wellenlängenbereiche; Interstellares Medium, ionisiertes Gas, neutrales Gas und Molekülwolken mit Sternentstehung, heiße Phase

Literaturhinweise:
Skriptum zur Vorlesung; Astronomie (PAETEC Verlag, ISBN 3-89517-798-9)

Modul: Einführungsveranstaltungen anderer Fächer

Modul-Nr.: physik120

Lehrveranstaltung: Einführung in die extragalaktische Astronomie

LV-Nr.: astro122

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Vorlesung mit Übungen	deutsch	2+1	4	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Einführung in die Astronomie

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Studierende sollen die extragalaktische Astronomie in ihrer Breite kennen lernen, werden an die Schwerpunkte der aktuellen Forschung herangeführt und sollen in die Lage versetzt werden, astrophysikalische Zusammenhänge auch für Laien verständlich darzustellen. Durch die Diskussion der Dunklen Materie und der Dunklen Energie werden auch zentrale Fragen der fundamentalen Physik angesprochen

Inhalte der LV:
Struktur der Galaxis: Scheibe, Bulge, Halo; Rotation der Galaxis, Entfernung zum Zentrum; Dunkle Materie; Spiralgalaxien und ihre Strukturen; Elliptische Galaxien und ihre stellare Populationen; Aktive Galaxien; Quasare; Galaxienhaufen, großskalige Strukturen im Universum; Gravitationslinsen; Bestimmung des Anteils an Dunkler Materie; Kosmologie, Expansion des Universums, Bestimmung der Entfernungen weit entfernter Objekte; Urknall, Kosmische Hintergrundstrahlung, kosmologische Parameter

Literaturhinweise:
Skriptum zur Vorlesung
P. Schneider, Einführung in die Extragalaktische Astronomie und Kosmologie (Springer Verlag, Heidelberg 2005)

Modul: Einführungsveranstaltungen anderer Fächer

Modul-Nr.: physik120

Lehrveranstaltung: Einführung in die Radioastronomie

LV-Nr.: astro123

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Vorlesung mit Übungen und Praktikum	deutsch	2+1	4	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Einführung in die Astronomie I + II (astro121, 122), Physik I-III (Physik 110, 210, 310)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (mündliche Prüfung oder Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis der Grundlagen der radioastronomischen Beobachtungstechnik und der wesentlichen astrophysikalischen Prozesse

Inhalte der LV:
Vorlesung:
Radioastronomische Empfangstechnik (Teleskope, Empfänger und Detektoren), atmosphärische Fenster, Strahlungstransport, Radiometergleichung, statistische Prozesse in der Signalerkennung, interstellares Medium, HI 21-cm Linienstrahlung, Sternentstehung in Molekülwolken, kontinuierliche Strahlungsprozesse, Maser, Radiogalaxien, Entwicklung der Galaxien im Universum, Pulsare, Physik in starken Gravitationsfeldern, Epoche der Re-Ionisation, frühes Universum, Zukunftsprojekte der Radioastronomie

Ergänzendes, optionales Praktikum (1 bis 2 tägig am Observatorium):
Eichung eines radioastronomischen Empfängers, Messung der HI 21-cm Linienstrahlung, Ableitung der Spiralstruktur der Milchstraße, Messung der kontinuierlichen Strahlung der Milchstraße, Messung und Analyse eines Pulsarsignals

Literaturhinweise:
Folien der Vorlesung werden zur Verfügung gestellt.

On-line material: http://www.cv.nrao.edu/course/astr534/ERA.shtml

Dieses Modul kann anstelle von astro122 anerkannt werden.

Modul-Nr.: physik130
Leistungspunkte: 4
Kategorie: Pflicht
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Einführung in die EDV

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	EDV für Physiker und Physikerinnen	physik131	4	Vorl. + Üb.	120 Std.	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Inhalt:
Rechner, Betriebssysteme, Programmpakete, C++, HTML, Webrecherchen

Lernziele/Kompetenzen:
Die Studierenden erhalten eine Einführung in die Funktionsweise von Rechnern und in die elektronische Datenverarbeitung, um geeignete Software auf sinnvolle Weise einsetzen zu können

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Abschlussbericht oder Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Einführung in die EDV

Modul-Nr.: physik130

Lehrveranstaltung: EDV für Physiker und Physikerinnen

LV-Nr.: physik131

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	1+2	4	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Abschlussbericht oder Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen mit Betriebssystemen vertraut gemacht werden, moderne Editierprogramme kennen lernen, gezielt lernen Webrecherchen durchzuführen und erste Schritte mit einer Programmiersprache machen. Die Lehrveranstaltung ist praxisbezogen und liefert damit eine solide Grundlage für den Umgang mit Rechnern im weiteren Studium

Inhalte der LV:
Betriebssysteme: Linux, UNIX; Editierprogramme: emacs, vi; LaTeX, TeX; Postscript, ghostview, PDF; Algebrasysteme: Maple, Mathematica; Programmiersprache: C++; Plotprogramme: gnuplot, root; shellscripts; Tabellenkalkulation; Web: effiziente Recherchen, Deutung von Webadressen, Einblick in HTML

Literaturhinweise:
Es werden kompakte Anleitungen zur Verfügung gestellt

Modul-Nr.: math140
Leistungspunkte: 13
Kategorie: Pflicht
Semester: 1.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mathematik I für Physiker und Physikerinnen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Mathematik I (für Physiker und Physikerinnen)	math141	13	Vorl. + Üb.	390 Std.	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Inhalt:
Lineare Algebra:
reelle und komplexe Zahlen, elementare Gruppentheorie, Vektorräume, Skalarprodukt, lineare Gleichungssysteme, Matrizen, Determinante, Eigenwerte, Diagonalisierung symmetrischer Matrizen (Hauptachsentransformation), geometrische Interpretation
Analysis:
Folgen und Reihen, Differentiation und Integration von Funktionen einer Veränderlichen. Gewöhnliche Differentialgleichungen, lineare Differentialgleichungssysteme und deren allgemeine Lösung, einige spezielle Lösungen. Differentiation von Funktionen mehrerer Veränderlichen.

Lernziele/Kompetenzen:
Vermittlung der mathematischen Grundbegriffe und Methoden; erforderlich für die Vorlesungen nach dem 1. Semester

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Mathematik I für Physiker und Physikerinnen

Modul-Nr.: math140

Lehrveranstaltung: Mathematik I (für Physiker und Physikerinnen)

LV-Nr.: math141

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	6+3 *	13	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Vermittlung der mathematischen Grundbegriffe und Methoden; erforderlich für die Vorlesungen nach dem 1. Semester

Inhalte der LV:
Lineare Algebra:
reelle und komplexe Zahlen, elementare Gruppentheorie, Vektorräume, Skalarprodukt, lineare Gleichungssysteme, Matrizen, Determinante, Eigenwerte, Diagonalisierung symmetrischer Matrizen (Hauptachsentransformation), geometrische Interpretation
Analysis:
Folgen und Reihen, Differentiation und Integration von Funktionen einer Veränderlichen. Gewöhnliche Differentialgleichungen, lineare Differentialgleichungssysteme und deren allgemeine Lösung, einige spezielle Lösungen. Differentiation von Funktionen mehrerer Veränderlichen.

Literaturhinweise:
G.B. Arfken, H.J. Weber; Mathematical Methods for Phycisists (Academic Press 6. Aufl. 2005)
S. Hassani; Mathematical Physics (Springer; New York 1999)
G. Fischer; Lineare Algebra, Eine Einführung für Studienanfänger (Vieweg Wiesbaden, 15. Aufl. 2005)
O. Forster; Analysis I (Vieweg Wiesbaden 2004)

* Diese Lehrveranstaltung kann auch als 4-stündige Vorlesung mit 3-stündigen Übungen angeboten werden und einer 2-stündigen Ergänzung durch einen anderen Dozenten der Mathematik oder der theoretischen Physik.

Modul-Nr.: physik210
Leistungspunkte: 10
Kategorie: Pflicht
Semester: 2.-3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik II (Elektromagnetismus)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik II (Elektromagnetismus)	physik211	7	Vorl. + Üb.	210 Std.	SS
2.	Praktikum Elektromagnetismus	physik212	3	Praktikum	90 Std.	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I (physik110)

Inhalt:
Elektromagnetismus: Elektrostatik, elektrische Leitung, magnetische Wechselwirkung, Materie in Feldern, Elektromagnetische Wellen, Maxwell-Gleichungen. Dazu 6 Praktikumsversuche

Lernziele/Kompetenzen:
Einarbeitung in die Phänomene von Elektrizitätslehre und Magnetismus, elektromagnetische Wellen und damit verwandte Phänomene. Dazu 6 Praktikumsversuche.

Prüfungsmodalitäten:
physik211: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen
physik212: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Bearbeitung der Versuchsprotokolle, mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer des Moduls: 2 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Physik II (Elektromagnetismus)

Modul-Nr.: physik210

Lehrveranstaltung: Physik II (Elektromagnetismus)

LV-Nr.: physik211

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I (physik110)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung):
erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die zweite Grundvorlesung Experimentalphysik behandelt im ersten Teil die elektrischen Phänomene in Experimenten und in elementarer theoretischer Betrachtung. Im zweiten Teil werden die elektromagnetischen Wechselwirkungen bis zu elektromagnetischen Wellen behandelt, um schließlich die vollständigen Maxwell-Gleichungen zu behandeln, auch in Vorbereitung auf die theoretischen Vorlesungen zur Elektrodynamik.

Inhalte der LV:
Elektromagnetismus, Vergleich mit Gravitation. Elektrostatik (Ladung, Coulomb-Gesetz, Feld, Dipol, elektrische Struktur der Materie, Fluss, Gauß-Gesetz, Poisson-Gleichung, Ladungsverteilung, Kapazität). Elektrische Leitung (Stromdichte, Ladungserhaltung, Ohmsches Gesetz, Rotation des Vektorfeldes, Stokes-Satz, Stromkreise, Kirchhoff-Gesetze, Leitungsmechanismen). Magnetische Wechselwirkung, (Magnetismus als relativistischer Effekt, Magnetfeld, stationäre Maxwell-Gleichungen, Lorentz-Kraft, Hall-Effekt, Magnetdipol, Vektorpotential, Biot-Savart-Gesetz). Materie in stationären Feldern (induzierte und permanente Dipole, Dielektrikum, Verschiebungsfeld, elektrische Polarisation, magnetische Dipole, magnetisiertes Feld H, Magnetisierungsfeld, Verhalten an Grenzflächen). Zeitabhängige Felder (Induktion, Maxwellscher Verschiebungsstrom, technischer Wechselstrom, Schwingkreise, Hochfrequenz-Phänomene, Abstrahlung, freie EM-Wellen, Hertz-Dipol, Polarisation, Reflexion). Vollständige Maxwell-Gleichungen, Symmetrie zwischen elektrischen und magnetischen Feldern.

Literaturhinweise:
W. Demtröder; Experimentalphysik 2 (Springer, Heidelberg 4. Aufl. 2006)
D. Meschede; Gerthsen Physik (Springer, Heidelberg 23. Aufl. 2006)
W. Otten, Repetitorium der Experimentalphysik (Springer Verlag, Heidelberg 2. Aufl. 2002)
P. Tipler, Physik (Spektrum Akad. Verlag, Heidelberg 2. Aufl. 2004)

Modul: Physik II (Elektromagnetismus)

Modul-Nr.: physik210

Lehrveranstaltung: Praktikum Elektromagnetismus

LV-Nr.: physik212

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	3	3	WS

Zulassungsvoraussetzungen:
Teilnahme an Physik II (physik211). Das heißt: erfolgreiche Teilnahme an den Übungen plus Anmeldung zur Modulteilprüfung physik211

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung):
erfolgreiche Bearbeitung der Versuchsprotokolle, mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit)

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten. Anfertigen von Versuchsprotokollen

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
6 Versuche im Praktikum zum Elektromagnetismus/ Zeitaufwand pro Versuch: Vorbereitung ~8 Std., Durchführung ~ 4 Std., Protokollanfertigung ~ 2 Std.

Auswahl:
Gleichströme; Spannungsquellen; Widerstände; elektrolytischer Trog; Galvanometer und gedämpfte Schwingungen; Wechselstromwiderstände und Phasenschieber; Transformator; RC-Glieder; Schwingkreis; harmonische Analyse einer Rechteckspannung; Hysteresemessung der Magnetisierung von Eisen; magnetische Kraftwirkung auf Elektronen; Fadenstrahlrohr.

Literaturhinweise:
Versuchsanleitungen: http://pi.physik.uni-bonn.de/~aprakt/
W. Walcher; Praktikum der Physik (Teubner, Wiebaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel, E. Lohrmann; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999)
S. Brandt; Datenanalyse (Spektrum Akademischer Vlg., Heidelberg 4. Aufl. 1999)
E.W. Otten; Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Westphal; Physikalisches Praktikum (Vieweg) Titel vergriffen, aber in der ULB vorhanden
Kohlrausch; Praktische Physik Bd. 1-3 (Teubner, Wiesbaden) Titel vergriffen, aber in der ULB vorhanden

Modul-Nr.: physik220
Leistungspunkte: 9
Kategorie: Pflicht
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik I (Mechanik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik I (Mechanik)	physik221	9	Vorl. + Üb.	270 Std.	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I für Physiker (math140), Physik I (physik110)

Inhalt:
Newtonsche Mechanik, starrer Körper, Lagrange-, Hamilton- und Jacobi-Formalismus

Lernziele/Kompetenzen:
Umgang mit Konzepten und Rechenmethoden der Klassischen Mechanik

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Theoretische Physik I (Mechanik)

Modul-Nr.: physik220

Lehrveranstaltung: Theoretische Physik I (Mechanik)

LV-Nr.: physik221

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	9	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I für Physiker (math140), Physik I (physik110)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Umgang mit Konzepten und Rechenmethoden der Klassischen Mechanik

Inhalte der LV:
Newtonsche Mechanik
Zentralkraftproblem
Mechanik des starren Körpers
Lagrangeformalismus
Symmetrien und Erhaltungssätze
Hamiltonformalismus
Hamilton/Jacobi-Gleichung

Literaturhinweise:
T. Fließbach; Lehrbuch der Theoretischen Physik 1: Mechanik (Spektrum Akademischer Vlg., Heidelberg 4. veränd. Aufl. 2003)
F. Kuypers; Klassische Mechanik (Wiley-VCH, Weinheim 7. erw. Aufl. 2005)
L. Landau; E. Lifschiz; Lehrbuch der Theoretischen Physik Band 1: Mechanik (Harri Deutsch, Frankfurt am Main 14. korr. Aufl. 1997)
W. Nolting; Grundkurs Theoretische Physik 1: Klassische Mechanik (Springer, Heidelberg 7. Nachdruck 2005)
W. Nolting; Grundkurs Theoretische Physik 2: Analytische Mechanik (Springer, Heidelberg korr. Nachdruck 2005)
H. R. Petry, B. Metsch; Theoretische Mechanik (Oldenburg, München 2005)

Modul-Nr.: math240
Leistungspunkte: 11
Kategorie: Pflicht
Semester: 2.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mathematik II für Physiker und Physikerinnen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Mathematik II (für Physiker und Physikerinnen)	math241	11	Vorl. + Üb.	330 Std.	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I für Physiker und Physikerinnen (math140)

Inhalt:
Mehrdimensionale Integration:
Transformationssatz, Integration auf gekrümmten Objekten (Gramsche Determinante), Längenberechnung von Kurven, Flächeninhaltsberechnung von gekrümmten Flächen, Berechnung von Volumina.
Vektoranalysis in drei Dimensionen: grad, rot, div, Gaußscher und Stokesscher Satz, Erhaltungsgrößen, Maxwellgleichungen. Verallgemeinerung auf beliebige Dimension.
Fourieranalysis, Fourierreihen, Fouriertransformation, Hilberträume, vollständige Funktionensysteme

Lernziele/Kompetenzen:
Vermittlung der mathematischen Grundbegriffe und Methoden, erforderlich für die theoretischen Physikvorlesungen nach dem 2. Semester

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Mathematik II für Physiker und Physikerinnen

Modul-Nr.: math240

Lehrveranstaltung: Mathematik II (für Physiker und Physikerinnen)

LV-Nr.: math241

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	11	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I für Physiker und Physikerinnen (math140)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Vermittlung der mathematischen Grundbegriffe und Methoden, erforderlich für die theoretischen Physikvorlesungen nach dem 2. Semester

Inhalte der LV:
Mehrdimensionale Integration:
Transformationssatz, Integration auf gekrümmten Objekten (Gramsche Determinate), Längenberechnung von Kurven, Flächeninhaltsberechnung von gekrümmten Flächen, Berechnung von Volumina.
Vektoranalysis in drei Dimensionen: grad, rot, div, Gaußscher und Stokesscher Satz, Erhaltungsgrößen, Maxwellgleichungen. Verallgemeinerung auf beliebige Dimension.
Fourieranalysis, Fourierreihen, Fouriertransformation, Hilberträume, vollständige Funktionensysteme

Literaturhinweise:
G. B. Arfken, H. J. Weber; Mathematical Methods for Physicists (Academic Press 6. Aufl. 2005)
S. Hassani; Mathematical Physics (Springer; New York 1999)
O. Forster; Analysis II (Vieweg, Wiesbaden 2005)
O. Forster; Analysis III (Vieweg, Wiesbaden 1984)

Modul-Nr.: physik310
Leistungspunkte: 14
Kategorie: Pflicht
Semester: 3.-4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik III (Optik und Wellenmechanik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik III (Optik und Wellenmechanik)	physik311	7	Vorl. + Üb.	210 Std.	WS
2.	Praktikum Optik, Wellenmechanik	physik312	3	Praktikum	90 Std.	WS
3.	Elektronikpraktikum	physik313	4	Praktikum	120 Std.	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - II (physik110, physik210)

Inhalt:
Grundzüge der Optik (Strahlen- und Wellenoptik); Grundzüge der mikroskopischen Physik, Behandlung mit elementarer Wellenmechanik; Laser, Photoeffekte, Stern-Gerlach-Experimente, Manipulation einzelner Teilchen. Dazu 6 Praktikumsversuche

Lernziele/Kompetenzen:
Anwendung der Maxwell-Gleichungen auf optische Phänomene, Einarbeitung in elementare Phänomene der mikroskopischen Physik; erste Kenntnisse über den Widerspruch von klassischer und Quantenphysik

Prüfungsmodalitäten:
physik311: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen
physik312, -313: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Bearbeitung der Versuchsprotokolle, mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer des Moduls: 2 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Physik III (Optik und Wellenmechanik)

Modul-Nr.: physik310

Lehrveranstaltung: Physik III (Optik und Wellenmechanik)

LV-Nr.: physik311

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - II (physik110, physik210)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die dritte Grundvorlesung Experimentalphysik stellt im ersten Teil optische Phänomene in Experimenten und elementarer theoretischer Behandlung als Erweiterung der Elektrizitätslehre dar. Insbesondere die Interferenzphänomene der Wellenlehre bieten eine sehr gute propädeutische Basis, um im zweiten Teil eine Einführung in die mikroskopische Physik mit Hilfe elementarer Wellenfunktionen der Quantenmechanik zu realisieren

Inhalte der LV:
Optik: Strahlenoptik und Matrizenoptik; Abbildungen und Abbildungsfehler; Mikroskop und Teleskop; Wellenoptik; Wellentypen; Gaußstrahlen; Kirchhoffsche Theorie der Beugung; Fraunhofer-Beugung; Fourier-Optik; Brechung und Dispersion; Polarisation und Doppelbrechung; Kohärenz und Zweistrahl-Interferometer; Vielstrahl-Interferometer; Michelson-Interferometer; Holographie, Laser-Speckel;

Wellenmechanik: Wellen- und Teilchenphänomene mit Licht,Wellenpakete, Tunnel-Effekt; Eingesperrte Teilchen, Kastenpotential, Harmonischer Oszillator, Paul-Falle; Meßgrößen in der Quantenphysik; Photo-, Compton-Effekt, Franck-Hertz-Versuch; Rutherford-Experiment; elementares Wasserstoff-Atom; Stern-Gerlach-Experimente; Manipulation einzelner Teilchen

Literaturhinweise:
Hecht, Optik (Oldenbourg-Verlag, München 4. Aufl. 2005)
D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2. überarb. Aufl. 2005)
W. Demtröder; Experimentalphysik 3: Atome, Moleküle und Festkörper (Springer, Heidelberg 2. überarb. Aufl. 2005)
D. Meschede; Gerthsen Physik (Springer, Heidelberg 23. Aufl. 2006)

Modul: Physik III (Optik und Wellenmechanik)

Modul-Nr.: physik310

Lehrveranstaltung: Praktikum Optik, Wellenmechanik

LV-Nr.: physik312

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	3	3	WS

Zulassungsvoraussetzungen:
Teilnahme an Physik III (physik311). Das heißt: erfolgreiche Teilnahme an den Übungen plus Anmeldung zur Modulteilprüfung physik311

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung):
erfolgreiche Bearbeitung der Versuchsprotokolle, mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester (im Blockkurs in der vorlesungsfreien Zeit)

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten; Anfertigung von Versuchsprotokollen

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
6 Versuche im Praktikum zur Optik.
Zeitaufwand pro Versuch: Vorbereitung ~8 Std., Durchführung ~ 4 Std., Protokollanfertigung ~ 2 Std.

Auswahl:
Linsen und optische Instrumente, Dispersion, Brechung, Beugung und Interferenz, Reflexionspolarisation, photoelektrische Bestimmung des Planckschen Wirkungsquantums, Absorption und Streuung

Literaturhinweise:
W. Walcher; Praktikum der Physik (Teubner, Wiebaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel, E. Lohrmann; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999)
S. Brandt; Datenanalyse (Spektrum Akademischer Vlg., Heidelberg 4. Aufl. 1999)
E.W. Otten; Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Westphal; Physikalisches Praktikum (Vieweg) Titel vergriffen, aber in der ULB vorhanden
Kohlrausch; Praktische Physik Bd. 1-3 (Teubner, Wiesbaden) Titel vergriffen, aber in der ULB vorhanden

Modul: Physik III (Optik und Wellenmechanik)

Modul-Nr.: physik310

Lehrveranstaltung: Elektronikpraktikum

LV-Nr.: physik313

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	4	4	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - II (physik110, physik210)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur):
erfolgreiche Bearbeitung der Versuchsprotokolle, mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis und Anwendungen der Grundlagen der Elektronik in der Praxis

Inhalte der LV:
Blockvorlesung und 8 Versuche zur Elektronik. Diese Lehrveranstaltung wird zum Teil in der vorlesungsfreien Zeit durchgeführt.

Ausbreitung von Signalen auf Leitungen
Diode
Transistor
Transistorverstärker
Operationsverstärker
Anwendung des Operationsverstärkers
Computeralgebra
Mikroprozessor

Literaturhinweise:
P. Horowitz, W. Hill; The Art of Electronics (Cambridge University Press, 2. Aufl. 1999)
A. Schlachetzki; Halbleiterelektronik (Teubner, Wiesbaden 1990)
U. Tietze, C. Schenk; Halbleiter-Schaltungstechnik (Springer, Heidelberg 12. Aufl. 2002)
K.-H. Rohe: Elektronik für Physiker: Eine Einführung in analoge Grundschaltungen (Teubner, Wiesbaden 1987)

Modul-Nr.: physik320
Leistungspunkte: 9
Kategorie: Pflicht
Semester: 3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik II (Elektrodynamik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik II (Elektrodynamik)	physik321	9	Vorl. + Üb.	270 Std.	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - II für Physiker (math140, math240)
Theoretische Physik I (physik220)
Physik I - II (physik110, physik210)

Inhalt:
Maxwellgleichungen, Elektro- und Magnetostatik, retardierte Potentiale, Strahlung und Wellen, Elektrodynamik in Medien

Lernziele/Kompetenzen:
Umgang mit Konzepten und Rechenmethoden der Klassischen Elektrodynamik und der Speziellen Relativitätstheorie.

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Theoretische Physik II (Elektrodynamik)

Modul-Nr.: physik320

Lehrveranstaltung: Theoretische Physik II (Elektrodynamik)

LV-Nr.: physik321

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	9	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - II für Physiker (math140, math240)
Theoretische Physik I (physik220)
Physik I - II (physik110, physik210)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Umgang mit Konzepten und Rechenmethoden der Klassischen Elektrodynamik und der Speziellen Relativitätstheorie

Inhalte der LV:
Maxwellgleichungen
Elektro- und Magnetostatik, Poisson- und Laplace-Gleichung, Kugelflächenfunktionen
Elektromagnetische Wellen
spezielle Relativitätstheorie
bewegte Ladungen, retardierte Potentiale
Strahlung, Hertzscher Dipol
kovariante Elektrodynamik
Elektrodynamik in Medien

Literaturhinweise:
T. Fließbach; Lehrbuch der Theoretischen Physik 2: Elektrodynamik (Spektrum Akademischer Verlag, Heidelberg 4. Aufl. 2004)
J. Jackson; Klassische Elektrodynamik (de Gruyter, Berlin 4. überarb. Aufl. 2006)
L. Landau, E. Lifschitz; Lehrbuch der Theoretischen Physik Band 2: Klassische Feldtheorie (Harri Deutsch, Frankfurt am Main 12. überarb. Aufl. 1991)
J.S. Schwinger, L.L. Deraad, K.A. Milton, W.Y. Tsai; Classical Electrodynamics (Perseus Books 1998)

Modul-Nr.: math340
Leistungspunkte: 11
Kategorie: Pflicht
Semester: 3.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mathematik III für Physiker und Physikerinnen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Mathematik III (für Physiker und Physikerinnen)	math341	11	Vorl. + Üb.	330 Std.	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - II für Physiker und Physikerinnen (math140, math240)

Inhalt:
Funktionentheorie:
Potenzreihen, Laurentreihen, Residuensatz, spezielle Funktionen.
Partielle Differentialgleichungen und Variationsrechnung. Harmonische Funktionen, Poissongleichung, Greensche Funktion

Lernziele/Kompetenzen:
Vermittlung der mathematischen Grundbegriffe und Methoden, erforderlich für die Vorlesungen der theoretischen Physik nach dem 3. Semester

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Mathematik III für Physiker und Physikerinnen

Modul-Nr.: math340

Lehrveranstaltung: Mathematik III (für Physiker und Physikerinnen)

LV-Nr.: math341

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	11	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - II für Physiker und Physikerinnen (math140, math240)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Vermittlung der mathematischen Grundbegriffe und Methoden, erforderlich für die - theoretischen - Physikvorlesungen nach dem 3. Semester

Inhalte der LV:
Funktionentheorie: Potenzreihen, Laurentreihen, Residuensatz, spezielle Funktionen.
Partielle Differentialgleichungen + Variationsrechnung. Harmonische Funktionen, Poissongleichung, Green'sche Funktion

Literaturhinweise:
G.B. Arfken, H.J. Weber; Mathematical Methods for Phycisists (Academic Press 6. Aufl. 2005)
S. Hassani; Mathematical Physics (Springer; New York 1999)
R. Remmert, G. Schumacher; Funktionentheorie I (Springer; Berlin 2001)

Modul-Nr.: physik410
Leistungspunkte: 12
Kategorie: Pflicht
Semester: 4.-5.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik IV (Atome, Moleküle, Kondensierte Materie)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik IV (Atome, Moleküle, Kondensierte Materie)	physik411	7	Vorl. + Üb.	210 Std.	SS
2.	Praktikum Atome, Moleküle, Kondensierte Materie	physik412	5	Praktikum	150 Std.	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - III (physik110, physik210, physik310)
Theoretische Physik I - II (physik220, physik320)

Inhalt:
Grundzüge der Atom- und Molekülphysik: Historische Entwicklung, Wasserstoffatom, Quantenmechanik des Wasserstoffatoms, Mehrelektronenatome, Periodensystem derr Elemente, zweiatomige Moleküle, Wechselwirkung zwischen Licht und Atomen
Grundzüge der Festkörperphysik: Kristallstrukturen, Gitterschwingungen, Elektronen in periodischen Potentialen, elektrische und magnetische Eigenschaften von Festkörpern

Lernziele/Kompetenzen:
Es soll ein Verständnis der elektronischen Struktur der Materie auf atomarer und molekularer Ebene sowie der Struktur von allgemein festen Materialien und von Halbleitern erlangt werden

Prüfungsmodalitäten:
physik411: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen
physik412: Zulassungsvoraussetzung zur Modulteilprüfung (Versuchsprotokoll): erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer des Moduls: 2 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Physik IV (Atome, Moleküle, Kondensierte Materie)

Modul-Nr.: physik410

Lehrveranstaltung: Physik IV (Atome, Moleküle, Kondensierte Materie)

LV-Nr.: physik411

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - III (physik110, physik210, physik310); Theoretische Physik I - II (physik220, physik320)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die vierte Grundvorlesung Experimentalphysik präsentiert eine Einführung in die Struktur der elektronisch dominierten Materie, wobei ein Bogen geschlagen wird von den atomaren Modellsystemen über die Grundzüge der Chemie zur Festkörperphysik und kondensierten Materie

Inhalte der LV:
Atome: Aufbau der Atome, Einelektronen-, Rydberg-Atome; Feinstruktur, LS-Kopplung, Atome in Magnetfeldern; Der Einfluß des Atomkerns, Isotopen-Effekte, Hyperfeinstrukturen; Mehr-Elektronen-Atom, Das periodische System der Elemente; Atomare Quantenzahlen; Röntgenstrahlung von Atomen;

Moleküle: Zweiatomige Moleküle: Born-Oppenheimer-Näherung; Molekulare Bindung; Vibrationen, Normalkoordinaten von Molekülen; Rotationsstruktur von Molekülen;

Kondensierte Materie: Kristallstrukturen, Strukturanalyse, Bindungstypen; Phononen, Dispersionsrelation, spezifische Wärme; freies Elektronengas; Bandstruktur, elektrische Eigenschaften von Festkörpern

Literaturhinweise:
W. Demtröder; Experimentalphysik 3: Atome, Moleküle und Festkörper (Springer, Heidelberg 3. überarb. Aufl. 2005)
H. Ibach, H. Lüth; Festkörperphysik (Springer Heidelberg 6. Aufl. 2002)
H. Haken, H.C. Wolf; Atom- und Quantenphysik (Springer, Heidelberg 8. aktual. u. erw. Aufl. 2003)
C. Kittel; Einführung in die Festkörperphysik (R. Oldenbourg Vlg., München 14. Aufl. 2005)

Modul: Physik IV (Atome, Moleküle, Kondensierte Materie)

Modul-Nr.: physik410

Lehrveranstaltung: Praktikum Atome, Moleküle, Kondensierte Materie

LV-Nr.: physik412

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	5	5	WS

Zulassungsvoraussetzungen:
Teilnahme an Physik IV (physik411). Das heißt: erfolgreiche Teilnahme an den Übungen plus Anmeldung zur Modulteilprüfung physik411

Empfohlene Vorkenntnisse:
Physik I - III (physik110, physik210, physik310)
Theoretische Physik I - II (physik220, physik320)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Versuchsprotokolle): erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit oder im Blockkurs in der vorlesungsfreien Zeit)

Lernziele der LV:
Verständnis der Grundlagen der Experimente der Atomphysik und der kondensierten Materie. Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten.

Inhalte der LV:
Vorbereiten auf physikalische Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
5 ausgewählte Versuche im Praktikum zur Atomphysik und kondensierten Materie.
Zeitaufwand pro Versuch: Vorbereitung ~14 Std., Durchführung 8 Std., Protokollanfertigung 8 Std.

Auswahl:
Balmerserie, Frank-Hertz-Versuch, optisches Pumpen. Hyperfeinstruktur, Zeeman-Effekt, Compton-Effekt, Hall-Effekt in Halbleitern, Rastertunnelmikroskopie, u. a.

Literaturhinweise:
C. Kittel; Einführung in die Festkörperphysik (R. Oldenbourg Vlg., München 14. Aufl. 2005)
L. Bergmann, C. Schaefer; Lehrbuch der Experimentalphysik Bd. 6: Festkörperphysik (de Gruyter, Berlin 2. Aufl. 2005)
H. Haken, H.C. Wolf; Atom- und Quantenphysik (Springer, Heidelberg 8. Aufl. 2003)
T. Mayer-Kuckuk; Atomphysik (Teubner, Wiesbaden 5. Aufl. 1997)

Modul-Nr.: physik420
Leistungspunkte: 11
Kategorie: Pflicht
Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik III (Quantenmechanik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik III (Quantenmechanik)	physik421	11	Vorl. + Üb.	330 Std.	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - III für Physiker (math140, math240, math340)
Theoretische Physik I - II (physik220, physik320)
Physik I - III (physik110, physik210, physik310)

Inhalt:
Schrödinger-Gleichung, Operatoren, Hilbert-Raum, harmonischer Oszillator, Wasserstoffatom, Störungstheorie

Lernziele/Kompetenzen:
Fähigkeit zur Lösung von Problemen der nichtrelativistischen Quantenmechanik

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Theoretische Physik III (Quantenmechanik)

Modul-Nr.: physik420

Lehrveranstaltung: Theoretische Physik III (Quantenmechanik)

LV-Nr.: physik421

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	11	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - III für Physiker (math140, math240, math340)
Theoretische Physik I - II (physik220, physik320)
Physik I - III (physik110, physik210, physik310)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Fähigkeit zur Lösung von Problemen der nichtrelativistischen Quantenmechanik

Inhalte der LV:
Schrödinger-Gleichung, einfache Potentialprobleme, harmonischer Oszillator
Formale Grundlagen, Operatoren auf Hilberträumen, Unschärferelation
Theorie des Drehimpulses, sphärisch-symmetrische Potentiale, Wasserstoffatom
Theorie des Spins, Drehimpulskopplung
stationäre Störungstheorie
Mehrelektronensysteme, Pauliprinzip, Heliumatom, Periodensystem
zeitabhängige Störungstheorie: elektromagnetische Übergänge, Goldene Regel

Literaturhinweise:
S. Gasiorowicz; Quantenphysik (R. Oldenbourg Vlg., München 9. erw. u. überarb. Aufl. 2005)
L. Landau, E. Lifschitz; Lehrbuch der Theoretischen Physik Band : Quantenmechanik (Harri Deutsch, Frankfurt am Main 9. bearb. Aufl. 1992)
W. Nolting; Grundkurs Theoretische Physik 5: Quantenmechanik Teil 1: Grundlagen (Springer, Heidelberg 4. verb. Aufl. 2000)
W. Nolting; Grundkurs Theoretische Physik 5: Quantenmechanik Teil 2: Methoden und Anwendungen (Springer, Heidelberg 3. verb. Aufl. 2000)
F. Schwabl; Quantenmechanik (QMI) (Springer, Heidelberg 6. korr. Nachdruck 2004)
J.J. Sakurai; Modern Quantum Mechanics (Addison-Wesley, 1995)
R. Shankar; Principles of Quantum Mechanics (Kluwer 1994)

Modul-Nr.: physik440
Leistungspunkte: 6
Kategorie: Pflicht
Semester: 4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Numerische Methoden der Physik

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Numerische Methoden der Physik	physik441	6	Vorl. + Üb.	180 Std.	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - III (physik110, physik210, physik310), Lineare Algebra, Analysis.

Inhalt:
Rechengenauigkeit, numerische und algorithmische Fehler, Programmiersprache C, Makefiles, numerische Bibliotheken, Software für Visualisierung wissenschaftlicher Daten; Lösung wissenschaftlicher Probleme mit numerischen Methoden: Lösung von Differentialgleichungen, Nullstellensuche, Fast Fourier Transform, Faltung, Numerische Integration; Minimierungsprobleme

Lernziele/Kompetenzen:
Fähigkeit, eine Programmiersprache auf wissenschaftliche Problemlösungen anzuwenden. Vorbereitung für Software-Entwicklung auch in nicht-universitären Bereichen.

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): Erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Numerische Methoden der Physik

Modul-Nr.: physik440

Lehrveranstaltung: Numerische Methoden der Physik

LV-Nr.: physik441

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	2+2	6	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - III (physik110, physik210, physik310), Lineare Algebra, Analysis

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): Erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Fähigkeit, eine Programmiersprache auf wissenschaftliche Problemlösungen anzuwenden. Vorbereitung für Software-Entwicklung auch in nicht-universitären Bereichen.

Inhalte der LV:
Rechengenauigkeit, numerische und algorithmische Fehler, Programmiersprache C, Makefiles, numerische Bibliotheken, Software für Visualisierung wissenschaftlicher Daten; Lösung wissenschaftlicher Probleme mit numerischen Methoden: Lösung von Differentialgleichungen, Nullstellensuche, Fast Fourier Transform, Faltung, Numerische Integration; Minimierungsprobleme

Literaturhinweise:
Lecture Notes
W.H. Press et al.; Numerical Recipes in C (Cambridge University Press, 1992)

Modul-Nr.: physik450
Leistungspunkte: 6
Kategorie: Wahlpflicht
Semester: 4.-6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Wahlpflichtmodul

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	siehe umseitige Liste	siehe umseitige Liste	6/7*	Vorl. + Üb.	180 Std./ 210 Std.	WS/SS
2.	Projektpraktikum Physik	physik458	6	Praktikum	180 Std.	WS/SS
3.	Betriebspraktikum	physik459	6	Praktikum	180 Std.	WS/SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Lehrveranstaltungen des 1.-3. Semesters

Inhalt:
A. Vorlesungen aus den Bereichen Experimentalphysik (Teilchenphysik, Kondensierte Materie & Photonik), Theoretische Physik, Astronomie/Astrophysik. Siehe dazu die gesonderte Anleitung.
B. Betriebspraktikum

Lernziele/Kompetenzen:
Mit den Wahlpflichtvorlesungen wird die Möglichkeit eröffnet, den Stoff des Pflichtkanons mit einer ausgewählten, fortgeschrittenen Lehrveranstaltung zu ergänzen; zum Teil dienen sie der Vorbereitung auf das Masterstudium. Alternativ kann im Betriebspraktikum Erfahrung mit der Arbeit in der Industrie oder in einer anderen Institution, in der physikalische Kenntnisse erforderlich sind, gesammelt werden

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur, mündliche Prüfung oder schriftlicher Bericht): erfolgreiche Teilnahme an den Übungen/Praktikum

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

* Wird für B.Sc. als 6 LP angerechnet

Eine Veranstaltung aus:

physics611: Particle Physics
physics612: Accelerator Physics
physics613: Condensed Matter Physics
physics615: Theoretical Particle Physics
physics616: Theoretical Hadron Physics
physics617: Theoretical Condensed Matter Physics
physics618: Physics of Particle Detectors
physics620: Advanced Atomic, Molecular, and Optical Physics

physics631: Quantum Optics
physics632: Physics of Hadrons
physics633: High Energy Collider Physics
physics634: Magnetism/Superconductivity
physics641: Photonics
physics642: Quantum Technology

physics606: Advanced Quantum Theory
physics751: Group Theory
physics754: General Relativity and Cosmology
physics755: Quantum Field Theory

astro608: Theoretical Astrophysics

astro811: Stars and Stellar Evolution
astro812: Cosmology
astro821: Astrophysics of Galaxies
astro822: Physics of the Interstellar Medium

Nähere Informationen dazu finden Sie in den Modulhandbüchern Master of Science Physik bzw. Master of Science Astrophysik der Fachgruppe Physik/Astronomie.

Stand: Sommersemester 2015

Modul: Wahlpflichtmodul

Modul-Nr.: physik450

Lehrveranstaltung: Projektpraktikum Physik

LV-Nr.: physik458

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Praktikum	deutsch	6	6	WS/SS

Zulassungsvoraussetzungen:
Erfolgreiche Teilnahme an physik260 und physik360

Empfohlene Vorkenntnisse:
physik110, physik210, physik310

Studien- und Prüfungsmodalitäten:
Führen eines Laborbuches, erfolgreiche Bearbeitung des Projekts, Posterpräsentation und Diskussion

Dauer der Lehrveranstaltung:
1 Semester (während Vorlesungszeit und evtl. vorlesungsfreier Zeit)

Lernziele der LV:
Einüben des experimentell-wissenschaftlichen Prozesses anhand ausgewählter (kleiner) Projekte. Dies beinhaltet u. a. eine "Forschungsfrage" zu formulieren, entsprechende Fachliteratur zu finden und zu verstehen, ein adäquates Versuchsdesign zu entwickeln, den entwickelten Versuch durchzuführen, Daten zu nehmen und auszuwerten, Ergebnisse zu dokumentieren und zu diskutieren. Grundlegend dafür sind entsprechende Fachkenntnisse.

Inhalte der LV:
Die Studenten identifizieren experimentelle Themen, die sie bearbeiten möchten und entwickeln einen Projektplan in Abstimmung mit der Praktikumsleitung, um die abgesprochenen Versuche zu entwickeln und durchzuführen. Die Themen sollen einen Bezug zu physikalischen Fragestellungen der experimentellen Vorlesungen des Bachelorstudiengangs (Physik 1 – Physik 5) haben. Physikalische Versuche werden entwickelt und durchgeführt. Die Ergebnisse werden in einer Posterpräsentation dem gesamten Kurs vorgestellt und diskutiert.

Literaturhinweise:

Modul: Wahlpflichtmodul

Modul-Nr.: physik450

Lehrveranstaltung: Betriebspraktikum

LV-Nr.: physik459

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Praktikum	deutsch	n.a.	6	WS/SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Lehrveranstaltungen des 1.-3. Semesters

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (schriftlicher Bericht): erfolgreiche Teilnahme am Praktikum

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Der Studierende soll in einem Praktikum in einem Industriebetrieb oder in einer Institution, in der physikalische Kenntnisse erforderlich sind, erste praktische Erfahrungen sammeln

Inhalte der LV:
Sammeln erster berufsnaher Erfahrungen in einem Betrieb der öffentlichen Hand oder der Wirtschaft.
Verfassen eines Erfahrungsberichtes

Literaturhinweise:

Die Durchführung eines Betriebspraktikums muss von den Studierenden in Eigeninitiative realisiert werden. Die Fachgruppe Physik/Astronomie kann Praktikumsplätze nicht garantieren

Modul-Nr.: physik510
Leistungspunkte: 12
Kategorie: Pflicht
Semester: 5.-6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik V (Kerne und Teilchen)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik V (Kern- und Teilchenphysik)	physik511	7	Vorl. + Üb.	210 Std.	WS
2.	Praktikum Kern- und Teilchenphysik	physik512	5	Praktikum	150 Std.	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - IV (physik110, physik210, physik310, physik410)
Theoretische Physik I - III (physik220, physik320, physik420)

Inhalt:
Aufbau und Physik der Atomkerne, Physik der Elementarteilchen, Beschleuniger und Detektoren, grundlegende Experimente

Lernziele/Kompetenzen:
Verständnis der Grundlagen der Kernphysik und der Elementarteilchenphysik sowie der Experimente, die zu dem derzeitigen Stand der Erkenntnis geführt haben

Prüfungsmodalitäten:
physik511: Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung):
erfolgreiche Teilnahme an den Übungen
physik512: Zulassungsvoraussetzung zur Modulteilprüfung (Versuchsprotokolle):
erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer des Moduls: 2 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Physik V (Kerne und Teilchen)

Modul-Nr.: physik510

Lehrveranstaltung: Physik V (Kern- und Teilchenphysik)

LV-Nr.: physik511

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+2	7	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Physik I - IV (physik110, physik210, physik310, physik410)
Theoretische Physik I - III (physik220, physik320, physik420)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Klausur oder mündliche Prüfung): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis der Grundlagen der Kernphysik und der Elementarteilchenphysik sowie der Experimente, die zu dem derzeitigen Stand der Erkenntnis geführt haben

Inhalte der LV:
Nukleonen und Kernaufbau, Isotope und Stabilität, Fermigas und Tröpfchenmodell, Schalenmodell, alpha-, beta- und gamma-Zerfall, Kernspaltung, Kernfusion, grundlegende Experimente der Kernphysik, Elementarteilchen, Wechselwirkungen, relativistische Kinematik, Wirkungsquerschnitte u. Lebensdauern, Symmetrien und Erhaltungssätze, Beschleuniger und Detektoren, Experimente zur elektromagnetischen und schwachen Wechselwirkung, Lepton-Nukleon-Streuung, Experimente zur starken Wechselwirkung, Standardmodell der Elementarteilchenphysik und Experimente dazu

Literaturhinweise:
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2. überarb. Aufl. 2006)
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
F Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1. Aufl. 1984)
D. Griffith; Introduction to Elementary Particle Physics (J. Wiley, Weinheim 1. Aufl. 1987)
Perkins; Introduction to High Energy Physics (Cambridge University Press, 4. Aufl. 2000)

Modul: Physik V (Kerne und Teilchen)

Modul-Nr.: physik510

Lehrveranstaltung: Praktikum Kern- und Teilchenphysik

LV-Nr.: physik512

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Praktikum	deutsch	5	5	SS

Zulassungsvoraussetzungen:
Teilnahme an Physik V (physik511). Das heißt: erfolgreiche Teilnahme an den Übungen plus Anmeldung zur Modulteilprüfung physik511

Empfohlene Vorkenntnisse:
Physik I - IV (physik110, physik210, physik310, physik410)
Theoretische Physik I - III (physik220, physik320, physik420)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Versuchsprotokolle): erfolgreiche mündliche Überprüfung der Versuchsvorbereitung und Durchführung der Versuche

Dauer der Lehrveranstaltung:
1 Semester (während der Vorlesungszeit oder im Blockkurs in der vorlesungsfreien Zeit)

Lernziele der LV:
Verständnis der Grundlagen der Experimente der Kernphysik und der Teilchenphysik.
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten

Inhalte der LV:
Erlernen der physikalischen Grundlagen anhand von Anleitungen und Versuchen. Praktisches Durchführen und Auswerten von Experimenten in kleinen Gruppen.
5 ausgewählte Versuche im Praktikum zur Kern- und/oder Teilchenphysik.
Zeitaufwand pro Versuch: Vorbereitung ~14 Std., Durchführung 8 Std., Protokollanfertigung 8 Std.

Auswahl:
Gamma - Spektroskopie, Höhenstrahlung (zählt doppelt), Compton-Effekt, Alpha-Spektroskopie mit Halbleiterzähler, Beta-Spektroskopie, kernmagnetische Relaxation

Literaturhinweise:
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2. überarb. Aufl. 2006)
B. Povh, K. Rith C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
E. Bodenstedt; Experimente der Kernphysik und ihre Deutung Bd. 1-3 (Bibliographisches Institut, Mannheim) Titel vergriffen, aber in der ULB vorhanden
T.Mayer-Kuckuk; Kernphysik (Teubner, Wiesbaden 7. Aufl. 2002)

Modul-Nr.: physik520
Leistungspunkte: 9
Kategorie: Pflicht
Semester: 5.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Theoretische Physik IV (Statistische Physik)

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Theoretische Physik IV (Statistische Physik)	physik521	9	Vorl. + Üb.	270 Std.	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - III für Physiker (math140, math240, math340)
Theoretische Physik I - III (physik220, physik320, physik420)
Physik I - IV (physik110, physik210, physik310, physik410)

Inhalt:
Thermodynamik, Entropie, Phasenübergänge; Klassische und Quanten-Statistik; Gesamtheiten, Fermi- und Bosegas, Stochastische Prozesse

Lernziele/Kompetenzen:
Umgang mit Konzepten und Rechenmethoden der Statistischen Physik

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Theoretische Physik IV (Statistische Physik)

Modul-Nr.: physik520

Lehrveranstaltung: Theoretische Physik IV (Statistische Physik)

LV-Nr.: physik521

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Vorlesung mit Übungen	deutsch	4+3	9	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematik I - III für Physiker (math140, math240, math340)
Theoretische Physik I - III (physik220, physik320, physik420)
Physik I - IV (physik110, physik210, physik310, physik410)

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulprüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Umgang mit Konzepten und Rechenmethoden der Statistischen Physik

Inhalte der LV:
Klassische Thermodynamik:
Hauptsätze, thermodynamische Potentiale, Entropie, ideale/reale Gase, thermodynamische Maschinen, Phasenübergänge
Klassische und Quanten-Statistik:
Mikrokanonische, kanonische und großkanonische Gesamtheit, Dichteoperator, Zustandssumme, Verteilungsfunktion, Fermi- und Bosegas, Bosekondensation, Schwarzkörperstrahlung, Magnetismus, Isingmodell, stochastische Prozesse

Literaturhinweise:
L. Landau, E. Lifschitz; Lehrbuch der Theoretischen Physik Bd. 5: Statistische Physik Teil 1 (Harri Deutsch, Frankfurt a. Main 8. korr. Aufl. 1991)
L. Landau; E. Lifschitz; Lehrbuch der Theoretischen Physik Bd. 9: Statistische Physik Teil 2 (Harri Deutsch, Frankfurt a. Main 4. ber. Aufl. 1992)
R. K. Pathria; Statistical Mechanics (Butterworth Heinemann, Oxford 1996)
L. E. Reichl; A Modern Course in Statistical Physics (Wiley + Sons, Wiesbaden, 2. Aufl. 1998)
F. Schwabl; Statistische Mechanik (Springer, Heidelberg 2. Aufl. 2004)

Modul-Nr.: physik530
Leistungspunkte: 8
Kategorie: Pflicht
Semester: 4.-6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Mündliche Prüfungen

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Prüfung Experimentalphysik	physik531	4	mündl. Prüf.		WS/SS
2.	Prüfung Theoretische Physik	physik532	4	mündl. Prüf.		WS/SS

Zulassungsvoraussetzungen:
physik531: 3 bestandene Module aus physik110, -210, -310 und -410
physik532: 3 bestandene Module aus physik220, -320, -420 und -520

Empfohlene Vorkenntnisse:
Ausreichende Vorleistungen im 1. - 4. Semester

Inhalt:
Prüfung über 2 Module in Experimentalphysik und 2 Module in theoretischer Physik

Lernziele/Kompetenzen:
Die Studierenden sollen die Lehrveranstaltungen in Experimentalphysik sowie in theoretischer Physik so aufarbeiten, dass in einer Prüfung das Verständnis mündlich dargestellt werden kann

Prüfungsmodalitäten:
Mündliche Prüfung von mindestens 30, höchstens 45 Minuten

Dauer des Moduls: 2 Semester

Max. Teilnehmerzahl:

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Mündliche Prüfungen

Modul-Nr.: physik530

Lehrveranstaltung: Prüfung Experimentalphysik

LV-Nr.: physik531

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Mündliche Prüfung	deutsch	n.a.	4	WS/SS

Zulassungsvoraussetzungen:
3 bestandene Module aus physik110, -210, -310 und -410

Empfohlene Vorkenntnisse:
physik110, -210, -310, -410 und -510

Studien- und Prüfungsmodalitäten:
Mündliche Prüfung von mindestens 30, höchstens 45 Minuten

Dauer der Lehrveranstaltung:
Prüfungs-Vorbereitungszeit

Lernziele der LV:
Die Studierenden sollen sich Überblickswissen erarbeiten

Inhalte der LV:
Mündliche Prüfung über den Inhalt von 2 Modulen aus physik110, -210, -310, -410 und -510. Die relevanten Module werden mit dem Prüfer festgelegt

Literaturhinweise:
Siehe Hinweise zu den Lehrveranstaltungen physik110, -210, -310, -410 und -510

Modul: Mündliche Prüfungen

Modul-Nr.: physik530

Lehrveranstaltung: Prüfung Theoretische Physik

LV-Nr.: physik532

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Mündliche Prüfung	deutsch	n.a.	4	WS/SS

Zulassungsvoraussetzungen:
3 bestandene Module aus physik220, -320, -420 und -520

Empfohlene Vorkenntnisse:
physik220, -320, -420 und -520

Studien- und Prüfungsmodalitäten:
Mündliche Prüfung von mindestens 30, höchstens 45 Minuten

Dauer der Lehrveranstaltung:
Prüfungs-Vorbereitungszeit

Lernziele der LV:
Die Studierenden sollen sich Überblickswissen erarbeiten

Inhalte der LV:
Mündliche Prüfung über den Inhalt von 2 Modulen aus physik220, -320, -420 und -520. Die relevanten Module werden mit dem Prüfer festgelegt

Literaturhinweise:
Siehe Hinweise zu den Lehrveranstaltungen physik220, -320, -420 und -520

Modul-Nr.: physik540
Leistungspunkte: 5
Kategorie: Pflicht
Semester: 5.-6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Präsentation

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Proseminar Präsentationstechnik	physik541	3	Proseminar	90 Std.	WS/SS
2.	Seminar zur Bachelorarbeit	physik542	2	Seminar	60 Std.	WS/SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Abgeschlossenes viertes Semester

Inhalt:
Abfassung von Texten, Relevanz der gewählten Einteilung, Bedeutung von Tabellen und Bildern, Quellenangaben; Vortragsstil, Vortragsgestaltung, Medien.

Lernziele/Kompetenzen:
Die Studierenden sollen in die Problematik der Präsentation eingeführt werden, sollen selber Texte und Vorträge verfassen, und schließlich den Vortrag zur Bachelorarbeit halten. Fähigkeiten zu Präsentationen sollen entwickelt werden.

Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Vortrag): regelmäßige Teilnahme

Dauer des Moduls: 2 Semester

Max. Teilnehmerzahl: ca. 200

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Modul: Präsentation

Modul-Nr.: physik540

Lehrveranstaltung: Proseminar Präsentationstechnik

LV-Nr.: physik541

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Seminar mit Übungen	deutsch	3	3	WS/SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Abgeschlossenes viertes Semester

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Vortrag): regelmäßige Teilnahme

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen lernen, Publikationen effizient vorzubereiten und optimal (Berücksichtigung der Zielgruppe) zu gestalten. Sie sollen lernen, Vorträge vorzubereiten, die zu behandelnden Themen zielgruppengerecht einzuteilen und didaktisch zu gestalten

Inhalte der LV:
Texte: an welche Leser richtet sich der Text?; Textteile: Einleitung, Messdaten, Reduktion, Analyse, Resultate, Wichtigkeit der Teile; Unterschiede zwischen Veröffentlichung, Antrag und Tagungsabstrakt; Einteilung in Sections, Subsections und Paragraphen; Struktur der jeweiligen Öffnungssätze; Relative Bedeutung von Tabellen, Abbildungen und Abstrakt; Vorgehensweise bei Textabfassung; Gestaltung von Abbildungen; Begutachtungsprozess, Beispiele.
Vortrag: Vortragsstruktur, Foliengestaltung, Einteilung einer Folie und Verwendung von Farben; Quellenangaben; zeitliche Abfolge; Körperhaltung beim Vortrag; Atemtechnik und Stimmvolumen; Verwendung einer Tafel; Zeigestock oder pointer; Laptop; Pausen beim Sprechen; Vermeidung von Füllwörtern.
Gelegenheit zum Vortrag

Literaturhinweise:

Modul: Präsentation

Modul-Nr.: physik540

Lehrveranstaltung: Seminar zur Bachelorarbeit

LV-Nr.: physik542

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Seminar	deutsch	2	2	WS/SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Abgeschlossenes viertes Semester

Studien- und Prüfungsmodalitäten:
Zulassungsvoraussetzung zur Modulteilprüfung (Vortrag): regelmäßige Teilnahme

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen lernen über ein Projekt zu berichten. Sie sollen aus den Vorträgen der Kommilitonen ersehen, wie Vorträge gehalten und gestaltet werden sollen

Inhalte der LV:
Die Studierenden sollen über ihre durchgeführten Projekte (die Bachelorarbeit) berichten. Sie sollen zugleich das im Proseminar physik541 (zum Gestalten und Halten von Vorträgen) Gelernte noch einmal in der Praxis unter Beweis stellen

Literaturhinweise:

Modul-Nr.:	physik590
Leistungspunkte:	12
Kategorie:	Pflicht
Semester:	5.-6.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Bachelorarbeit

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Bachelorarbeit	physik591	12	Projekt	360 Std.	WS/SS

Zulassungsvoraussetzungen:
Das Thema der Bachelorarbeit wird erst ausgegeben, wenn die Studentin, der Student mindestens 90 Leistungspunkte aus dem Bachelorstudium erworben hat

Empfohlene Vorkenntnisse:
Ausreichende Vorleistungen im 3. und 4. Semester. Mit der Bachelorarbeit kann in der Regel im 5. Semester begonnen werden. Diese muss innerhalb von 4 Kalendermonaten abgeschlossen werden.

Inhalt:
Die Studierenden sollen ein Projekt physikalischer Art durchführen bzw. eine physikalische Fragestellung bearbeiten.
Variante FV:
Die wissenschaftliche Vorbereitung basiert auf dem Inhalt einer weiterführenden/vertiefenden Vorlesung aus den Bereichen Experimentalphysik, Theoretische Physik oder Astronomie/Astrophysik (siehe nächste Seite)
Variante AG:
Die wissenschaftliche Vorbereitung basiert auf der Methoden- und Projektplanung in einer wissenschaftlichen Arbeitsgruppe.

Lernziele/Kompetenzen:
Die Studierenden sollen dokumentieren, dass sie in der Lage sind, ein physikalisches Projekt durchzuführen bzw. eine physikalische Fragestellung zu bearbeiten und darüber eine schriftliche Ausarbeitung anzufertigen.

Prüfungsmodalitäten:

Dauer des Moduls: 1 Semester

Max. Teilnehmerzahl:

Anmeldeformalitäten:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Mögliche Lehrveranstaltungen bei Variante „FV“: Vorlesungen aus den Bereichen Experimentalphysik, Theoretische Physik, Astronomie/Astrophysik

physics611	Particle Physics
physics612	Accelerator Physics
physics618	Physics of Particle Detectors
physics613	Condensed Matter Physics
physics614	Laser Physics and Nonlinear Optics
physics620	Advanced Atomic, Molecular, and Optical Physics
physics615	Theoretical Particle Physics
physics616	Theoretical Hadron Physics
physics617	Theoretical Condensed Matter Physics
physics632	Physics of Hadrons
physics633	High Energy Collider Physics
physics631	Quantum Optics
physics634	Magnetism/Superconductivity
physics640	Photonic Devices
physics606	Advanced Quantum Theory
physics751	Group Theory
physics754	General Relativity and Cosmology
physics755	Quantum Field Theory
astro811	Stars and Stellar Evolution
astro812	Cosmology
astro821	Astrophysics of Galaxies
astro822	Physics of the Interstellar Medium

Modul: Bachelorarbeit

Modul-Nr.: physik590

Lehrveranstaltung: Bachelorarbeit

LV-Nr.: physik591

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Pflicht	Bachelorarbeit	deutsch	n.a.	12	WS/SS

Zulassungsvoraussetzungen:
Das Thema der Bachelorarbeit kann erst ausgegeben werden, wenn die Studentin, der Student mindestens 90 Leistungspunkte aus dem Bachelorstudium erworben hat.

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Die Prüfungsleistung ist eine schriftliche Ausarbeitung über ein selbst durchgeführtes Projekt im Rahmen eines "Praktikums in einer Arbeitsgruppe" oder über ein selbst bearbeitetes Thema einer weiterführenden/vertiefenden Wahlpflichtvorlesung (s. oben genannte Lehrveranstaltungen). Sie soll in der Regel den Umfang von 20 DIN A4 Seiten nicht überschreiten. Die Bestätigung über die erfolgreiche Durchführung des Praktikums in der Arbeitsgruppe bzw. über die Teilnahme an der Vorlesung wird zusammen mit der Beurteilung der schriftlichen Ausarbeitung von der betreuenden Dozentin / dem betreuenden Dozenten vorgenommen. Die Note der Bachelorarbeit wird durch die Beurteilung der schriftlichen Ausarbeitung festgelegt und wird mit dem Gewicht von 12 Leistungspunkten in der Endnote berücksichtigt. Das Modul muss insgesamt innerhalb von 4 Monaten abgeschlossen werden. Auf begründeten Antrag hin kann der Prüfungsausschuss eine Verlängerung der Bearbeitungszeit um bis zu 6 Wochen genehmigen.

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden sollen dokumentieren, dass sie in der Lage sind, ein physikalisches Projekt durchzuführen bzw. eine physikalische Fragestellung zu bearbeiten und darüber eine schriftliche´Ausarbeitung anzufertigen.

Inhalte der LV:
Die Studierenden sollen ein Projekt physikalischer Art durchführen bzw. eine physikalische Fragestellung bearbeiten.
Variante FV:
Die wissenschaftliche Vorbereitung basiert auf dem Inhalt einer weiterführenden/vertiefenden Vorlesung aus den Bereichen Experimentalphysik, Theoretische Physik oder Astronomie/Astrophysik
Variante AG:
Die wissenschaftliche Vorbereitung basiert auf der Methoden- und Projektplanung in einer wissenschaftlichen Arbeitsgruppe.

Literaturhinweise:
siehe die entsprechenden Modulbeschreibungen des Masterstudienganges Physik bzw. Astrophysik

Wichtig: Falls Variante "AG" gewählt wird, kann der Antrag auf Genehmigung des Themas beim Prüfungsausschuss zu jedem Zeitpunkt von der Studentin, dem Studenten gestellt werden. Falls Variante "FV" gewählt wird, soll der Beginn der Bachelorarbeit bzw. die gewählte Lehrveranstaltung im Wintersemester bis zum 30. November und im Sommersemester bis zum 31. Mai vom Prüfungsausschuss genehmigt worden sein, damit die Bachelorarbeit noch im selben Semester abgeschlossen werden kann.

s. auch http://bamawww.physik.uni-bonn.de

Module-Handbook
Master in Physics
PO von 2006

SS 2024

We don’t offer each of these modules regularly.

For any update please see:

https://www.physik-astro.uni-bonn.de/de/studium/

lehrveranstaltungen/termine-und-lehrveranstaltungen

Master in Physics, University of Bonn

1st Term

physics600	physics605	physics610	physics700
Base Module: Laboratory Course	**Base Module: Theoretical Physics**	**Specialization I**	**Elective Advanced Lectures**
7 CP	7 CP	12 CP	(a)

2nd Term

physics630	physics710	physics720	physics730	physics650
Specialization II	**Experimental Physics**	**Applied Physics**	**Theoretical Physics**	**Seminar**
12 CP	(a)			4 CP

3rd Term

physics910	physics920
Scientific Exploration of Master Thesis Topic	**Methods and Project Planning**
15 CP	15 CP

4th Term

physics930
Master Thesis
30 CP

Notes: The students must achieve the indicated number of CP (Credit Points).
(a): In the modules 700, 710, 720, 730 at least 18 CP altogether must be achieved.

Abbreviations:

CP	Credit Points (*Leistungspunkte*)
ex.	exercises
hrs	hours
lab.	laboratory
Ma-PO	"Master-Prüfungsordnung" (Examination Regulations (Master Course))
n.a.	not applicable
ST	Summer Term
TH	Teaching Hours
WT	Winter Term
E	Experimental Physics
A	Applied Physics
T	Theoretical Physics

On proposal of the board of examination, the Dean may agree to further compulsory selectable (sub-) modules. The office of the board of examination will announce these compulsory selectable (sub-) modules agreed upon, electronically or by public notice, in due time before the beginning of the semester.

Note about programme language:
The M.Sc. in Physics programme is a programme in English language. At the discretion of the lecturer and the class German language may be used as the teaching language as well. Furthermore non-German speaking students are expected to learn German language on their own accord during the course of this programme.

Note to the points "Requirements" and "Preparation":
The point "Requirements" contains courses that have to be passed in order for the students to be able to participate in the module.
The point "Preparation" contains other courses whose content helps significantly towards the understanding of this course.

Note about module (submodule) examinations:
The details about the submodule examination will be announced by the lecturer before the start of the lecture
Please find updated versions of the module-handbook at http://www.physik-astro.uni-bonn.de

Table of Contents: M.Sc. in Physics (PO von 2006)

physics600 Base Module Laboratory Course 1
physics605 Base Module Theoretical Physics 2
- physics606 Advanced Quantum Theory 3
- physics607 Advanced Theoretical Physics 4

physics610 Specialization I 5
- physics611 Particle Physics 6
- physics612 Accelerator Physics 7
- physics618 Physics of Particle Detectors 8
- physics613 Condensed Matter Physics 9
- Condensed Matter Physics I 10
- physics619 Applied Photonics 11
- physics620 Advanced Atomic, Molecular, and Optical Physics 12
- Molecular Physics I 13
- physics615 Theoretical Particle Physics 14
- physics616 Theoretical Hadron Physics 15
- physics617 Theoretical Condensed Matter Physics 16
- Solid State Theory I 17

physics630 Specialization II 18
- physics632 Physics of Hadrons 19
- physics633 High Energy Collider Physics 20
- physics639 Advanced Topics in High Energy Particle Physics 21
- physics634 Magnetism/Superconductivity 22
- physics635 Laser Spectroscopy 23
- Molecular Physics II 24
- physics636 Advanced Theoretical Particle Physics 25
- physics637 Advanced Theoretical Hadron Physics 26
- physics638 Advanced Theoretical Condensed Matter Physics 27

physics700 Elective Advanced Lectures 28
physics710 Experimental Physics 29
physics720 Applied Physics 30
physics730 Theoretical Physics 31
physics650 Seminar 32
physics910 Scientific Exploration of the Master Thesis Topic 33
physics920 Methods and Project Planning 34
physics930 Master Thesis 35
Catalogue of 700-courses in Particle Physics 36
- physics711 Particle Astrophysics and Cosmology (E) 37
- physics712 Advanced Electronics and Signal Processing (E/A) 38
- physics713 Particle Detectors and Instrumentation (E/A) 39
- physics714 Advanced Accelerator Physics (E/A) 40
- physics715 Experiments on the Structure of Hadrons (E) 41
- physics716 Statistical Methods of Data Analysis (E) 42
- physics717 High Energy Physics Lab (E) 43
- physics718 Programming in Physics and Astronomy with C++ or Python (E/A) 44
- physics720 Physics with Antiprotons (E) 45
- physics721 Intensive Week: Advanced Topics in Hadron Physics (E) 46
- physics722 Advanced Gaseous Detectors - Theory and Practice (E) 47

Catalogue of 700-courses in Condensed Matter & Photonics 48

physics731 Low Temperature Physics (E/A) 49
physics732 Optics Lab (E/A) 50
physics734 Holography (E/A) 51
physics735 Laser Cooling and Matter Waves (E) 52
physics736 Crystal Optics (E/A) 53
physics737 Intensive Week: Advanced Topics in Photonics and Quantum Optics (E) 54
physics738 Lecture on Advanced Topics in Quantum Optics (E) 55
physics739 Lecture on Advanced Topics in Photonics (E/A) 56
physics740 Hands-on Seminar: Experimental Optics and Atomic Physics (E/A) 57
physics741 Modern Spectroscopy (E/A) 58
physics742 Ultracold Atomic Gases (E/T) 59
Catalogue of 700-courses in Theoretical Physics 60
physics742 Ultracold Atomic Gases (E/T) 61
physics751 Group Theory (T) 62
physics752 Superstring Theory (T) 63
physics753 Theoretical Particle Astrophysics (T) 64
physics754 General Relativity and Cosmology (T) 65
physics755 Quantum Field Theory (T) 66
physics756 Critical Phenomena (T) 67
physics757 Effective Field Theory (T) 68
physics758 Quantum Chromodynamics (T) 69
physics760 Computational Physics (T) 70
physics761 Supersymmetry (T) 71
physics762 Transport in mesoscopic systems (T) 72
physics763 Advanced Topics in String Theory (T) 73
physics764 Advanced Topics in Field and String Theory (T) 74
physics765 Advanced Topics in Quantum Field Theory (T) 75
physics766 Physics of Higgs Bosons (T) 76
physics767 Computational Methods in Condensed Matter Theory (T) 77
physics768 General Relativity for Experimentalists (T) 78
physics769 Lattice QCD (T) 79
physics7502 Random Walks and Diffusion (T) 80
physics7503 Selected Topics in Modern Condensed Matter Theory (T) 81
physics7504 Theory of Superconductivity and Superfluidity (T) 82
Catalogue of 700-courses in Special Topics 83
physics771 Environmental Physics & Energy Physics (A) 84
physics772 Physics in Medicine: Fundamentals of Analyzing Biomedical Signals (A) 85
physics773 Physics in Medicine: Fundamentals of Medical Imaging (A) 86
physics774 Electronics for Physicists (E/A) 87
physics775 Nuclear Reactor Physics (A) 88
physics776 Physics in Medicine: Physics of Magnetic Resonance Imaging (A) 89
Cologne Courses in General Relativity and Quantum Field Theory 90
Relativity and Cosmology I (T) 91
Relativity and Cosmology II (T) 92
Quantum Field Theory I (T) 93
Quantum Field Theory II (T) 94
Geometry in Physics (T) 95
Topology for Physicists (T) 96
Cologne Courses in Nuclear and Particle Physics 97
Nuclear physics II (E) 98
Physics of Detectors (E/A) 99

Particle physics (E) 100
Groundbreaking experiments in nuclear physics (E) 101
Cologne Courses in Condensed Matter Physics 102
Condensed Matter Physics I 103
Condensed Matter Physics II (E) 104
Semiconductor Physics and Nanoscience (E/A) 105
Superconductivity (E/A) 106
Magnetism (E/A) 107
Experimental methods in condensed matter physics (E/A) 108
Physics of Surfaces and Nanostructures (E/A) 109
Introduction to neutron scattering (E/A) 110
Optical Spectroscopy (E/A) 111
Cologne Courses in Molecular Physics 112
Molecular Physics I 113
Molecular Physics II 114
Astrochemistry (E/A) 115
Fundamentals of Molecular Symmetry (E/A/T) 116
Cologne Courses in Statistical and Biological Physics 117
Physical biology (T/A) 118
Statistical physics of soft matter and biomolecules (T/A) 119
Statistical physics far from equilibrium (T) 120
Disordered systems (T) 121
Nonequilibrium physics with interdisciplinary applications (T) 122
Probability theory and stochastic processes for physicists (T) 123
Cologne Courses in Theoretical Solid State Physics 124
Solid State Theory I 125
Quantum Field Theory I (T) 126
Quantum Field Theory II (T) 127

Module No.: physics600
Credit Points (CP): 7
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Base Module Laboratory Course

Requirements:

Preparation:

Content:
Every student has to complete this Laboratory Course. The course consists of advanced experiments introducing into important subfields of contemporary experimental physics and astrophysics. The lab-course is accompanied by a seminar.

Aims/Skills:
The students shall gain insight in the conceptual and complex properties of relevant contemporary experiments. The students gain experience in setting up an experiment, data logging and data analysis. They experience the intricacies of forefront experimental research

Form of Testing and Examination:
Before carrying out an experiment, the students shall demonstrate to have acquired the necessary preparatory knowledge. Experiments are selected from the catalogue of laboratory set-ups offered. Cumulative lab-units of >= 9 are required.
Requirements for the submodule examination (written report for every laboratory): successful completion of the experiment and initial oral questioning

Length of Module: 1 semester

Maximum Number of Participants: 60

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.: physics605
Credit Points (CP): 7
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Base Module Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Quantum Theory	physics606	7	Lect. + ex.	210 hrs	WT
2.	Advanced Theoretical Physics	physics607	7	Lect. + ex.	210 hrs	WT

Requirements:

Preparation:

Content:
The course provides fundamental knowledge needed for theoretical lectures in the Master course

Aims/Skills:
The M.Sc. Physics programme includes one obligatory module for all students. It includes a theoretical unit to extend the B.Sc. in Physics knowledge

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: When the student has (upon admission) demonstrated satisfactory knowledge of Advanced Quantum Theory already, the class Advanced Theoretical Physics may be taken instead

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Quantum Theory

Course No.: physics606

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
Ability to solve problems in relativistic quantum mechanics, scattering theory and many-particle theory

Contents of the Course:
Born approximation, partial waves, resonances
advanced scattering theory: S-matrix, Lippman-Schwinger equation
relativistic wave equations: Klein-Gordon equation, Dirac equation
representations of the Lorentz group
many body theory
second quantization
basics of quantum field theory
path integral formalism
Greens functions, propagator theory

Recommended Literature:
L. D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.3 Quantum Mechanics (Butterworth-Heinemann 1997)
J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley 1995)
F. Schwabl, Advanced Quantum Mechanics. (Springer, Heidelberg 3rd Ed. 2005)

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Theoretical Physics

Course No.: physics607

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
3-year theoretical physics course with extended interest in theoretical physics and mathematics

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to modern methods and developments in Theoretical Physics in regard to current research

Contents of the Course:
Selected Topics in Modern Theoretical Physics for example:
Anomalies
Solitons and Instantons
Quantum Fluids
Bosonization
Renormalization Group
Bethe Ansatz
Elementary Supersymmetry
Gauge Theories and Differential Forms
Applications of Group Theory

Recommended Literature:
M. Nakahara; Geometry, Topology and Physics (Institute of Physics Publishing, London 2nd Ed. 2003)
R. Rajaraman; Solitons and Instantons, An Introduction to Solitons and Instantons in Quantum Field Theory (North Holland Personal Library, Amsterdam 3rd reprint 2003)
A. M. Tsvelik; Quantum Field Theory in Condensed Matter Physics (Cambridge University Press 2nd Ed. 2003)
A. Zee; Quantum Field Theory in a Nutshell (Princeton University Press 2003)

Module No.: physics610
Credit Points (CP): 12
Category: Elective
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Specialization I

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Particle Physics	physics611	6	Lect. + ex.	180 hrs	WT
2.	Accelerator Physics	physics612	6	Lect. + ex.	180 hrs	WT
3.	Physics of Particle Detectors	physics618	6	Lect. + ex.	180 hrs	WT
Condensed Matter and Photonics						
1.	Condensed Matter Physics	physics613	6	Lect. + ex.	180 hrs	WT
2.	Condensed Matter Physics I	CondMatter I	6	Lect. + ex.	180 hrs	WT
3.	Applied Photonics	physics619	6	Lect. + ex.	180 hrs	WT
4.	Advanced Atomic, Molecular, and Optical Physics	physics620	6	Lect. + ex.	180 hrs	WT
5.	Molecular Physics I	MolPhys I	6	Lect. + ex.	180 hrs	WT
Theoretical Physics						
1.	Theoretical Particle Physics	physics615	7	Lect. + ex.	210 hrs	WT
2.	Theoretical Hadron Physics	physics616	7	Lect. + ex.	210 hrs	WT
3.	Theoretical Condensed Matter Physics	physics617	7	Lect. + ex.	210 hrs	WT
4.	Solid State Theory I	TheoSolidSt	6	Lect. + ex.	180 hrs	WT

Requirements:

Preparation:
See with the description of the course

Content:
Teaching of advanced fundamentals of physics from two research areas of physics in Bonn

Aims/Skills:
The students will get acquainted with two research topics of today

Form of Testing and Examination:
Requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve 12 CP from two different specialization areas (Particle Physics; Condensed Matter and Photonics; Theoretical Physics)

Module: Specialization I

Module No.: physics610

Course: Particle Physics

Course No.: physics611

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Introductory particle physics and quantum mechanics courses

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the fundamentals of particle physics: properties of quarks and leptons and their interactions (electromagnetic, weak, strong), experiments that have led to this understanding, the Standard Model of particle physics and measurements that test this model, the structure of hadrons

Contents of the Course:
Basics: leptons and quarks, antiparticles, hadrons, forces / interactions, Feynman graphs, relativistic kinematics, two-body decay, Mandelstam variables, cross-section, lifetime
Symmetries and Conservation Laws. Positronium, Quarkonium. Accelerators and Detectors
Electromagnetic interactions: (g-2) experiments, lepton-nucleon scattering
Strong interactions: colour, gauge principle, experimental tests of QCD. Electroweak interactions and the Standard Model of particle physics: spontaneous symmetry breaking, Higgs mechanism, experimental tests of the Standard Model. Neutrino physics, neutrino oscillations; CP violation

Recommended Literature:
F Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1. Aufl. 1984)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2. überarb. Aufl. 2006)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
D. Griffith; Introduction to Elementary Particle Physics (J. Wiley, Weinheim 1. Aufl. 1987)
A. Seiden; Particle Physics : A Comprehensive Introduction (2005)
Martin & Shaw; Particle Physics, Wiley (2nd edition, 1997)

Module: Specialization I

Module No.: physics610

Course: Accelerator Physics

Course No.: physics612

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the functional principle of different types of particle accelerators
Layout and design of simple magneto-optic systems
Basic knowledge of radio frequency engineering and technology
Knowledge of linear beam dynamics in particle accelerators

Contents of the Course:
Elementary overview of different types of particle accelerators: electrostatic and induction accelerators, RFQ, Alvarez, LINAC, Cyclotron, Synchrotron, Microtron
Subsystems of particle accelerators: particle sources, RF systems, magnets, vacuum systems
Linear beam optics: equations of motion, matrix formalism, particle beams and phase space
Circular accelerators: periodic focusing systems, transverse beam dynamics, longitudinal beam dynamics
Guided tours through the ELSA accelerator of the Physics Institute and excursions to other particle accelerators (COSY, MAMI, HERA, ...) complementing the lecture

Recommended Literature:
F. Hinterberger; Physik der Teilchenbeschleuniger und Ionenoptik (Springer Heidelberg 1997)
H. Wiedemann; Particle Accelerator Physics (Springer, Heidelberg 2. Aufl. 1999)
K. Wille; Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen (Teubner, Wiesbaden 2. Aufl. 1996)
D. A. Edwards, M.J. Syphers; An Introduction to the Physics of High Energy Accelerators, Wiley & Sons 1993)
Script of the Lecture "Particle Accelerators"
http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/

Module: Specialization I

Module No.: physics610

Course: Physics of Particle Detectors

Course No.: physics618

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Useful: physik510

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the basics of the physics of particle detectors, their operation and readout

Contents of the Course:
Physics of detectors and detection mechanisms, interactions of charged particles and photons with matter, ionization detectors, drift and diffusion, gas filled wire chambers, proportional and drift chambers, semiconductor detectors, microstrip detectors, pixel detectors, radiation damage, cerenkov detectors, transition radiation detectors, scintillation detectors (anorganic crystals and plastic scintillators), electromagnetic calorimeters, hadron calorimeters, readout techniques, VLSI readout and noise

Recommended Literature:
Wermes: Skriptum and web-based Teaching Module
K. Kleinknecht; Detectors for Particle Radiation (Cambridge University Press 2nd edition 1998)
W.R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2nd ed. 1994)
H. Spieler, Semiconductor detector system (Oxford University Press 2005)
L. Rossi, P. Fischer, T. Rohe, N. Wermes, Pixel Detectors: From Fundamentals to Applications (Springer 2006)

Module: Specialization I

Module No.: physics610

Course: Condensed Matter Physics

Course No.: physics613

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the concepts of condensed matter physics

Contents of the Course:
Crystallographic structures: Bravais lattices, Millers indices, crystallographic defects, structural analysis;
Chemical bonds: van der Waals bond, covalent bond, hybridisation, ionic bond, metallic bond, Hydrogen bridge bond;
Lattice vibrations: acoustic and optical phonons, specific heat, phonon-phonon interaction;
Free electrons in the solid state: free electron gas, Drude model, Fermi distribution, specific heat of the electrons;
Band structure: metals, semiconductors, insulators, effective masses, mobility of charge carrier, pn-transition, basic principles of diodes, bipolar and unipolar transistors;
Superconductivity: basic phenomena, Cooper pairs, BSC-theory and its consequences;
Magnetic properties: diamagnetism, Langevin-theory of paramagnetism, Pauli-paramagnetism, spontaneous magnetic order, molecular field, Heisenberg-exchange;
Nuclear solid state physics: Hyperfine interaction, Mössbauer spectroscopy, perturbed angular correlation, positron annihilation, typical applications.

Recommended Literature:
N. W. Ashcroft , N. D. Mermin , Solid State Physics (Brooks Cole 1976) ISBN-13: 978-0030839931
N. W. Ashcroft , N. D. Mermin, Festkörphysik (Oldenbourg 2001) ISBN-13: 978-3486248340
H. Ibach, H. Lüth, Solid-State Physics (Springer 2003) ISBN-13: 978-3540438700
H. Ibach, H. Lüth, Festkörperphysik (Springer 2002) ISBN-13: 978-3540427384
C. Kittel, Einführung in die Festkörperphysik (Oldenbourg 2006) ISBN-13: 978-3-486-57773-5
W. Demtröder, Experimentalphysik, Bd. 3. Atome, Moleküle und Festkörper (Springer 2005) ISBN-13: 978-3540214731
K. Kopitzki, P. Herzog Einführung in die Festkörperphysik (Vieweg+Teubner 2007) ISBN-13: 978-3835101449
L. Bergmann, C. Schaefer, R. Kassing, Lehrbuch der Experimentalphysik 6.: Festkörper (Gruyter 2005) ISBN-13: 978-3110174854
W. Buckel, R. Kleiner, Supraleitung (Wiley-VCH 2004) ISBN-13: 978-3527403486

Module: Specialization I

Module No.: physics610

Course: Condensed Matter Physics I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral or written examination

Length of Course:
2 semesters

Aims of the Course:
Comprehensive introduction to the basic principles of solid state physics and to some experimental methods. Examples of current research will be discussed.

Contents of the Course:
The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:
Crystal structure and binding
Reciprocal space
Lattice dynamics and thermal properties
Electronic structure (free-electron gas, Fermi surface, band structure)
Semiconductors and metals
Transport properties
Dielectric function and screening
Superconductivity
Magnetism

Recommended Literature:
Skriptum (available during the course)
Ashcroft/Mermin: Solid State Physics
Kittel: Introduction to Solid State Physics
Ibach/Lüth: Festkörperphysik

Module: Specialization I

Module No.: physics610

Course: Applied Photonics

Course No.: physics619

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
To make the students understand physical and technological foundations of photonics and enable them to practically apply their knowledge in research and development.

Contents of the Course:
Optics: Rays, Beams, Waves;
Waveguides, Fibers
Light sources; Detectors; Imaging devices
Optical amplification; Acoustooptics, electrooptics
Photonic circuits, optical communication
Optical Metrology (angle, distance, velocity, density...);
Material Processing (cutting, welding, lithography, lasers in medicine)

Recommended Literature:
D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2. überarb. Aufl. 2005)
A. Yariv; Photonics: Optical Electronics in Modern Communications (Oxford Univ. Press 6th edition 2006)
B. Saleh, M. Teich; Fundamentals of Photonics (John Wiley & Sons, New York, 1991)
C. Yeh; Applied Photonics (Academic Press, 1994)
R. Menzel; Photonics (Springer, Berlin 2001)

Module: Specialization I

Module No.: physics610

Course: Advanced Atomic, Molecular, and Optical Physics

Course No.: physics620

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Fundamentals of Quantum Mechanics, Atomic Physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to give the students a deeper insight to the field of atomic, molecular and optical (AMO) physics. Building on prior knowledge from the Bachelor courses it will cover advanced topics of atomic and molecular physics, as well as the interaction of light and matter.

Contents of the Course:
Atomic physics: Atoms in external fields; QED corrections: Lamb-Shift; Interaction of light and matter: Lorentz oscillator, selection rules; magnetic resonance; Coherent control

Molecular physics: Hydrogen Molecule; Vibrations and rotations of molecules; Hybridization of molecular orbitals; Feshbach Resonances; Photoassociation; Cold Molecules

Bose Condensation; Matterwave Optics

Recommended Literature:
C. J. Foot, Atomic Physics, Oxford University Press 2005
H. Haken, The physics of atoms and quanta, Springer 1996
S. Svanberg, Atomic and molecular spectroscopy basic aspects and practical applications, Springer 2001
W. Demtröder, Molecular Physics, Wiley VCH 2005
T. Buyana, Molecular physics, World Scientific 1997
W. Demtröder, Atoms, Molecules and Photons, Springer 2010
P, Meystre, Atom Optics, Springer 2010

Module: Specialization I

Module No.: physics610

Course: Molecular Physics I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the first part of the core courses the students learn the main concepts of molecular physics: separation of electronic, vibrational and rotational motion. Simple molecular spectra can be analyzed on the basis of the problem class. Fundamental group theory is used to predict vibrational and rotational spectra of more complex molecules.

This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Basics of molecular spectroscopy, phenomenology, diatomic molecules
- Born-Oppenheimer Approximation, separation of rotation and vibration
- Molecular Dipole moment and rotational transitions
- Rotational spectra and the rigid rotor approach
- Selection rules, parallel and perpendicular type spectra
- Nuclear spin statistics
- Hyperfine structure of molecular lines

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module: Specialization I

Module No.: physics610

Course: Theoretical Particle Physics

Course No.: physics615

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum field theory (physics755)
Group theory (physics751)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the standard model of elementary particle physics and its extensions (unified theories)

Contents of the Course:
Classical field theory, gauge theories, Higgs mechanism;
Standard model of strong and electroweak interactions;
Supersymmetry and the supersymmetric extension of the standard model;
Grand unified theories (GUTs);
Neutrino physics;
Cosmological aspects of particle physics (dark matter, inflation)

Recommended Literature:
T. P. Cheng, L.F. Li: Gauge theories of elementary particle physics (Clarendon Press, Oxford 1984)
M. E. Peskin, D.V. Schroeder; An introduction to quantum field theory (Addison Wesley, 1995)
J. Wess; J. Bagger; Supersymmetry and supergravity (Princeton University Press 1992)

Module: Specialization I

Module No.: physics610

Course: Theoretical Hadron Physics

Course No.: physics616

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum field theory (physics755)
Group theory (physics751)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the theory of strong interaction, hadron structure and dynamics

Contents of the Course:
Meson and Baryon Spectra: Group theoretical Classification, Simple Quark Models
Basics of Quantum Chromodynamics: Results in Perturbation Theory
Effective Field Theory
Bethe-Salpeter Equation

Recommended Literature:
F. E. Close, An Introduction to Quarks and Partons (Academic Press 1980)
F. Donoghue, E. Golowich, B.R. Holstein; Dynamics of the Standard Model (Cambridge University Press 1994)
C. Itzykson, J.-B. Zuber; Quantum Field Theory (Dover Publications 2005)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Module: Specialization I

Module No.: physics610

Course: Theoretical Condensed Matter Physics

Course No.: physics617

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Advanced Quantum Theory (physics606)
Quantum Field Theory (physics755)
Group theory (physics751)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the theoretical standard methods and understanding important phenomena in the Physics of Condensed Matter

Contents of the Course:
Crystalline Solids: Lattice structure, point groups, reciprocal lattice
Elementary excitations of a crystal lattice: phonons
Electrons in a lattice; Bloch theorem, band structure
Fermi liquid theory
Magnetism
Symmetries and collective excitations in solids
Superconductivity
Integer and fractional quantum Hall effects

Recommended Literature:
N. W. Ashcroft, N.D. Mermin, Solid State Physics (Saunders College 1976)
P. M. Chaikin, T.C. Lubensky; Principles of Condensed Matter Physics (Cambridge University Press 1997)
W. Nolting; Grundkurs Theoretische Physik Band 7: Vielteilchentheorie (Springer, Heidelberg 2002)
Ch. Kittel; Quantentheorie der Festkörper (Oldenburg Verlag, München 3. Aufl. 1989)

Module: Specialization I

Module No.: physics610

Course: Solid State Theory I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
training in theoretical physics at the B.Sc. level, experimental solid state physics

Form of Testing and Examination:
written or oral examination

Length of Course:
1 semester

Aims of the Course:
this course gives an introduction to the physics of electrons and phonons in solids together with theoretical concepts and techniques as applied to these systems.

Contents of the Course:
The lecture investigates basic concepts to describe solids and their excitations. Various applications are discussed with emphasis on experimental and theoretical research directions of the physics department in Cologne.

Recommended Literature:
Ashcroft/ Mermin: "Solid State Physics"

Module No.: physics630
Credit Points (CP): 12
Category: Elective
Semester: 8.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Specialization II

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Physics of Hadrons	physics632	6	Lect. + ex.	180 hrs	ST
2.	High Energy Collider Physics	physics633	6	Lect. + ex.	180 hrs	ST
3.	Advanced Topics in High Energy Particle Physics	physics639	6	Lect. + ex.	180 hrs	ST
Condensed Matter and Photonics						
1.	Magnetism/Superconductivity	physics634	6	Lect. + ex.	180 hrs	ST
2.	Laser Spectroscopy	physics635	6	Lect. + ex.	180 hrs	ST
3.	Molecular Physics II	MolPhys II	6	Lect. + ex.	180 hrs	ST
Theoretical Physics						
1.	Advanced Theoretical Particle Physics	physics636	7	Lect. + ex.	210 hrs	ST
2.	Advanced Theoretical Hadron Physics	physics637	7	Lect. + ex.	210 hrs	ST
3.	Advanced Theoretical Condensed Matter Physics	physics638	7	Lect. + ex.	210 hrs	ST

Requirements:

Preparation:

Content:
In depth knowledge on the basics of the research programme in physics at Bonn University

Aims/Skills:
The students shall learn the basics as well as the present state of current research in the fields

Form of Testing and Examination:
Requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The student must achieve 12 CP from one or two specialization areas.

Module: Specialization II

Module No.: physics630

Course: Physics of Hadrons

Course No.: physics632

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Completed B.Sc. in Physics, with experience in electrodynamics, quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the many-body structure of hadrons, understanding structural examinations with electromagnetic probes, introduction into experimental phenomenology

Contents of the Course:
Structure Parameters of baryons and mesons; hadronic, electromagnetic and weak probes; size, form factors and structure functions; quarks, asymptotic freedom, confinement, resonances; symmetries and symmetry breaking, hadron masses;
quark models, meson and baryon spectrum; baryon spectroscopy and exclusive reactions; missing resonances, exotic states

Recommended Literature:
B. Povh, K. Rith C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
K. Gottfried, F. Weisskopf; Concepts of Particle Physics (Oxford University Press 1986)

Module: Specialization II

Module No.: physics630

Course: High Energy Collider Physics

Course No.: physics633

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
physics611 (Particle Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
In depth treatment of particle physics at high energy colliders with emphasis on LHC

Contents of the Course:
Kinematics of electron-proton and proton-(anti)proton collisions,
Electron-positron, electron-hadron and hadron-hadron reactions, hard scattering processes,
Collider machines (LEP, Tevatron and LHC) and their detectors (calorimetry and tracking),
the Standard Model of particle physics in the nutshell, fundamental questions posed to the LHC,
spontaneous symmetry breaking and experiment,
QCD and electroweak physics with high-energy hadron colliders,
Physics of the top quark, top cross section and mass measurements,
Higgs Physics at the LHC (search strategies, mass measurement, couplings),
Supersymmetry and beyond the Standard Model physics at the LHC
Determination of CKM matrix elements, CP violation in K and B systems,
Neutrino oscillations

Recommended Literature:
V. D. Barger, R. Phillips; Collider Physics (Addison-Wesley 1996)
R. K. Ellis, W.J. Stirling, B.R. Webber; QCD and Collider Physics (Cambridge University Press 2003)
D. Green; High PT Physics at Hadron Colliders (Cambridge University Press 2004)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2nd revised edition 2006)
A. Seiden; Particle Physics A Comprehensive Introduction (Benjamin Cummings 2004)
T. Morii, C.S. Lim; S.N. Mukherjee Physics of the Standard Model and Beyond (World Scientific 2004)

Module: Specialization II

Module No.: physics630

Course: Advanced Topics in High Energy Particle Physics

Course No.: physics639

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
physics611 (Particle Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises.

Length of Course:
1 semester

Aims of the Course:
To discuss advanced topics of high energy particle physics which are the subject of current research efforts and to deepen understanding of experimental techniques in particle physics.

Contents of the Course:
Selected topics of current research in experimental particle physics. Topics will be updated according to progress in the field. For example:
- LHC highlights
- CP-violation experiments
- Experimental challenges in particle and astroparticle physics
- Current questions in neutrino physics

Recommended Literature:
A. Seiden; Particle Physics: A Comprehensive Introduction (Cummings 2004)
R.K. Ellis, B.R. Webber, W.J. Stirling; QCD and Collider Physics (Cambridge Monographs on Particle Physics 1996)
C. Burgess, G. Moore; The Standard Model: A Primer (Cambridge University Press 2006)
F. Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1998)
C. Berger; Elementarteilchenphysik (Springer, Heidelberg, 2. überarb. Aufl. 2006)

Module: Specialization II

Module No.: physics630

Course: Magnetism/Superconductivity

Course No.: physics634

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
To give an introduction to the standard theories of both fields as major example of collective phenomena in condensed-matter physics and comparison with experiments

Contents of the Course:
Magnetism:
orbital and spin magnetism without interactions, exchange interactions, phase transitions, magnetic ordering and domains, magnetism in 1-3 dimensions, spin waves (magnons), itinerant magnetism, colossal magnetoresistance
Superconductivity:
macroscopic aspects, type I and type II superconductors, Ginzburg-Landau theory, BCS theory, Josephson effect, superfluidity, high-temperature superconductivity

Recommended Literature:
L. P. Lévy: Magnetism and superconductivity (Springer; Heidelberg 2000)
P. Mohn: Magnetism in the Solid State - An Introduction (Springer, Heidelberg 2005)
J. Crangle: Solid State Magnetism, Van Nostrand Reinhold (Springer, New York 1991)
C. N. R. Rao, B. Raveau: Colossal Magnetoresistance [...] of Manganese Oxides (World Scientific 2004)
J. F. Annett: Superconductivity, super fluids and condensates (Oxford University Press 2004)
A. Mourachkine: High-Temperature Superconductivity in Cuprates [...] (Springer/Kluwer, Berlin 2002)

Module: Specialization II

Module No.: physics630

Course: Laser Spectroscopy

Course No.: physics635

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Make the students understand the principles of spectroscopy and enable them to practically apply their knowledge in research and development.

Contents of the Course:
Spectroscopy phenomena - time and frequency domain;
high resolution spectroscopy;
pulsed spectroscopy; frequency combs;
coherent spectroscopy; nonlinear spectroscopy: Saturation, Raman spectroscopy, Ramsey spectroscopy.
Single molecule spectroscopy; spectroscopy at interfaces & surfaces
Advanced optical imaging;
spectroscopy of cold atoms;
atomic clocks; atom interferometry

Recommended Literature:
W. Demtröder; Laser spectroscopy (Springer 2002)
S. Svanberg; Atomic and molecular spectroscopy basic aspects and practical applications (Springer 2001)
A. Corney; Atomic and laser spectroscopy (Clarendon Press 1988)
N. B. Colthup, L. H. Daly, S. E. Wiberley; Introduction to infrared and Raman spectroscopy (Academic Press 1990)
P. Hannaford; Femtosecond laser spectroscopy (Springer New York 2005)
C. Rulliere; Femtosecond laser pulses: principles and experiments (Springer Berlin 1998)

Module: Specialization II

Module No.: physics630

Course: Molecular Physics II

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the second part of the core courses more complex issues of molecular spectra are introduced. The students will be enabled to analyze spectra of complex molecules which are subject to couplings between electronic, vibrational and rotational motions.
In the special courses basic and advanced molecular physics are applied to atmospherical and astronomical environments.
This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Vibrational modes of polyatomic molecules
- Fundamentals of point group symmetry
- Vibrational dipole moment and selection rules
- Characteristic ro-vibrational spectra of selected molecules
- Breakdown of Born-Oppenheimer Approximation
- Coupling of rotation and vibration
- Coupling of angular momenta in molecular physics

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module: Specialization II

Module No.: physics630

Course: Advanced Theoretical Particle Physics

Course No.: physics636

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Survey of methods of theoretical high energy physics beyond the standard model, in particular supersymmetry and extra dimensions in regard to current research

Contents of the Course:
Introduction to supersymmetry and supergravity,
Supersymmetric extension of the electroweak standard model,
Supersymmetric grand unification,
Theories of higher dimensional space-time,
Unification in extra dimensions

Recommended Literature:
J. Wess; J. Bagger; Supersymmetry and supergravity (Princeton University Press 1992)
H. P. Nilles, Supersymmetry, Supergravity and Particle Physics, Physics Reports 110 C (1984) 1
D. Bailin; A. Love; Supersymmetric Gauge Field Theory and String Theory (IOP Publishing Ltd. 1994)
M. F. Sohnius; Introducing supersymmtry, (Phys.Res. 128 C (1985) 39)
P. Freund; Introduction to Supersymmetry (Cambridge University Press 1995)

Module: Specialization II

Module No.: physics630

Course: Advanced Theoretical Hadron Physics

Course No.: physics637

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
physics616 (Theoretical Hadron Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Survey of methods of theoretical hadron physics in regard to current research

Contents of the Course:
Quantum Chromodynamics: Nonperturbative Results, Confinement
Lattice Gauge Theory
Chiral Perturbation Theory
Effective Field Theory for Heavy Quarks

Recommended Literature:
F. E. Close; An Introduction Quarks and Partons (Academic Press 1980)
F. Donoghue, E. Golowich, B. R. Holstein, Dynamics of the Standard Model (Cambridge University Press 1994)
C. Itzykson, J.-B. Zuber; Quantum Field Theory (Dover Publications 2006)
A. V. Manohar, M. B. Wise; Heavy Quark Physics (Cambridge University Press 2000)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Module: Specialization II

Module No.: physics630

Course: Advanced Theoretical Condensed Matter Physics

Course No.: physics638

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
physics617 (Theoretical Condensed Matter Physics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Survey of methods of theoretical condensed matter physics and their application to prominent examples in regard to current research

Contents of the Course:
Bosonic systems:
Bose-Einstein condensation
Photonics

Quantum dynamics of many-electrons systems:
Feynman diagram technique for many-particle systems at finite temperature
Quantum magnetism, Kondo effect, Renormalization group techniques
Disordered systems: Electrons in a random potential
Superconductivity

Recommended Literature:
A. A. Abrikosov, L.P. Gorkov; Methods of Quantum Field Theory in Statistical Physics (Dover, New York 1977)
W. Nolting; Grundkurs Theoretische Physik Band 7: Vielteilchentheorie (Springer, Heidelberg 2002)
A. C. Hewson, The Kondo Problem to Heavy Fermions (Cambridge University Press, 1997)
C. Itzykson, J.-M. Drouffe; Statistical Field Theory (Cambridge University Press 1991)
J. R. Schrieffer; Theory of Superconductivity (Benjamin/Cummings, Reading/Mass, 1983)

Module No.: physics700
Credit Points (CP):
Category: Elective
Semester: 7.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Elective Advanced Lectures

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
1.	Selected 700-courses from catalogue	physics711-729	4-6	see catalogue	120-180 hrs	WT/ST
Condensed Matter and Photonics						
1.	Selected 700-courses from catalogue	physics731-749	3-6	see catalogue	90-180 hrs	WT/ST
Theoretical Physics						
1.	Selected 700-courses from catalogue	physics751-769	5-7	see catalogue	150-210 hrs	WT/ST
Special Topics						
1.	Selected 700-courses from catalogue	physics771-779	3-6	see catalogue	90-180 hrs	WT/ST
Research Internship						
1.	Internships in the Research Groups	physics799	4	internship		WT/ST
Cologne Courses						
1.	Courses from Cologne marked "E", "A", or "T"	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
1.	Also possible classes from M.Sc. in Astrophysics					

Requirements:

Preparation:

Content:
Special lectures on research topics of the physics section of the Bonn University

Aims/Skills:
The students are offered the opportunity to get insight into today's research problems

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the module examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The students must obtain 18 CP in all out of the modules physics700, -710, -720, -730.

Module No.: physics710
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Experimental Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 700-courses from catalogue type "E" (Experimental) or "E/A" (E/Applied)	see catalogue	3-6	see catalogue	90-180 hrs	ST/WT
2.	Courses from Cologne marked "E"	see catalogue	3-5	see catalogue	90-150 hrs	WT/ST
3.	Also possible classes from M.Sc. in Astrophysics					

Requirements:

Preparation:

Content:
Advanced lectures in experimental physics from the catalogue of selected courses

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The students must obtain 18 CP in all out of the modules physics700, -710, -720, -730.

Module No.: physics720
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Applied Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 700-courses from catalogue type "A" (Applied) or "E/A" (Experimental/A)	see catalogue	3-6	see catalogue	90-180 hrs	ST/WT
2.	Courses from Cologne marked "A"	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
3.	Also possible classes from M.Sc. in Astrophysics					

Requirements:

Preparation:

Content:
Advanced lectures in applied physics from the catalogue of selected courses

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The students must obtain 18 CP in all out of the modules physics700, -710, -720, -730.

Module No.: physics730
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 700-courses from catalogue type "T" (Theoretical)	see catalogue	3-7	see catalogue	90-210 hrs	ST/WT
2.	Courses from Cologne marked "T"	see catalogue	4-8	see catalogue	120-240 hrs	WT/ST
3.	Also possible classes from M.Sc. in Astrophysics					

Requirements:

Preparation:

Content:
Advanced lectures in theoretical physics from the catalogue of selected courses.

Aims/Skills:
Preparation for Master's Thesis work; broadening of scientific knowledge

Form of Testing and Examination:
Requirements for the submodule examination (written examination): successful work with the exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: The students must obtain 18 CP in all out of the modules physics700, -710, -720, -730.

Module No.: physics650
Credit Points (CP): 4
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Seminar

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminars on Current Topics in Particle Physics		4	seminar	120 hrs	ST
2.	Seminars on Current Topics in Condensed Matter and Photonics		4	seminar	120 hrs	ST
3.	Seminars on Current Topics in Theoretical Physics		4	seminar	120 hrs	ST

Requirements:

Preparation:

Content:
Topics from the research areas covered by the research group, including current journal literature

Aims/Skills:
The students shall learn to explore a specific scientific topic with the help of libraries and electronic media. The presentation must be concise and structured

Form of Testing and Examination:
Presentation of the topic

Length of Module: 1 semester

Maximum Number of Participants: 20 per seminar

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.: physics910
Credit Points (CP): 15
Category: Required
Semester: 9.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Scientific Exploration of the Master Thesis Topic

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Scientific Exploration of the Master Thesis Topic	physics911	15		450 hrs	WT

Requirements:
Successful completion of 40 credit points from the first year of the Master phase, including the Base Modules physics600 and physics605 and the Specialization Modules physics610 and physics630

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall explore the science field, read the relevant recent literature, and perhaps participate in further specialised classes and in seminars. The student shall write an essay about the acquired knowledge, which may serve as the introduction part of the M.Sc. thesis

Aims/Skills:
The student shall demonstrate to have understood the scientific question to be studied in the Master Thesis

Form of Testing and Examination:
Essay

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.: physics920
Credit Points (CP): 15
Category: Required
Semester: 9.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Methods and Project Planning

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Methods and Project Planning	physics921	15		450 hrs	WT

Requirements:
Successful completion of 40 credit points from the first year of the Master phase, including the Base Modules physics600 and physics605 and the Specialization Modules physics610 and physics630

Preparation:

Content:
Under guidance of the supervisor of the planned Master Thesis topic, the student shall acquire knowledge about the methods required to carry out the Master Thesis project. This may include the participation in specialised seminars or specialised classes for the master programme. The student shall plan the steps needed to successfully complete the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the methods to be used in the Master Thesis research. The project plan has to be presented

Form of Testing and Examination:
Short proposal for Master Thesis

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.: physics930
Credit Points (CP): 30
Category: Required
Semester: 10.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Master Thesis

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Master Thesis	physics931	30		900 hrs	ST

Requirements:
Successful completion of the preparatory phase for the Master Thesis (physics910 and physics920)

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall carry out the research of the Master Thesis project

Aims/Skills:
The student shall demonstrate to be able to do research

Form of Testing and Examination:
Master Thesis and oral presentation

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Catalogue of

700-courses in

Particle Physics

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Particle Astrophysics and Cosmology (E)

Course No.: physics711

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
physics611 (Particle Physics), useful: Lectures Observational Astronomy

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Basics of particle astrophysics and cosmology

Contents of the Course:
Observational Overview (distribution of galaxies, redshift, Hubble expansion, CMB, cosmic distance latter, comoving distance, cosmic time, comoving distance and redshift, angular size and luminosity distance); Standard Cosmology (cosmological principle, expansion scale factor, curved space-time, horizons, Friedmann-Equations, cosmological constant, cosmic sum rule, present problems); Particle Physics relevant to cosmology (Fundamental Particles and their Interactions, quantum field theory and Lagrange formalism, Gauge Symmetry, spontaneous symmetry breaking and Higgs mechanism, parameters of the Standard Model, Running Coupling Constants, CP Violation and Baryon Asymmetry, Neutrinos); Thermodynamics in the Universe (Equilibrium Thermodynamics and freeze out, First Law and Entropy, Quantum Statistics, neutrino decoupling, reheating, photon decoupling); Nucleosynthesis (Helium abundance, Fusion processes, photon/baryon ratio)
Dark Matter (Galaxy Rotation Curves, Clusters of Galaxies, Hot gas, Gravitational lensing, problems with Cold Dark Matter Models, Dark Matter Candidates); Inflation and Quintessence; Cosmic Microwave Background (origin, intensity spectrum, CMB anisotropies, Temperature correlations, power spectrum, cosmic variance, density and temperature fluctuations, causality and changing horizons, long and short wavelength modes, interpretation of the power spectrum)

Recommended Literature:
A. Liddle; An Introduction to Modern Cosmology (Wiley & Sons 2. Ed. 2003)
E. Kolb, M. Turner; The Early Universe (Addison Wesley 1990)
J. Peacock; Cosmological Physics (Cambridge University Press 1999)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Advanced Electronics and Signal Processing (E/A)

Course No.: physics712

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Electronics laboratory of the B.Sc. in physics programme
Recommended: module nuclear and particle physics of the B.Sc. programme

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Comprehension of the basics of electronics circuits for the processing of (detector) signals, mediation of the basics of experimental techniques regarding electronics and micro electronics as well as signal processing

Contents of the Course:
The physics of electronic devices, junctions, transistors (BJT and FET), standard analog and digital circuits, amplifiers, elements of CMOS technologies, signal processing, ADC, DAC, noise sources and noise filtering, coupling of electronics to sensors/detectors, elements of chip design, VLSI electronics, readout techniques for detectors

Recommended Literature:
P. Horowitz, W. Hill; The Art of Electronics (Cambridge University Press 2. Aufl. 1989)
S. Sze; The Physics of Semiconductor Devices (Wiley & Sons 1981)
H. Spieler, Semiconductor detector system (Oxford University Press 2005))
J. Krenz; Electronics Concepts (Cambridge University Press 2000)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: universitätbonn Particle Detectors and Instrumentation (E/A)

Course No.: physics713

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with laboratory	English	3+1	6	ST

Requirements:

Preparation:
Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Designing an experiment in photoproduction on pi-0, selection and building of appropriate detectors, set-up and implementation of an experiment at ELSA

Contents of the Course:
Quark structure of mesons and baryons, nucleon excitation; electromagnetic probes, electron accelerators, photon beams, relativistic kinematics interaction of radiation with matter, detectors for photons, leptons and hadrons; laboratory course: setup of detectors and experiment at ELSA

Recommended Literature:
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 6. Aufl. 2004)
Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
W. R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2. Ed. 1994)
K. Kleinknecht; Detektoren für Teilchenstrahlung (Teubner, Wiesbaden 4. überarb. Aufl. 2005)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Advanced Accelerator Physics (E/A)

Course No.: physics714

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST/WT

Requirements:

Preparation:
Accelerator Physics (physics612)

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the physics of synchrotron radiation and its influence on beam parameters
Basic knowledge of collective phenomena in particle accelerators
General knowledge of applications of particle accelerators (research, medicine, energy management)

Contents of the Course:
Synchrotron radiation:
radiation power, spatial distribution, spectrum, damping, equilibrium beam emittance, beam lifetime
Space-charge effects:
self-field and wall effects, beam-beam effects, space charge dominated beam transport, neutralization of beams by ionization of the residual gas
Collective phenomena:
wake fields, wake functions and coupling impedances, spectra of a stationary and oscillating bunches, bunch interaction with an impedance, Robinson instability
Applications of particle accelerators:
medical accelerators, neutrino facilities, free electron lasers, nuclear waste transmutation, etc.

Recommended Literature:
F. Hinterberger; Physik der Teilchenbeschleuniger und Ionenoptik (Springer, Heidelberg 1997)
H. Wiedemann; Particle Accelerator Physics (Springer, Heidelberg 2 Aufl. 1999)
K. Wille; Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen (Teubner, Wiesbaden 2. Aufl. 1996)
D. A. Edwards, M.J. Syphers; An Introduction to the Physics of High Energy Accelerators (Wiley & Sons 1993)
A. Chao; Physics of Collective Beam Instabilities in High Energy Accelerators (Wiley & Sons 1993)
Script of the Lecture Particle Accelerators (physics612)
http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/

Modules:	physics700 **Elective Advanced Lectures** physics710 **Experimental Physics**

Course: universitätbonn Experiments on the Structure of Hadrons (E)

Course No.: physics715

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:
Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the structure of the nucleon, understanding experiments on baryon-spectroscopy, methods of identifying resonance contributions, introduction into current issues in meson-photoproduction

Contents of the Course:
Discoveries in hadron physics, quarks, asymptotic freedom and confinement; multiplets, symmetries, mass generation; quark models, baryon spectroscopy, formation and decay of resonances, meson photoproduction; hadronic molecules and exotic states

Recommended Literature:
Perkins, Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
K. Gottfried, F. Weisskopf; Concepts of Particle Physics (Oxford University Press 1986)
A. Thomas, W. Weise, The Structure of the Nucleon (Wiley-VCH, Weinheim, 2001)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Statistical Methods of Data Analysis (E)

Course No.: physics716

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Provide a foundation in statistical methods and give some concrete examples of how the methods are applied to data analysis in particle physics experiments

Contents of the Course:
Fundamental concepts of statistics, probability distributions, Monte Carlo methods, fitting of data, statistical and systematic errors, error propagation, upper limits, hypothesis testing, unfolding

Recommended Literature:
R. Barlow: A Guide to the Use of Statistical Methods in the Physical Sciences; J. Wiley Ltd. Wichester 1993
S. Brandt: Datenanalyse (Spektrum Akademischer Verlag, Heidelberg 4. Aufl. 1999)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: High Energy Physics Lab (E)

Course No.: physics717

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English		4	WT/ST

Requirements:

Preparation:
Recommended: B.Sc. in physics, physics611 (Particle Physics) or physics618 (Physics of Particle Detectors)

Form of Testing and Examination:
Credit points can be obtained after completion of a written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
This is a research internship in one of the high energy physics research groups which prepare and carry out experiments at external accelerators. The students deepen their understanding of particle and/or detector physics by conducting their own small research project as a part-time member of one of the research groups. The students learn methods of scientific research in particle physics data analysis, in detector development for future colliders or in biomedical imaging (X-FEL) and present their work at the end of the project in a group meeting.

Contents of the Course:
Several different topics are offered among which the students can choose. Available projects can be found at http://heplab.physik.uni-bonn.de. For example:
- Analysis of data from one of the large high energy physics experiments (ATLAS, DØ, ZEUS)
- Investigation of low-noise semiconductor detectors using cosmic rays, laser beams or X-ray tubes
- Study of particle physics processes using simulated events
- Signal extraction and data mining with advanced statistical methods (likelihoods, neural nets or boosted decision trees)

Recommended Literature:
Will be provided by the supervisor

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Programming in Physics and Astronomy with C++ or Python (E/A)

Course No.: physics718

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Basic knowledge of programming and knowledge of simple C/C++ or Python constructs.

Form of Testing and Examination:
C/C++ part: Requirements for the examination (written or oral): successful work with the exercises.
Python part: Requirements for examination: successful implementation of the scientific projects in Python during the semester.

Length of Course:
1 semester

Aims of the Course:
C++ part: In-depth understanding of C++ and its applications in particle physics. Discussion of advanced features of C++ using examples from High Energy Physics. The course is intended for students with some background in C++ or for advanced students who wish to apply C++ in their graduate research.
Python part: Effective and flexible program solving with the easy-to-learn, high level programming language Python. The course addresses master and PhD students with prior Python-programming knowledge as taught in the bachelor course physics131.

Contents of the Course:
C++ part: - Basic ingredients of C++, - Object orientation: classes, inheritance, polymorphism, - How to solve physics problems with C++, - Standard Template Library, - C++ in data analysis, example: the ROOT library, - C++ and large scale calculations, - How to write and maintain complex programs, - Parallel computing and the Grid, - Debugging and profiling
Python part: - In-depth introduction to Python based on prior programming experience, - Introduction to numpy arrays (primary Python data structure for scientific computing), - Introduction to scientific-Python modules (scipy, astropy), - Interactive work / development with Python (ipython), - Web interaction with Python (jupyter notebooks, web and database queries), - Plotting with Python (the matplotlib module)

Recommended Literature:
Eckel: Thinking in C++, Prentice Hall 2000.
Lippman, Lajoie, Moo: C++ Primer, Addison-Wesley 2000.
Deitel and Deitel, C++ how to program, Prentice Hall 2007.
Stroustrup, The C++ Programming Language, Addison-Wesley 2000.

- The course is given in the summer term and alternates between C++ and Python
- The course can only be taken once for credit points.

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Physics with Antiprotons (E)

Course No.: physics720

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:
Completed B.Sc. in Physics, with experience in quantum mechanics, atomic- and nuclear physics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Insight in current research topics with antiprotons, understanding experimental methods in particle and nuclear physics, understanding interrelations between different fields of physics such as hadron physics, (astro-)particle physics, atomic physics

Contents of the Course:
Matter-antimatter asymmetry, test of the standard model, anti-hydrogen, anti-protonic atoms, antiproton beams, key issues in hadron physics with antiprotons, planned research facilities (FAIR) and experiments (PANDA)

Recommended Literature:
B. Povh, K. Rith, C. Scholz, F. Zetsche; Teilchen und Kerne (Springer, Heidelberg 8. Aufl. 2009)
D.H. Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)
further literature will be given in the lecture

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Intensive Week: Advanced Topics in Hadron Physics (E)

Course No.: physics721

Category	Type	Language	Teaching hours	CP	Semester
Elective	Combined lecture, seminar, lab course	English	3	4	WT/ST

Requirements:

Preparation:
Fundamentals of hadron physics

Form of Testing and Examination:
Presentation, working group participation

Length of Course:
1 - 2 weeks

Aims of the Course:
This course will convey recent topics in hadron physics. Guided by lectures, original publications and tutors, the students will prepare a proposal for a planned or recent experiment. The class will not only focus on the experimental aspects, but also on the theoretical motivation for the experiment.

Contents of the Course:
As announced in the course catalogue. The main topics will vary from semester to semester.

Recommended Literature:
Will be given in the lecture

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Advanced Gaseous Detectors - Theory and Practice (E)

Course No.: physics722

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with laboratory	English	3+1	6	ST

Requirements:

Preparation:
Completed B.Sc. in physics, with experience in electrodynamics, quantum mechanics, nuclear and particle physics, physics618 (Physics of Particle Detectors)

Form of Testing and Examination:
Form of examination: written or oral report

Length of Course:
1 semester

Aims of the Course:
- Design, construction, commissioning and characterization of a modern gaseous particle detector
- Simulations: GARFIELD, GEANT, FE-Methods, etc.
- Signals, Readout electronics and Data Acquisition
- Data analysis: pattern recognition methods, track fitting
- Scientific writing: report

Contents of the Course:
- Signal formation in detectors
- Microscopic processes in gaseous detectors
- Readout electronics
- Tools for detector design and simulation
- Performance criteria
- Laboratory course: commissioning of detector with sources, beam test at accelerator
- Track reconstruction

Recommended Literature:
http://root.cern.ch
http://garfieldpp.web.cern.ch/garfieldpp/
Blum, Rolandi, Riegler: Particle Detection with Drift Chambers
Spieler: Semiconductor Detector Systems

Catalogue of

700-courses in

Condensed Matter &

Photonics

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Low Temperature Physics (E/A)

Course No.: physics731

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT/ST

Requirements:

Preparation:
Elementary thermodynamics; principles of quantum mechanics; introductory lecture on solid state physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Experimental methods at low (down to micro Kelvin) temperatures; methods of refrigeration; thermometry; solid state physics at low temperatures

Contents of the Course:
Thermodynamics of different refrigeration processes, liquefaction of gases; methods to reach low (< 1 Kelvin) temperatures: evaporation cooling, He-3-He-4 dilution cooling, Pomeranchuk effect, adiabatic demagnetisation of atoms and nuclei; thermometry at low temperatures (e.g. helium, magnetic thermometry, noise thermometry, thermometry using radioactive nuclei); principles for the construction of cryostats for low temperatures

Recommended Literature:
O.V. Lounasmaa; Experimental Principles and Methods Below 1K (Academic Press, London 1974)
R.C. Richardson, E.N. Smith; Experimental Techniques in Condensed Matter Physics at Low Temperatures (Addison-Wesley 1988)
F. Pobell, Matter and Methods at Low Temperatures (Springer-Verlag, Heidelberg 2. Aufl. 1996)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Optics Lab (E/A)

Course No.: physics732

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English		4	WT/ST

Requirements:

Preparation:

Form of Testing and Examination:
Credit points can be obtained after completion of a written report.

Length of Course:
4-6 weeks

Aims of the Course:
The student learns to handle his/her own research project within one of the optics groups

Available projects and contact information can be found at: http://www.iap.uni-bonn.de/opticslab/

Contents of the Course:
Practical training/internship in a research group, which can have several aspects:
- setting up a small experiment
- testing and understanding the limits of experimental components
- simulating experimental situations

Recommended Literature:
Will be given by the supervisor

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Holography (E/A)

Course No.: physics734

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to provide in-depth knowledge and to provide practical abilities in the field of holography as an actual topic of applied optics

Contents of the Course:
The course will cover the basic principle of holography, holographic recording materials, and applications of holography. In the first part the idea behind holography will be explained and different hologram types will be discussed (transmission and reflection holograms; thin and thick holograms; amplitude and phase holograms; white-light holograms; computer-generated holograms; printed holograms). A key issue is the holographic recording material, and several material classes will be introduced in the course (photographic emulsions; photochromic materials; photo-polymerization; photo-addressable polymers; photorefractive crystals; photosensitive inorganic glasses). In the third section several fascinating applications of holography will be discussed (art; security-features on credit cards, banknotes, and passports; laser technology; data storage; image processing; filters and switches for optical telecommunication networks; novelty filters; phase conjugation ["time machine"]; femtosecond holography; space-time conversion). Interested students can also participate in practical training. An experimental setup to fabricate own holograms is available

Recommended Literature:
Lecture notes;
P. Hariharan; Optical Holography - Principles, Techniques, and Applications (Cambridge University Press, 2nd Edition, 1996)
P. Hariharan; Basics of Holography (Cambridge University Press 2002)
J. W. Goodman; Introduction to Fourier Optics (McGraw-Hill Education - Europe 2nd Ed. 2000)
A. Yariv; Photonics (Oxford University Press 6th Ed. 2006)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Laser Cooling and Matter Waves (E)

Course No.: physics735

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT/ST

Requirements:

Preparation:
Basic thermodynamics: fundamentals of quantum mechanics, fundamentals of solid state physics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The in-depth lecture shows, in theory and experiments, the fundamentals of laser cooling. The application of laser cooling in atom optics, in particular for the preparation of atomic matter waves, is shown. New results in research with degenerated quantum gases enable us to gain insight into atomic many particle physics

Contents of the Course:
Outline: Light-matter interaction; mechanic effects of light; Doppler cooling; polarization gradient cooling, magneto-optical traps; optical molasses; cold atomic gases; atom interferometry; Bose-Einstein condensation of atoms; atom lasers; Mott insulator phase transitions; mixtures of quantum gases; fermionic degenerate gases

Recommended Literature:
P. v. d. Straten, H. Metcalf; Laser Cooling (Springer, Heidelberg 1999)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Crystal Optics (E/A)

Course No.: physics736

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Because of their aesthetic nature crystals are termed "flowers of mineral kingdom". The aesthetic aspect is closely related to the symmetry of the crystals which in turn determines their optical properties. It is the purpose of this course to stimulate the understanding of these relations. The mathematical and tools for describing symmetry and an introduction to polarization optics will be given before the optical properties following from crystal symmetry are discussed. Particular emphasis will be put on the magneto-optical properties of crystals in magnetic internal or external fields. Advanced topics such as the determination of magnetic structures and interactions by nonlinear magneto-optics will conclude the course

Contents of the Course:
Crystal classes and their symmetry; basic group theory; polarized light; optical properties in the absence of fields; electro-optical properties; magneto-optical properties: Faraday effect, Kerr effect, magneto-optical materials and devices, semiconductor magneto-optics, time-resolved magneto-optics, nonlinear magneto-optics

Recommended Literature:
R. R. Birss, Symmetry and Magnetism, North-Holland (1966)
R. E. Newnham: Properties of Materials: Anisotropy, Symmetry, Structure, Oxford University (2005)
A. K. Zvezdin, V. A. Kotov: Modern Magnetooptics & Magnetooptical Materials, Taylor/Francis (1997)
Y. R. Shen: The Principles of Nonlinear Optics, Wiley (2002)
K. H. Bennemann: Nonlinear Optics in Metals, Oxford University (1999)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Intensive Week: Advanced Topics in Photonics and Quantum Optics (E)

Course No.: physics737

Category	Type	Language	Teaching hours	CP	Semester
Elective	Combined lecture, seminar, lab course	English	3	4	WT/ST

Requirements:

Preparation:
Fundamentals of optics, fundamentals of quantum mechanics

Form of Testing and Examination:
Seminar or oral examination

Length of Course:
1 - 2 weeks

Aims of the Course:
The intensive course will convey the basics of a recent topic in photonics or quantum optics in theory and experiments. Guided by a combination of lectures, seminar talks (based on original publications) and practical training, the participants will gain insight into recent developments in photonics/quantum optics.

Contents of the Course:
Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:
Will be given in the lecture

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Lecture on Advanced Topics in Quantum Optics (E)

Course No.: physics738

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements:

Preparation:
Fundamentals of Quantum Mechanics, Atomic Physics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce the students to a special field of research in quantum optics. New research results will be presented and their relevance is discussed.

Contents of the Course:
Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:
Will be given in the lecture

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: universitätbonn Lecture on Advanced Topics in Photonics (E/A)

Course No.: physics739

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements:

Preparation:
Optics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce the students to a special field of research in photonics. New research results will be presented and their relevance is discussed.

Contents of the Course:
Will be given in the bulletin of lectures. The main theme will vary from term to term

Recommended Literature:
Will be given in the lecture

This course may be offered as "Teaching hours (3+1)" with 6 cp, as well

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Hands-on Seminar: Experimental Optics and Atomic Physics (E/A)

Course No.: physics740

Category	Type	Language	Teaching hours	CP	Semester
Elective	Laboratory	English	2	3	WT/ST

Requirements:

Preparation:
Fundamentals of optics and quantum mechanics

Form of Testing and Examination:
Credit points can be obtained after successful carrying out the experiments and preparing a written report on selected experiments

Length of Course:
1 semester

Aims of the Course:
The students learn to handle optical setups and carry out optical experiments. This will prepare participants both for the successful completion of research projects in experimental quantum optics/photonics and tasks in the optics industry.

Contents of the Course:
Practical training in the field of optics, where the students start their experiment basically from scratch (i.e. an empty optical table). The training involves the following topics:
- diode lasers
- optical resonators
- acousto-optic modulators
- spectroscopy
- radiofrequency techniques

Recommended Literature:
Will be given by the supervisor

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Modern Spectroscopy (E/A)

Course No.: physics741

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements:

Preparation:
Fundamentals of Optics, Fundamentals of Quantum Mechanics

Form of Testing and Examination:
Requirements for the examination (oral or written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to introduce the students to both fundamental and advanced concepts of spectroscopy and enable them to practically apply their knowledge.

Contents of the Course:
Spectroscopy phenomena - time and frequency domain;
high resolution spectroscopy;
pulsed spectroscopy; frequency combs;
coherent spectroscopy;
nonlinear spectroscopy: Saturation, Raman spectroscopy, Ramsey spectroscopy.
Applications of spectroscopic methods (e.g. Single molecule spectroscopy; spectroscopy at interfaces & surfaces, spectroscopy of cold atoms; atomic clocks; atom interferometry)

Recommended Literature:
W. Demtröder; Laser spectroscopy (Springer 2002)
S. Svanberg; Atomic and molecular spectroscopy basic aspects and practical applications (Springer 2001)
A. Corney; Atomic and laser spectroscopy (Clarendon Press 1988)
N. B. Colthup, L. H. Daly, S. E. Wiberley; Introduction to infrared and Raman spectroscopy (Academic Press 1990)
P. Hannaford; Femtosecond laser spectroscopy (Springer New York 2005)
C. Rulliere; Femtosecond laser pulses: principles and experiments (Springer Berlin 1998)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics730 **Theoretical Physics**

Course: Ultracold Atomic Gases (E/T)

Course No.: physics742

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Quantum Mechanics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
This lecture discusses both the experimental and theoretical concepts of ultra-cold atomic gases.

Contents of the Course:
Almost hundred years ago, in 1924, A. Einstein and S.N. Bose predicted the existence of a new state of matter, the so-called Bose-Einstein condensate. It took 70 years to successfully realize this macroscopic quantum state in the lab using ultracold atomic gases (Nobel prize 2001). The main challenge was to achieve cooling to Nanokelvin temperatures, the coolest temperatures ever reached by mankind. Nowadays, ultracold gases are exciting systems to study a broad range of quantum phenomena. These phenomena range from the direct observation of quantum matter waves and superfluidity over the creation of artificial crystal structures as analogous to solids, to the realization of complex quantum phase transitions of interacting atoms, e.g. the formation of a bosonic Mott-insulator or the BCS superconducting state for Fermions. In this lecture we will discuss both the experimental and theoretical concepts of ultra-cold atomic gases.

Outline: Introduction and revision of basic concepts, Fundamentals of atom-laser interaction
Laser cooling & trapping, Bose-Einstein condensation of atomic gases. Dynamics of Bose-Einstein condensates
Optical lattices: strongly interacting atomic gases and quantum phase transitions
The crossover of Fermi-gases between a BCS superconducting state and a Bose-Einstein condensate of molecules.

Recommended Literature:
C. J. Pethick and H. Smith, Bose-Einstein Condensation in Dilute Gases (Cambridge University Press)

Catalogue of

700-courses in

Theoretical Physics

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics730 **Theoretical Physics**

Course: Ultracold Atomic Gases (E/T)

Course No.: physics742

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Quantum Mechanics

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
This lecture discusses both the experimental and theoretical concepts of ultra-cold atomic gases.

Contents of the Course:
Almost hundred years ago, in 1924, A. Einstein and S.N. Bose predicted the existence of a new state of matter, the so-called Bose-Einstein condensate. It took 70 years to successfully realize this macroscopic quantum state in the lab using ultracold atomic gases (Nobel prize 2001). The main challenge was to achieve cooling to Nanokelvin temperatures, the coolest temperatures ever reached by mankind.
Nowadays, ultracold gases are exciting systems to study a broad range of quantum phenomena. These phenomena range from the direct observation of quantum matter waves and superfluidity over the creation of artificial crystal structures as analogous to solids, to the realization of complex quantum phase transitions of interacting atoms, e.g. the formation of a bosonic Mott-insulator or the BCS superconducting state for Fermions. In this lecture we will discuss both the experimental and theoretical concepts of ultra-cold atomic gases.

Outline: Introduction and revision of basic concepts, Fundamentals of atom-laser interaction
Laser cooling & trapping, Bose-Einstein condensation of atomic gases. Dynamics of Bose-Einstein condensates
Optical lattices: strongly interacting atomic gases and quantum phase transitions
The crossover of Fermi-gases between a BCS superconducting state and a Bose-Einstein condensate of molecules.

Recommended Literature:
C. J. Pethick and H. Smith, Bose-Einstein Condensation in Dilute Gases (Cambridge University Press)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Group Theory (T)

Course No.: physics751

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
physik421 (Quantum Mechanics)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Acquisition of mathematical foundations of group theory with regard to applications in theoretical physics

Contents of the Course:
Mathematical foundations:
Finite groups, Lie groups and Lie algebras, highest weight representations, classification of simple Lie algebras, Dynkin diagrams, tensor products and Young tableaux, spinors, Clifford algebras, Lie super algebras

Recommended Literature:
B. G. Wybourne; Classical Groups for Physicists (J. Wiley & Sons 1974)
H. Georgi; Lie Algebras in Particle Physics (Perseus Books 2. Aufl. 1999)
W. Fulton, J. Harris; Representation Theory (Springer, New York 1991)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Superstring Theory (T)

Course No.: physics752

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Quantum Field Theory (physics755)
Group Theory (physics751)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the

Length of Course:
1 semester

Aims of the Course:
Survey of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:
Bosonic String Theory, Elementary Conformal Field Theory
Kaluza-Klein Theory
Crash Course in Supersymmetry
Superstring Theory
Heterotic String Theory
Compactification, Duality, D-Branes
M-Theory

Recommended Literature:
D. Lüst, S. Theisen; Lectures on String Theory (Springer, New York 1989)
S. Förste; Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055
C. Johnson, D-Brane Primer (Cambridge University Press 2003)
M. Green, J. Schwarz, E. Witten; Superstring Theory I & II (Cambridge University Press 1988)
H.P. Nilles, Supersymmetry and phenomenology (Phys. Reps. 110 C (1984) 1)
J. Polchinski; String Theory I & II (Cambridge University Press 2005)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Theoretical Particle Astrophysics (T)

Course No.: physics753

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
General Relativity and Cosmology (physics754)
Quantum Field Theory (physics755)
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to the current status at the interface of particle physics and cosmology

Contents of the Course:
Topics on the interface of cosmology and particle physics:
Inflation and the cosmic microwave background;
baryogenisis,
Dark Matter,
nucleosynthesis
the cosmology and astrophysics of neutrinos

Recommended Literature:
J. Peacock, Cosmological Physics (Cambridge University Press 1998)
E. Kolb, M. Turner; The Early Universe (Addison Wesley 1990)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: General Relativity and Cosmology (T)

Course No.: physics754

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
physik221 and physik321 (Theoretical Physics I and II)
Differential geometry

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the general theory of relativity and its cosmological implications

Contents of the Course:
Relativity principle
Gravitation in relativistic mechanics
Curvilineal coordinates
Curvature and energy-momentum tensor
Einstein-Hilbert action and the equations of the gravitational field
Black holes
Gravitational waves
Time evolution of the universe
Friedmann-Robertson-Walker solutions

Recommended Literature:
S.Weinberg; Gravitation and Cosmology (J. Wiley & Sons 1972)
R. Sexl: Gravitation und Kosmologie, Eine Einführung in die Allgemeine Relativitätstheorie (Spektrum Akadem. Verlag 5. Aufl 2002)
L.D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.2: Classical field theory (Butterworth-Heinemann 1995), also available in German from publisher Harry Deutsch

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Quantum Field Theory (T)

Course No.: physics755

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
Advanced quantum theory (physics606)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding quantum field theoretical methods, ability to compute processes in quantum electrodynamics (QED) and many particle systems

Contents of the Course:
Classical field theory
Quantization of free fields
Path integral formalism
Perturbation theory
Methods of regularization: Pauli-Villars, dimensional
Renormalizability
Computation of Feynman diagrams
Transition amplitudes in QED
Applications in many particle systems

Recommended Literature:
N. N. Bogoliubov, D.V. Shirkov; Introduction to the theory of quantized fields (J. Wiley & Sons 1959)
M. Kaku, Quantum Field Theory (Oxford University Press 1993)
M. E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Harper Collins Publ. 1995)
L. H. Ryder; Quantum Field Theory (Cambridge University Press 1996)
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Critical Phenomena (T)

Course No.: physics756

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
Advanced quantum theory (physics606)
Theoretical condensed matter physics (physics617)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Acquisition of important methods to treat critical phenomena

Contents of the Course:
Mean Field Approximation and its Improvements
Critical Behaviour at Surfaces
Statistics of Polymers
Concept of a Tomonaga-Luttinger Fluid
Random Systems
Phase Transitions, Critical Exponents
Scale Behaviour, Conformal Field Theory
Special Topics of Nanoscopic Physics

Recommended Literature:
J. Cardy, Scaling and Renormalization in Statistical Physics (Cambridge University Press, 1996)
A. O. Gogolin, A. A. Nersesyan, A.N.Tsvelik; Bosonisation and strongly correlated systems (Cambridge University Press, 1998)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Effective Field Theory (T)

Course No.: physics757

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum Field Theory (physics755)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding basic properties and construction of Effective Field Theories, ability to perform calculations in Effective Field Theories

Contents of the Course:
Scales in physical systems, naturalness
Effective Quantum Field Theories
Renormalization Group, Universality
Construction of Effective Field Theories
Applications: effective field theories for physics beyond the Standard Model, heavy quarks, chiral dynamics, low-energy nuclear physics, ultracold atoms

Recommended Literature:
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)
J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)
A.V. Manohar, M.B. Wise; Heavy Quark Physics (Cambridge University Press 2007)
P. Ramond, Journeys Beyond The Standard Model (Westview Press 2003)
D.B. Kaplan, Effective Field Theories (arXiv:nucl-th/9506035)
E. Braaten, H.-W. Hammer; Universality in Few-Body Systems with Large Scattering Length (Phys. Rep. 428 (2006) 259)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: universitätbonn Quantum Chromodynamics (T)

Course No.: physics758

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Advanced quantum theory (physics606)
Quantum Field Theory (physics755)

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding basic properties of Quantum Chromodynamics, ability to compute strong interaction processes

Contents of the Course:
Quantum Chromodynamics as a Quantum Field Theory
Perturbative Quantum Chromodynamics
Topological objects: instantons etc.
Large N expansion
Lattice Quantum Chromodynamics
Effective Field Theories of Quantum Chromodynamics
Flavor physics (light and heavy quarks)

Recommended Literature:
S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)
M.E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Westview Press 1995)
F.J. Yndurain; The Theory of Quark and Gluon Interactions (Springer 2006)
J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)
E. Leader and E. Predazzi; An Introduction to Gauge Theories and Modern Particle Physics (Cambridge University Press 1996)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Computational Physics (T)

Course No.: physics760

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises and project work	English	2+2+1	7	WT/ST

Requirements:
Knowledge of a modern programming language (like C, C++)

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
successful participation in exercises,
presentation of an independently completed project

Length of Course:
1 semester

Aims of the Course:
ability to apply modern computational methods for solving physics problems

Contents of the Course:
Statistical Models, Likelihood, Bayesian and Bootstrap Methods
Random Variable Generation
Stochastic Processes
Monte-Carlo methods
Markov-Chain Monte-Carlo

Recommended Literature:
W.H. Press et al.: Numerical Recipes in C (Cambridge University Press)
http://library.lanl.gov/numerical/index.html
C.P. Robert and G. Casella: Monte Carlo Statistical Methods (Springer 2004)
Tao Pang: An Introduction to Computational Physics (Cambridge University Press)
Vesely, Franz J.: Computational Physics: An Introduction (Springer)
Binder, Kurt and Heermann, Dieter W.: Monte Carlo Simulation in Statistical Physics (Springer)
Fehske, H.; Schneider, R.; Weisse, A.: Computational Many-Particle Physics (Springer)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Supersymmetry (T)

Course No.: physics761

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT/ST

Requirements:
Quantum Field Theory I

Preparation:

Form of Testing and Examination:
Individual Oral Examinations

Length of Course:
1 semester

Aims of the Course:
Teach the students the basics of supersymmetric field theory and how it can be tested at the LHC.

Contents of the Course:
Superfields; Supersymmetric Lagrangians; MSSM; Testing the MSSM at the LHC

Recommended Literature:
Theory and phenomenology of sparticles: An account of four-dimensional N=1 supersymmetry in high energy physics.
M. Drees, (Bonn U.) , R. Godbole, (Bangalore, Indian Inst. Sci.) , P. Roy, (Tata Inst.) . 2004. 555pp.
Hackensack, USA: World Scientific (2004) 555 p.

Weak scale supersymmetry: From superfields to scattering events.
H. Baer, (Florida State U.) , X. Tata, (Hawaii U.) . 2006. 537pp.
Cambridge, UK: Univ. Pr. (2006) 537 p.

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Transport in mesoscopic systems (T)

Course No.: physics762

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements:

Preparation:
Classical mechanics
Elementary thermodynamics and statistical physics (physik521)
Advanced quantum theory (physics606)
Introductory theoretical condensed matter physics (physics617)

Form of Testing and Examination:
Requirements for the examination (written or oral); successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding essential transport phenomena in solids and mesoscopic systems
Acquisition of important methods for treating transport problems

Contents of the Course:
Linear response theory
Disordered and ballistic systems
Semiclassical approximation
Introduction to quantum chaos theory, chaos and integrability in classical and quantum mechanics
Elements of random matrix theory
Specific problems of mesoscopic transport (weak localization, universal conductance fluctuations, shot noise, spin-dependent transport, etc.)
Quantum field theory away from thermodynamic equilibrium

Recommended Literature:
K. Richter, Semiclassical Theory of Mesoscopic Quantum Systems, Springer, 2000 (http://www.physik.uni-regensburg.de/forschung/richter/richter/pages/research/springer-tracts-161.pdf)
M. Brack, R. K. Bhaduri, Semiclassical Physics, Westview Press, 2003
S. Datta, Electronic Transport in Mesoscopic Systems, Cambrige University Press, 1995
M. C. Gutzwiller, Chaos in Classical and Quantum Mechanics, Springer, New York, 1990
F. Haake, Quantum signatures of chaos, Springer, 2001
M. L. Mehta, Random matrices, Elsevier, 2004
J. Imry, Introduction to mesoscopic physics, Oxford University Press
Th. Giamarchi, The physics of one-dimensional systems, Oxford University Press

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Advanced Topics in String Theory (T)

Course No.: physics763

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:
Quantum Field Theory (physics755)
Group Theory (physics751)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Theoretical Particle Physics (physics615)
Superstring Theory (physics752)

Form of Testing and Examination:
active participation in exercises, written examination

Length of Course:
1 semester

Aims of the Course:
Detailed discussion of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:
Realistic compactifications
Interactions
Effective actions
Heterotic strings in four dimensions
Intersecting D-branes

Recommended Literature:
D. Lüst, S. Theisen: Lectures on String Theory (Springer, New York 1989)
S. Förste: Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055
C. Johnson: D-Brane Primer (Cambridge University Press 2003)
M. Green, J. Schwarz, E. Witten: Superstring Theory I & II (Cambridge University Press 1988)
H.P. Nilles: Supersymmetry and Phenomenology (Phys. Reps. 110C (1984)1)
J. Polchinski: String Theory I & II (Cambridge University Press 2005)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Advanced Topics in Field and String Theory (T)

Course No.: physics764

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:
Prerequisite knowledge of Quantum Field Theory, Superstring Theory, and General Relativity is helpful.

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Superstring Theory (physics752)

Form of Testing and Examination:
active participation in exercises, oral or written examination

Length of Course:
1 semester

Aims of the Course:
An introduction into modern topics in Mathematical High Energy Physics in regard to current research areas

Contents of the Course:
String and Supergravity Theories in various dimensions
Dualities in Field Theory and String Theory
Topological Field Theories and Topological Strings
Large N dualities and integrability

Recommended Literature:
Selected review articles an arXiv.org [hep-th]
J. Polchinski: String Theory I & II
S. Weinberg: Quantum Theory of Fields

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Advanced Topics in Quantum Field Theory (T)

universitätbonn

Course No.: physics765

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:
Prerequisite knowledge of Quantum Field Theory

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Form of Testing and Examination:
active participation in exercises, oral or written examination

Length of Course:
1 semester

Aims of the Course:
Covers advanced topics in Quantum Field Theory that are relevant for current developments in the field.

Contents of the Course:
TBA

Recommended Literature:
Selected articles on arXiv.org [hep-th]
TBA

Modules:	physics700 **Elective Advanced Lectures** physics730 **Theoretical Physics**

Course: universitätbonn Physics of Higgs Bosons (T)

Course No.: physics766

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Theoretical Particle Physics (physics615)

Form of Testing and Examination:
Requirement for the examination (written or oral): successful participation in the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the physics of electroweak symmetry breaking, and the interpretations of the recently discovered signals for the existence of a Higgs boson

Contents of the Course:
Spontaneous symmetry breaking
The Higgs mechanism
The Higgs boson of the Standard Model
Experimental situation
Extended Higgs sectors
Precision calculations

Recommended Literature:
J. Gunion, H.E. Haber, G.L. Kane and S. Dawson: The Higgs Hunter's Guide (Frontiers of Physics, 2000)
A. Djouadi: Anatomy of Electroweak Symmetry Breaking I (Phys. Rep. 457 (2008) 1, hep-ph/0503173)
A. Djouadi: Anatomy of Electroweak Symmetry Breaking II (Phys. Rep. 459 (2008) 1, hep-ph/0504090)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Computational Methods in Condensed Matter Theory (T)

Course No.: physics767

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Quantum Field Theory (physics755)
Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)
Advanced Theoretical Condensed Matter Physics (physics638)

Form of Testing and Examination:
Active participation in exercises, written examination

Length of Course:
1 semester

Aims of the Course:
Detailed discussion of computational tools in modern condensed matter theory

Contents of the Course:
Exact Diagonalization (ED)
Quantum Monte Carlo (QMC)
(Stochastic) Series expansion (SSE)
Density Matrix Renormalization (DMRG)
Dynamical Mean Field theory (DMFT)

Recommended Literature:
will be given in the lecture

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: General Relativity for Experimentalists (T)

Course No.: physics768

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:
Theoretische Physik I & II, Analysis I & II

Form of Testing and Examination:
Weekly homework sets (50% required), Final exam

Length of Course:
1 semester

Aims of the Course:
The students shall learn the basics of general relativity and be able to apply it to applications such as experimental tests of GR, GPS, astrophysical objects and simple issues in cosmology.

Contents of the Course:
Review of special relativity
Curved spacetime of GR
Experimental tests of GR
GPS
Black holes
Gravitational waves
Introductory cosmology

Recommended Literature:
GRAVITY, by James Hartle
A FIRST COURSE IN GENERAL RELATIVITY, by Bernard Schutz
EXPLORING BLACK HOLES, by Taylor and Wheeler

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Lattice QCD (T)

Course No.: physics769

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST/WT

Requirements:

Preparation:
Quantum Mechanics 1+2, Quantum Field Theory 1

Form of Testing and Examination:
Written / oral examination

Length of Course:
1 semester

Aims of the Course:
To give an introduction to the quantum field theory on the lattice

Contents of the Course:
- Introduction: Quantum mechanics on the lattice
- Numerical algorithms
- Spin systems on the lattice: The Ising model
- Scalar field theory on the lattice: Discretization; Perturbation theory; Continuum limit
- Gauge fields: Link variables; Plaquette action; Wilson loop and confinement
- Fermions on the lattice: Fermion doubling; Different formulations for lattice fermions; Axial anomaly; Chiral fermions
- Use of Effective Field Theory methods: Extrapolation in the quark masses; Resonances in a finite volume

Recommended Literature:
J. Smit, Introduction to quantum fields on a lattice: A robust mate, Cambridge Lect. Notes Phys. (2002)

I. Montvay and G. Münster, Quantum Fields on a Lattice, Cambridge Monographs on Mathematical Physics, Cambridge University Press 1994

C. Gattringer and Ch. Lang, Quantum Chromodynamics on the Lattice: An Introductory Presentation Series: Lecture Notes in Physics, Vol. 788

H.J. Rothe, Lattice Gauge Theories: An Introduction, World Scientific, (2005)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: universitätbonn Random Walks and Diffusion (T)

Course No.: physics7502

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	1+1	3	ST

Requirements:

Preparation:
Quantum mechanics and Thermodynamics

Form of Testing and Examination:
Requirements for the (written or oral) examination: Successful work within the exercises

Length of Course:
1 semester

Aims of the Course:
The aim of the course is to introduce the student to random processes and their application to diffusion phenomena

Contents of the Course:
Basics of probability theory, Master equation and Langevin equation, Law of large numbers and Central Limit Theorem, First passage problems, Large scale dynamics, Dynamical scaling.

Recommended Literature:
Will be announced in the first lecture

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Selected Topics in Modern Condensed Matter Theory (T)

Course No.: physics7503

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
+ Introductory Condensed Matter Theory
+ Quantum Mechanics
+ Statistical Physics

Form of Testing and Examination:
oral or written examination

Length of Course:
1 semester

Aims of the Course:
Knowledge of topics of contemporary condensed matter research
Knowledge of theoretical methods of condensed matter physics

Contents of the Course:
Covers topics and methods of contemporary research, such as
+ Feynman diagram technique
+ Phase transitions and critical phenomena
+ Topological aspects of phenomena in condensed matter physic

Recommended Literature:
R. D. Mattuck, A Guide to Feynman Diagrams in the Many-Body Problem
N. Goldenfeld, Lectures on Phase Transitions and the Renormalization Group
B. A. Bernevig, Topological Insulators and Topological Superconductors

The course can be taken in parallel to physics617 Theoretical Condensed Matter Physics.

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Theory of Superconductivity and Superfluidity (T)

Course No.: physics7504

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements:

Preparation:
Quantum Mechanics, Thermodynamics and Statistics, Quantum Field Theory

Form of Testing and Examination:
Requirements for the (written or oral) examination: Successful participation in the exercises

Length of Course:
1 semester

Aims of the Course:
The goal of the course is to introduce students to the theory of superconductivity and superfluidity.

Contents of the Course:
Phenomenological theory of basic superconductivity, type I and type II superconductivity, vortices and their dynamics, Meissner-Ochsenfeld Effekt, microscopic theory of superconductivity: Gor'kov equation, BCS theory, Migdal theorem, strong coupling theory of superconductivity: Eliashberg equation, Andreev scattering, Josephson effect, Anderson theorem: impurity scattering, Collective excitations in superconductors and superfluids, Anderson (Higgs) mechanism for the mass generation. Superfluidity in 3He, superconductivity in heavy fermion compounds, high temperature superconductivity and open questions.

Recommended Literature:
Will be announced in the first lecture

Catalogue of

700-courses in

Special Topics

Modules:

physics700 **Elective Advanced Lectures**
physics720 **Applied Physics**

Course: Environmental Physics & Energy Physics (A)

Course No.: physics771

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:
Physik I-V (physik110-physik510)

Form of Testing and Examination:
Active contributions during term and written examination

Length of Course:
1 semester

Aims of the Course:
A deeper understanding of energy & environmental facts and problems from physics (and, if needed, nature or agricultural science) point of view

Contents of the Course:
After introduction into related laws of nature and after a review of supply and use of various resources like energy a detailed description on each field of use, use-improvement strategies and constraints and consequences for environment and/or human health & welfare are given.

Recommended Literature:
Diekmann, B., Heinloth, K.: Physikalische Grundlagen der Energieerzeugung, Teubner 1997
Hensing, I., Pfaffenberger, W., Ströbele, W.: Energiewirtschaft, Oldenbourg1998
Fricke, J., Borst, W., Energie, Oldenbourg 1986
Bobin, J. L.,Huffer,E., Nifenecker,H., L'Energie de Demain ,EDP Sciences 2005
Thorndyke, W., Energy and Environment, Addison Wesley 1976
Schönwiese, C. D., Diekmann, B., Der Treibhauseffekt , DVA 1986
Boeker, E., von Grondelle, R., Physik und Umwelt, Vieweg, 1997

Modules:
physics700 **Elective Advanced Lectures**
physics720 **Applied Physics**

Course:

Physics in Medicine: Fundamentals of Analyzing Biomedical Signals (A)

Course No.: physics772

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Elementary thermodynamics; principles of quantum mechanics, principles of condensed matter

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the principles of physics and the analysis of complex systems

Contents of the Course:
Introduction to the theory of nonlinear dynamical systems; selected phenomena (e.g. noise-induced transition, stochastic resonance, self-organized criticality); Nonlinear time series analysis: state-space reconstruction, dimensions, Lyapunov exponents, entropies, determinism, synchronization, interdependencies, surrogate concepts, measuring non-stationarity.
Applications: nonlinear analysis of biomedical time series (EEG, MEG, EKG)

Recommended Literature:
Lehnertz: Skriptum zur Vorlesung
E. Ott; Chaos in dynamical systems (Cambridge University Press 2. Aufl. 2002)
H. Kantz, T. Schreiber ; Nonlinear time series analysis. (Cambridge University Press 2:Aufl. 2004).
A. Pikovsky, M. Rosenblum, J. Kurths; Synchronization: a universal concept in nonlinear sciences (Cambridge University Press 2003)

Modules: physics700 **Elective Advanced Lectures**
physics720 **Applied Physics**

Course: universitätbonn

Physics in Medicine: Fundamentals of Medical Imaging (A)

Course No.: physics773

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding of the principles of physics of modern imaging techniques in medicine

Contents of the Course:
Introduction to physical imaging methods and medical imaging; Physical fundamentals of transmission computer tomography (Röntgen-CT), positron emission computer tomography (PET), magnetic resonance imaging (MRI) and functional MRI
detectors, instrumentation, data acquisition, tracer, image reconstruction, BOLD effect; applications: analysis of structure and function.
Neuromagnetic (MEG) and Neuroelectrical (EEG) Imaging; Basics of neuroelectromagnetic activity, source models
instrumentation, detectors, SQUIDs; signal analysis, source imaging, inverse problems, applications

Recommended Literature:
K. Lehnertz: Scriptum zur Vorlesung
S. Webb; The Physics of Medical Imaging (Adam Hilger, Bristol 1988)
O. Dössel; Bildgebende Verfahren in der Medizin (Springer, Heidelberg 2000)
W. Buckel; Supraleitung (Wiley-VCH Weinheim 6. Aufl. 2004)
E. Niedermeyer/F. H. Lopes da Silva; Electroencephalography (Urban & Schwarzenberg, 1982)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: universitätbonn Electronics for Physicists (E/A)

Course No.: physics774

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Electronics laboratory of the B.Sc. in physics programme

Form of Testing and Examination:
Requirements for the examination (written): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Comprehension of electronic components, methods to derive the dynamical performance of circuits and mediation that these methods are widely used in various fields of physics

Contents of the Course:
Basics of electrical engineering, RF-electronics I: Telegraph equation, impedance matching for lumped circuits and electromagnetic fields, diodes, transistors, analogue and digital integrated circuits, system analysis via laplace transformation, basic circuits, circuit synthesis, closed loop circuits, oscillators, filters, RF-electronics II: low-noise oscillators and amplifiers

Recommended Literature:
P. Horrowitz, W. Hill; The Art of Electronics (Cambridge University Press)
Murray R. Spiegel; Laplace Transformation (McGraw-Hill Book Company)
A.J. Baden Fuller; Mikrowellen (Vieweg)
Lutz v. Wangenheim; Aktive Filter (Hüthig)

Modules:

physics700 **Elective Advanced Lectures**
physics720 **Applied Physics**

Course: Nuclear Reactor Physics (A)

Course No.: physics775

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:
Fundamental nuclear physics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Deeper understanding of nuclear power generation (fisson and fusion)

Contents of the Course:
Physics of nuclear fission and fusion, neutron flux in reactors, different reactor types, safety aspects, nuclear waste problem, future aspects
and
Excursion to a nuclear power plant

Recommended Literature:
H. Hübel: Reaktorphysik (Vorlesungsskript, available during the lecture)
M. Borlein: Kerntechnik, Vogel (2009)
W. M. Stacey: Nuclear Reactor Physics, Wiley & Sons (2007)

Modules:

physics700 **Elective Advanced Lectures**
physics720 **Applied Physics**

Course:

Physics in Medicine: Physics of Magnetic Resonance Imaging (A)

Course No.: physics776

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the principles of Magnetic Resonance Imaging Physics

Contents of the Course:
- Theory and origin of nuclear magnetic resonance (QM and semiclassical approach)
- Spin dynamics, T1 and T2 relaxation, Bloch Equations and the Signal Equation
- Gradient echoes and spin echoes and the difference between T2 and T2*
- On- and off-resonant excitation and the slice selection process
- Spatial encoding by means of gradient fields and the k-space formalism
- Basic imaging sequences and their basic contrasts, basic imaging artifacts
- Hardware components of an MRI scanner, accelerated imaging with multiple receiver
- Computation of signal amplitudes in steady state sequences
- The ultra-fast imaging sequence EPI and its application in functional MRI
- Basics theory of diffusion MRI and its application in neuroimaging
- Advanced topics: quantitative MRI, spectroscopic imaging, X-nuclei MRI

Recommended Literature:
- T. Stöcker: Scriptum zur Vorlesung
- E.M. Haacke et al, Magnetic Resonance Imaging: Physical Principles and Sequence Design, John Wiley 1999
- M.T. Vlaardingerbroek, J.A. den Boer, Magnetic Resonance Imaging: Theory and Practice, Springer, 20
- Z.P. Liang, P.C. Lauterbur, Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, SPIE 1999

Cologne Courses in General Relativity and Quantum Field Theory

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Relativity and Cosmology I (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	WT

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Introduction into Einstein's theory of general relativity and its major applications

Contents of the Course:
Gravity as a manifestation of geometry
Introduction to differential geometry
Einstein field equations
The Schwarzschild solution
Experimental tests
Gravitational waves

Recommended Literature:
T. Padmanabhan, Gravitation: Foundation and Frontiers
J. B. Hartle, Gravity: An introduction to Einstein's general relativity

Modules:	
	physics700 **Elective Advanced Lectures**
	physics730 **Theoretical Physics**

Course: Relativity and Cosmology II (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Application of Einstein's theory of general relativity to black holes and cosmology

Contents of the Course:
Black holes
Introduction to cosmology
The early Universe

Recommended Literature:
V. Mukhanov, Physical Foundations of Cosmology
T. Padmanabhan, Gravitation: Foundation and Frontiers
J. B. Hartle, Gravity: An introduction to Einstein's general relativity

Modules: physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Quantum Field Theory I (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Methods of quantum field theory are in use in almost all areas of modern physics. Strongly oriented towards applications, this course offers an introduction based on examples and phenomena taken from the area of solid state physics.

Contents of the Course:
Second quantization and applications
Functional integrals
Perturbation theory
Mean-field methods

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Modules:	physics700 **Elective Advanced Lectures**
	physics730 **Theoretical Physics**

Course: Quantum Field Theory II (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Quantum Field Theory I

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Quantum field theory is one of the main tools of modern physics with many applications ranging from high-energy physics to solid state physics. A central topic of this course is the concept of spontaneous symmetry breaking and its relevance for phenomena like superconductivity, magnetism or mass generation in particle physics.

Contents of the Course:
Correlation functions: formalism, and their role as a bridge between theory and experiment
Renormalization
Topological concepts

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Geometry in Physics (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The course introduces the background in differential geometry necessary to understand the geometrically oriented languages of modern theoretical physics. Applications include the coordinate invariant formulation of electrodynamics, phase space and symplectic mechanics, and a brief introduction to the foundations of general relativity.

Contents of the Course:
exterior calculus
manifolds
Lie groups
fibre bundles

Recommended Literature:
M. Göckeler & T. Schücker, Differential geometry, gauge theory, and gravity, Cambridge University Press, 1987.

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Topology for Physicists (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Bachelor of physics or mathematics; the basics of exterior calculus are assumed

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
This course gives an introduction to various topological concepts and results that play an important role in modern theoretical physics.

Contents of the Course:
Elements of homotopy theory: homeomorphic spaces, homotopic maps, fundamental group, covering spaces, homotopy groups, long exact homotopy sequence of a fibration
Homology and cohomology: Poincare lemma, Mayer-Vietoris sequence, Cech-deRham complex, Hurewicz isomorphism theorem, spectral sequences
Vector bundles and characteristic classes: Euler form, Thom isomorphism, Chern classes
Applications: Berry phase; Dirac monopole problem; visualization of closed differential forms by Poincare duality; cohomology of electrical conductance; supersymmetry and Morse theory; index theorems; homotopy classification of topological insulators

Recommended Literature:
R. Bott and L.W. Tu: Differential forms in algebraic topology (Springer, 1982)
A.S. Schwarz, Topology for physicists (Springer, 1994)

Cologne Courses in Nuclear and Particle Physics

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Nuclear physics II (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	5	WT

Requirements:

Preparation:
Nuclear Physics I, Quantum Mechanics

Form of Testing and Examination:
Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Study of nuclear reactions, fission and fusion.

Contents of the Course:
- Kinematics in nuclear reactions
- Cross section
- Rutherford scattering
- Scattering in quantum mechanics
- The Born approximation
- Partial wave analysis
- Inelastic scattering, resonances
- Optical model
- Direct, compound, spallation and fragmentation reactions
- Neutron sources and detectors
- Neutron cross sections
- Fission
- Nuclear reactors
- Fusion
- Solar fusion
- Man-made thermonuclear fusion
- Controlled thermonuclear fusion

Recommended Literature:
A script for parts of the course will be distributed during the course.
K.S. Krane, Introductory nuclear physics, chapters 11-14

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Physics of Detectors (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

Requirements:

Preparation:
Nuclear Physics I, Quantum Mechanics

Form of Testing and Examination:
Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Study detection methods of experimental techniques in nuclear and particle physics.

Contents of the Course:
- Interaction of electrons and charged heavy particles in matter
- Coherent effects: Cherenkov and transition radiation
- Interaction of gamma-radiation in matter
- Detection of neutal particles: neutrons and neutrinos
- Measurement of 4-momentum in particle physics
- Ionisation detectors: Bragg chamber, avalanche detectors
- Position sensitive detectors: drift chambers, time-procjection chamber
- Anorganic and organic scintillators
- Energy detection, calorimeter and shower detectors
- Semiconductor detectors
- Position sensitive Si detectors (strip-, pixel-detectors)
- Ge detectors
- Low background measurements
- Lifetime measurements
- Mössbauer Spectroscopy
- Basic principles of analoge and digital signal processing

Recommended Literature:
A script or slides of the course will be distributed during the course.
R. Leo, Techniques for Nuclear and Particle Physics Experiments
K Kleinknecht, Detektoren für Teilchenstrahlung
G.F. Knoll, Radiation Detection and Measurement

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Particle physics (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

Requirements:

Preparation:
Quantum Mechanics

Form of Testing and Examination:
Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Introduction into particle physics, accelerators and detectors

Contents of the Course:
- Relativistic kinematics
- Interaction of radiation with matter
- Particle accelerators
- Targets and detectors
- Symmetries in particle physics
- QED
- Weak interaction, neutrinos
- Quark model
- QCD
- Standard model
- Cosmology

Recommended Literature:
A script for course will be available on-line

D.H. Perkins: Introduction to High Energy Physics, Cambridge University Press, ISBN 0521621968
H. Frauenfelder, E.M. Henley: Subatomic Physics, Prentice Hall, ISBN 0138594309
F. Halzen: A.D. Martin: Quarks and Leptons, John Wiley and Sons, ISBN 0471887412
D. Griffiths: Introduction to Elementary Particles, John Wiley and Sons ISBN: 0471603864
B. Povh, K. Rith, C. Scholz, F. Zetsche: Teilchen und Kerne, Springer-Verlag, ISBN 3540659285
C. Berger: Elementarteilchenphysik, Springer-Verlag, ISBN 3-540-41515-7

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Groundbreaking experiments in nuclear physics (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:
Basic knowledge in Nuclear Physics

Form of Testing and Examination:
Part of courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Length of Course:
1 semester

Aims of the Course:
Study of original publications of fundamental experiments in nuclear physics. The students should participate actively in the course.

Contents of the Course:
- Discovery of radioactivity
- Rutherford and his many discoveries using alpha sources
- The discovery of the neutron and deuteron
- Determination of magnetic moments
- Hofstadters electron scattering experiments
- The use of cosmic rays to discover mesons
- Fermi work in neutron physics
- Properties of neutrinos
- Mößbauereffekt

Recommended Literature:
Will be distributed during the course.

Cologne Courses in

Condensed Matter

Physics

Module: Specialization I

Module No.: physics610

Course: Condensed Matter Physics I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral or written examination

Length of Course:
2 semesters

Aims of the Course:
Comprehensive introduction to the basic principles of solid state physics and to some experimental methods. Examples of current research will be discussed.

Contents of the Course:
The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:
Crystal structure and binding
Reciprocal space
Lattice dynamics and thermal properties
Electronic structure (free-electron gas, Fermi surface, band structure)
Semiconductors and metals
Transport properties
Dielectric function and screening
Superconductivity
Magnetism

Recommended Literature:
Skriptum (available during the course)
Ashcroft/Mermin: Solid State Physics
Kittel: Introduction to Solid State Physics
Ibach/Lüth: Festkörperphysik

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**

Course: Condensed Matter Physics II (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

Requirements:

Preparation:
Basic knowledge in condensed matter physics and quantum mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
2 semesters

Aims of the Course:
Advanced topics in condensed matter physics with examples of current research.

Contents of the Course:
The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:
Crystal structure and binding
Reciprocal space
Lattice dynamics and thermal properties
Electronic structure (free-electron gas, Fermi surface, band structure)
Semiconductors and metals
Transport properties
Dielectric function and screening
Superconductivity
Magnetism

Recommended Literature:
Skriptum (available during the course)
Ashcroft/Mermin: Solid State Physics
Kittel: Introduction to Solid State Physics
Ibach/Lüth: Festkörperphysik

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Semiconductor Physics and Nanoscience (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
No examination

Length of Course:
1 semester

Aims of the Course:
Understanding of theoretical and experimental concepts of semiconductor physics, nanotechnology as well as aspects of future information technology.
Knowledge of basic fields and important applications of information technology.

Contents of the Course:
Semiconducting material and nanostructures represent the backbone of modern electronics and information technology. At the same time they are fundamental to the research of problems of modern solid state physics, information technology and biophysics. This lecture will provide an introduction to semiconductor physics and its applications.
Topics covered are
introduction to semiconductor physics, crystalline structure, band structure, electronic and optical properties,
heterostructures, junction and interfaces,
basic semiconductor device concepts,
up to date techniques and strategies of information technology ranging from nowadays preparation technologies and nanoscience to concepts of molecular electronic and bioelectronics.

Recommended Literature:
Skriptum (available during the course)
Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)
Ibach/Lüth, Festkörperphysik

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Superconductivity (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of the fundamental aspects of superconductivity.

Contents of the Course:
The lecture provides an overview of the fundamental aspects of superconductivity, theoretical description and technological applications, including the following topics:

Basic experimental facts and critical parameters
Phenomenological description: London equations
Ginzburg-Landau theory
Magnetic flux quantization
Type I and type II superconductors, characteristic length scales, vortices
Microscopic description: BSC theory
Electron-phonon interaction, Cooper pairs
Josephson effects
Applications of superconductivity in science, transport, and medicine
Brief introduction to unconventional superconductivity with recent examples

Recommended Literature:
J. F. Annett: Superconductivity, Superfluids and Condensates (2004)
M. Tinkham: Introduction to Superconductivity (1996)
V. V. Schmidt: The Physics of Superconductors (1997)
J. R. Waldram: Superconductivity of Metals and Cuprates (1996)
D. R. Tilley and J. Tilley: Superfluidity and Superconductivity (1990)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Magnetism (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of magnetism in condensed matter systems

Contents of the Course:
The lecture introduces to the magnetism in condensed matter systems. Starting from basic concepts of the magnetic properties of free atoms it is aimed to illustrate the extremely rich field of collective magnetism that arises from the mutual interaction of an extremely large number of interacting particles.
Topics covered are
Magnetism of free atoms
Magnetism of ions in the crystal electric field
Magnetic interactions and ordering phenomena
Magnetic ground states and excitations
Itinerant magnetism
Magnetic frustration and low dimensionality
Magnetic order vs. competing ordering phenomena

Recommended Literature:
Skriptum (available during the course)
S. Blundell, Magnetism in Condensed Matter
Ashcroft/Mermin, Solid State Physics
Kittel, Festkörperphysik

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Experimental methods in condensed matter physics (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of experimental concepts in condensed matter science
Knowledge of basic fields and important applications

Contents of the Course:
The lecture introduces to modern experimental approaches in solid state physics. Basic concepts are illustrated with examples of physical problems investigated employing different methods.
Topics covered are
Introduction on sample preparation
X-ray powder diffraction
Specific heat, Thermal expansion
Magnetization and magnetic susceptibility
DC-Transport
Dielectric spectroscopy
Photo-emission spectroscopy
Inelastic scattering (neutrons, light)
THz spectroscopy / Optical spectroscopy
Scanning probe microscopy/spectroscopy (AFM, STM)

Recommended Literature:
Skriptum (available during the course)
Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)
Ibach/Lüth, Festkörperphysik
Ashcroft/Mermin, solid state physics

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Physics of Surfaces and Nanostructures (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:
Basic knowledge of solid state physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts in surface and nanostructure science
Knowledge of basic fields and important applications

Contents of the Course:
The lecture introduces to modern topics of surface and nanostructure physics. Basic concepts are illustrated with examples and the link to technical applications is emphazised. Topics covered are
- surface structure and defects,
- adsorption and heterogeneous catalysis,
- surface thermodynamics and energetics
- surface electronic structure and quantum dots,
- magnetism at surfaces
- epitaxy and thin film processes,
- oxide films
- ion beam processes at surfaces,
- clusters,
- graphene

Recommended Literature:
Michely: Skriptum (available during the course)
H. Ibach: Physics of Surfaces and Interfaces (Springer, Berlin 2006)
K. Oura et al: Surface Science - an introduction (Springer, Berlin 2003)
M. Prutton: Introduction to Surface Physics (Oxford University Press, 1994)
H. Lüth: Solid Surfaces, Interfaces and Thin Films, (Springer, Berlin 2001)
M. Henzler/ W. Göpel: Oberflächenphysik des Festkörpers (Teubner, Stuttgart 1994)

Modules:	physics700 **Elective Advanced Lectures** physics710 **Experimental Physics** physics720 **Applied Physics**

Course: Introduction to neutron scattering (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of the basic concepts and techniques of elastic and inelastic neutron scattering experiments.

Contents of the Course:
The lecture introduces to the techniques of elastic and inelastic neutron scattering that can be used to determine the crystal or magnetic structure as well as the dispersion of nuclear or magnetic excitations.
Topics covered are
Crystal structures and reciprocal space
Neutron powder diffraction
Single-crystal diffraction
Structure refinements
Inelastic neutron scattering
Phonon dispersion
Magnetic excitations
Examples of current research (high-temperature superconductors, manganates with colossal magnetoresistivity, multiferroics)
Polarized neutron scattering

Recommended Literature:
Skriptum (available during the course)
S. W. Lovesey, Theory of Neutron Scattering from Condensed Matter, Oxford (1981)
G. E. Bacon, Neutron Diffraction, Oxford (1979)
Shirane, Shapiro and, Tranquada, Neutr. Scattering with a triple-axis spectrometer, Cambridge (2002)
Izyumov, Ozerov, Magnetic Neutron Diffraction Plenum (1970)
Marshall and Lovesey, Theory of thermal neutron scattering,Oxford (1971)
Squires, Introduction to the theory of Thermal Neutron scattering, Cambridge (1978)

Modules:

physics700 **Elective Advanced Lectures**
physics710 **Experimental Physics**
physics720 **Applied Physics**

Course: Optical Spectroscopy (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT/ST

Requirements:

Preparation:
Basic knowledge in condensed matter physics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of the basic concepts and techniques of optical spectroscopy on solid-state samples.

Contents of the Course:
Topics covered are:
Electromagnetic waves in matter, dielectric function
Electromagnetic response of metals and insulators, Drude-Lorentz model
Kramers-Kronig relations
THz spectroscopy (time domain and cw)
Fourier-transform spectroscopy
Ellipsometry
Examples of current research (phonons, magnons, orbital excitations, superconductors, …)

Recommended Literature:
Skriptum (available during the course)
Dressel/Grüner: Electrodynamics of Solids: Optical Properties of Electrons in Matter (Cambridge, 2002)
Klingshirn: Semiconductor Optics (Springer, 1997)
Kuzmany: Solid-State Spectroscopy: An Introduction (Springer, 2009)

Cologne Courses in

Molecular Physics

Module: Specialization I

Module No.: physics610

Course: Molecular Physics I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the first part of the core courses the students learn the main concepts of molecular physics: separation of electronic, vibrational and rotational motion. Simple molecular spectra can be analyzed on the basis of the problem class. Fundamental group theory is used to predict vibrational and rotational spectra of more complex molecules.

This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Basics of molecular spectroscopy, phenomenology, diatomic molecules
- Born-Oppenheimer Approximation, separation of rotation and vibration
- Molecular Dipole moment and rotational transitions
- Rotational spectra and the rigid rotor approach
- Selection rules, parallel and perpendicular type spectra
- Nuclear spin statistics
- Hyperfine structure of molecular lines

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Module: Specialization II

Module No.: physics630

Course: Molecular Physics II

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
In the second part of the core courses more complex issues of molecular spectra are introduced. The students will be enabled to analyze spectra of complex molecules which are subject to couplings between electronic, vibrational and rotational motions.
In the special courses basic and advanced molecular physics are applied to atmospherical and astronomical environments.
This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the Course:
- Vibrational modes of polyatomic molecules
- Fundamentals of point group symmetry
- Vibrational dipole moment and selection rules
- Characteristic ro-vibrational spectra of selected molecules
- Breakdown of Born-Oppenheimer Approximation
- Coupling of rotation and vibration
- Coupling of angular momenta in molecular physics

Recommended Literature:
Bernath, "Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, Microwave Spectra" (Wiley)
Engelke, "Aufbau der Moleküle" (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", (NRC Research Press, Ottawa)

Modules:	physics700 **Elective Advanced Lectures**
	physics710 **Experimental Physics**
	physics720 **Applied Physics**

Course: Astrochemistry (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	4	ST

Requirements:

Preparation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
The lecture introduces to astrochemistry of various astrophysical environments. Fundamental processes, such as molecular collisions, fragmentations, and chemical reactions, are explained, and implications for astrophysical observations by means of high resolution spectroscopy are treated.

Contents of the Course:
- Detection of Molecules in Space
- Elementary Chemical Processes
- Chemical Networks
- Grain Formation (Condensation)
- Properties of Grains and Ice
- Grain Chemistry
- Diffuse Clouds, Shocks, Dark Clouds, Star Forming Regions

Recommended Literature:
A.Tielens "The Physics and Chemistry of the Interstellar Medium" Cambridge University Press, 2005
S. Kwok "Physics and Chemistry of the Interstellar Medium" University Science Books, 2006
D. Rehder "Chemistry in Space, From Interstellar Matter to the Origin of Life" Wiley-VCCH, Weinheim, 2010
J. Lequeux "The interstellar Medium" Spinger, 2004
A. Shaw "Astrochemistry" Wiley, 2006
D. Whittet "Dust in the Galactic Environment", Taylor and Francis, 2nd edition, 2002

Modules:	physics700 **Elective Advanced Lectures** physics710 **Experimental Physics** physics720 **Applied Physics** physics730 **Theoretical Physics**

Course: Fundamentals of Molecular Symmetry (E/A/T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	4	ST

Requirements:

Preparation:
Basic knowledge of quantum mechanics

Form of Testing and Examination:
Oral Examination

Length of Course:
1 semester

Aims of the Course:
Understanding the fundamental concepts of representation theory and its application to describe the symmetry of molecules

Contents of the Course:
The lecture introduces to group theory with special emphasis on representations and their use to describe the symmetry of molecules in high-resolution spectroscopy and in molecular physics generally. The theory is accompanied by a series of "prototypical" examples Topics covered are
- symmetry in general and symmetry of a molecule.
- groups and point groups.
- irreducible representations, characters.
- vanishing integral rule
- the Complete Nuclear Permutation-Inversion (CNPI) group.
- the Molecular Symmetry (MS) group).
- the molecular point group.
- classification of molecular states: electronic, vibrational, rotational, and nuclear spin states
- nuclear spin statistical weights
- hyperfine structure
- non-rigid molecules (inversion, internal rotation)

Recommended Literature:
Jensen: Script (text of powerpoint presentation files; available during the course)
P. Jensen and P. R. Bunker: The Symmetry of Molecules, in: "Encyclopedia of Chemical Physics and Physical Chemistry" (J. H. Moore and N. D. Spencer, Eds.), IOP Publishing, Bristol, 2001.
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition," NRC Research Press, Ottawa, 1998 (ISBN 0-660-17519-3).
P. R. Bunker and P. Jensen: "Fundamentals of Molecular Symmetry", IOP Publishing, Bristol, 2004 (ISBN 0-7503-0941-5).

Cologne Courses in Statistical and Biological Physics

Modules:

physics700 **Elective Advanced Lectures**
physics720 **Applied Physics**
physics730 **Theoretical Physics**

Course: Physical biology (T/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Acquaintance with basic concepts of molecular and evolutionary biology; understanding of statistical issues arising in the analysis of sequence data and the application of methods from statistical physics addressing them.

Contents of the Course:
Statistics of the genome
Sequence analysis and sequence alignement
Evolutionary theory and population genetics
Theory of bio-molecular networks

Recommended Literature:
J.H. Gillespie, Population Genetics: A concise guide (Johns Hopkins University Press, 2004)
R. Durbin, S.R. Eddy, A. Krogh, G. Mitchison, Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids (Cambridge University Press, 1998)
F. Kepes, Biological Networks (World Scientific, Singapore 2007)
D.J. Wilkinson, Stochastic Modelling for Systems Biology (Chapman&Hall, 2006)

Modules:

physics700 **Elective Advanced Lectures**
physics720 **Applied Physics**
physics730 **Theoretical Physics**

Course: Statistical physics of soft matter and biomolecules (T/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the molecular structure and mesoscopic properties of various types of soft matter systems, in particular with regard to their role in living cells.

Contents of the Course:
Colloids, polymers and amphiphiles
Biopolymers and proteins
Membranes
Physics of the cell

Recommended Literature:
J. K. G. Dhont, An Introduction to Dynamics of Colloids (Elsevier, Amsterdam, 1996).
M. Doi and S. F. Edwards, The Theory of Polymer Dynamics (Clarendon Press, Oxford, 1986).
S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes (Addison-Wesley, Reading, MA, 1994).
G. Gompper, U. B. Kaupp, J. K. G. Dhont, D. Richter, and R. G. Winkler, eds., Physics meets Biology — From Soft Matter to Cell Biology, vol. 19 of Matter and Materials (FZ Jülich, Jülich, 2004).
D. H. Boal, Mechanics of the Cell (Cambridge University Press, Cambridge, 2002).

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Statistical physics far from equilibrium (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the generic behavior of fluctuation-dominated systems far from equilibrium, and acquaintance with the basic mathematical tools used for their description.

Contents of the Course:
Stochastic methods
Transport processes
Scale-invariant growth
Pattern formation far from equilibrium

Recommended Literature:
P.L. Krapivsky, S. Redner and E. Ben-Naim: A kinetic view of statistical physics (Cambridge University Press, 2010)
M. Kardar, Statistical Physics of Fields (Cambridge University Press, 2007)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Disordered systems (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Advanced statistical mechanics

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding the novel types of behaviour that arise in systems with quenched disorder, as well as the specific mathematical challenges associated with their theoretical description.

Contents of the Course:
Disorder average
Replica methods
Percolation
Phase transitions in disordered systems
Localization
Glassy dynamics

Recommended Literature:
D. Stauffer and A..Aharony, Introduction to Percolation Theory (Taylor & Francis, London 1994)
K.H. Fischer and J.A. Hertz, Spin Glasses (Cambridge University Press, Cambridge 1991)
K. Binder and W. Kob, Glassy Materials and Disordered Solids (World Scientific, Singapore 2005)
T. Nattermann, lecture notes

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Nonequilibrium physics with interdisciplinary applications (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Statistical mechanics

Form of Testing and Examination:
Oral examination or term paper

Length of Course:
1 semester

Aims of the Course:
Acquaintance with basic concepts of nonequilibrium physics; ability to apply the basic methods for the investigation of nonequilibrium problems; application of physics-based models to interdisciplinary problems.

Contents of the Course:
Principles of nonequilibrium physics
Stochastic systems and their desription (master equation, Fokker-Planck equation,..)
Analytical and numerical methods
Nonequilibrium phase transitions
Applications to traffic, pedestrian dynamics, economic systems, biology, pattern formation,..

Recommended Literature:
A. Schadschneider, D. Chowdhury, K. Nishinari: Stochastic Transport in Complex Systems (Elsevier, 2010)
P.L. Krapivsky, S. Redner, E. Ben-Naim: A Kinetic View of Statistical Physics (Cambridge University Press, 2010)
V. Privman (Ed.): Nonequilibrium Statistical Mechanics in One Dimension (Cambridge University Press, 1997)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Probability theory and stochastic processes for physicists (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	WT

Requirements:

Preparation:
Statistical mechanics on the bachelor level

Form of Testing and Examination:
Oral examination or term paper

Length of Course:
1 semester

Aims of the Course:
Acquaintance with probabilistic concepts and stochastic methods commonly used in the theory of disordered systems and nonequilibrium phenomena, as well as in interdisciplinary applications of statistical physics.

Contents of the Course:
Limit laws and extremal statistics
Point processes
Markov chains and birth-death processes
Stochastic differential equations and path integrals
Large deviations and rare events

Recommended Literature:
D. Sornette: Critical Phenomena in Natural Sciences (Springer, 2004)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

Cologne Courses in Theoretical Solid State Physics

Module: Specialization I

Module No.: physics610

Course: Solid State Theory I

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
training in theoretical physics at the B.Sc. level, experimental solid state physics

Form of Testing and Examination:
written or oral examination

Length of Course:
1 semester

Aims of the Course:
this course gives an introduction to the physics of electrons and phonons in solids together with theoretical concepts and techniques as applied to these systems.

Contents of the Course:
The lecture investigates basic concepts to describe solids and their excitations. Various applications are discussed with emphasis on experimental and theoretical research directions of the physics department in Cologne.

Recommended Literature:
Ashcroft/ Mermin: "Solid State Physics"

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Quantum Field Theory I (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Training in theoretical physics at the B.Sc. level

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Methods of quantum field theory are in use in almost all areas of modern physics. Strongly oriented towards applications, this course offers an introduction based on examples and phenomena taken from the area of solid state physics.

Contents of the Course:
Second quantization and applications
Functional integrals
Perturbation theory
Mean-field methods

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Modules:

physics700 **Elective Advanced Lectures**
physics730 **Theoretical Physics**

Course: Quantum Field Theory II (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

Requirements:

Preparation:
Quantum Field Theory I

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Quantum field theory is one of the main tools of modern physics with many applications ranging from high-energy physics to solid state physics. A central topic of this course is the concept of spontaneous symmetry breaking and its relevance for phenomena like superconductivity, magnetism or mass generation in particle physics.

Contents of the Course:
Correlation functions: formalism, and their role as a bridge between theory and experiment
Renormalization
Topological concepts

Recommended Literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Module-Handbook
Master in Astrophysics
PO von 2006

SS 2024

July 2023

We don’t offer each of these modules regularly.

For any update please see:

https://www.physik-astro.uni-bonn.de/de/studium/

lehrveranstaltungen/termine-und-lehrveranstaltungen

Master in Astrophysics, University of Bonn

1st Term

physics600	physics605	astro810	astro830
Base Module: Laboratory Course	**Base Module: Theoretical Physics**	**Compulsory Astrophysics I**	**Elective Advanced Lectures**
7 CP	7 CP	12 CP	(a)

2nd Term

astro820	astro840	astro850	astro890
Compulsory Astrophysics II	**Observational Astronomy**	**Modern Astrophysics**	**Seminar**
12 CP	(a)		4 CP

3rd Term

astro940	astro950
Scientific Exploration of Master Thesis Topic	**Methods and Project Planning**
15 CP	15 CP

4th Term

astro960
Master Thesis
30 CP

Note: The students must achieve the indicated number of CP (Credit Points)
(a): In the modules 830, 840, 850 at least 18 CP altogether must be achieved.

Abbreviations:

CP	Credit Points (*Leistungspunkte*)
ex.	exercises
hrs	hours
lab.	laboratory
Ma-PO	"Master-Prüfungsordnung" (Examination Regulations (Master Course))
n.a.	not applicable
ST	Summer Term
TH	Teaching Hours
WT	Winter Term

On proposal of the board of examination, the Dean may agree to further compulsory selectable (sub-) modules. The office of the board of examination will announce these compulsory selectable (sub-) modules agreed upon, electronically or by public notice, in due time before the beginning of the semester.

Note about programme language:
The M.Sc. in Astrophysics programme is a programme in English language. At the discretion of the lecturer and the class German language may be used as the teaching language as well. Furthermore non-German speaking students are expected to learn German language on their own accord during the course of this programme.

Note to the points "Requirements" and "Preparation":
The point "Requirements" contains courses that have to be passed in order for the students to be able to participate in the module.
The point "Preparation" contains other courses whose content helps significantly towards the understanding of this course.

Note about module (submodule) examinations:
The details about the submodule examination will be announced by the lecturer before the start of the lecture
Please find updated versions of the module-handbook at http://www.physik-astro.uni-bonn.de

Table of Contents: M.Sc. in Astrophysics (PO von 2006)

physics600 Base Module Laboratory Course 1
physics605 Base Module Theoretical Physics 2
physics606 Advanced Quantum Theory 3
physics607 Advanced Theoretical Physics 4
astro810 Compulsory Astrophysics I 5
astro811 Stars and Stellar Evolution or specific: Stellar Structure and Evolution 6
astro812 Cosmology 7
astro820 Compulsory Astrophysics II 8
astro821 Astrophysics of Galaxies 9
astro822 Physics of the Interstellar Medium 10
astro830 Elective Advanced Lectures 11
astro831 Internships in the Research Groups 12
astro840 Observational Astronomy 13
astro850 Modern Astrophysics 14
astro890 Seminar 15
astro891 Seminar on Cosmology 16
astro892 Seminar on Radio Astronomy 17
astro893 Seminar on Stellar Systems: "Star Clusters and Dwarf Galaxies" 18
astro894 Specialized Seminars 19
astro940 Scientific Exploration of the Master Thesis Topic 20
astro950 Methods and Project Planning 21
astro960 Master Thesis 22
Catalogue of 84* and 85* courses 23
astro841 Radio Astronomy: Tools, Applications, Impacts 24
astro842 Submillimeter Astronomy 25
astro843 Astronomical Interferometry and Digital Image Processing 26
astro845 Observational Cosmology 27
astro846 Wave Optics and Astronomical Applications 28
astro847 Optical Observations 29
astro848 Galactic and Intergalactic Magnetic Fields 30
astro849 Multiwavelength Observations of Galaxy Clusters 31
astro8401 Introduction to Hydro- and Magnetohydrodynamics 32
astro8402 X-Ray Astronomy 33
astro8403 Hydrodynamics and astrophysical magnetohydrodynamics 34
astro8404 Radiointerferometry: Methods and Science 35
astro851 Stellar and Solar Coronae 36
astro852 Gravitational Lensing 37
astro8531 The Physics of Dense Stellar Systems as the Building Blocks of Galaxies 38
astro854 Numerical Dynamics 40
astro856 Quasars and Microquasars 41
astro857 Star Formation 42
astro858 Nucleosynthesis 43
astro859 The cosmic history of the intergalactic medium 44
astro8501 Binary Stars 45
astro8502 Physics of Supernovae and Gamma-Ray Bursts 46
astro8503 Radio and X-Ray Observations of Dark Matter and Dark Energy 47
astro8504 Lecture on Advanced Topics in Modern Astrophysics 48
Cologne Courses in Astrophysics 49

Astrophysics II (MA) 50
Star Formation (MA) 51
Galaxy Dynamics (MA) 52
Active Galactic Nuclei (OA) 53
Methods of Experimental Astrophysics (OA) 54
The Fourier-Transform and its Applications (OA) 55

Module No.:	physics600
Credit Points (CP):	7
Category:	Required
Semester:	7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Base Module Laboratory Course

Requirements:

Preparation:

Content:
Every student has to complete this Laboratory Course. The course consists of advanced experiments introducing into important subfields of contemporary experimental physics and astrophysics. The lab-course is accompanied by a seminar.

Aims/Skills:
The students shall gain insight in the conceptual and complex properties of relevant contemporary experiments. The students gain experience in setting up an experiment, data logging and data analysis. They experience the intricacies of forefront experimental research

Form of Testing and Examination:
Before carrying out an experiment, the students shall demonstrate to have acquired the necessary preparatory knowledge. Experiments are selected from the catalogue of laboratory set-ups offered.
Cumulative lab-units of >= 9 are required.
Requirements for the submodule examination (written report for every laboratory): successful completion of the experiment and initial oral questioning

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.: physics605
Credit Points (CP): 7
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Base Module Theoretical Physics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Advanced Quantum Theory	physics606	7	Lect. + ex.	210 hrs	WT
2.	Advanced Theoretical Physics	physics607	7	Lect. + ex.	210 hrs	WT

Requirements:

Preparation:

Content:
The course provides fundamental knowledge needed for theoretical lectures in the Master course

Aims/Skills:
The M.Sc. Physics programme includes one obligatory module for all students. It includes a theoretical unit to extend the B.Sc. in Physics knowledge

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: When the student has (upon admission) demonstrated satisfactory knowledge of Advanced Quantum Theory already, the class Advanced Theoretical Physics may be taken instead

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Quantum Theory

Course No.: physics606

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
Ability to solve problems in relativistic quantum mechanics, scattering theory and many-particle theory

Contents of the Course:
Born approximation, partial waves, resonances
advanced scattering theory: S-matrix, Lippman-Schwinger equation
relativistic wave equations: Klein-Gordon equation, Dirac equation
representations of the Lorentz group
many body theory
second quantization
basics of quantum field theory
path integral formalism
Greens functions, propagator theory

Recommended Literature:
L. D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.3 Quantum Mechanics (Butterworth-Heinemann 1997)
J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley 1995)
F. Schwabl, Advanced Quantum Mechanics. (Springer, Heidelberg 3rd Ed. 2005)

Module: Base Module Theoretical Physics

Module No.: physics605

Course: Advanced Theoretical Physics

universitätbonn

Course No.: physics607

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:
3-year theoretical physics course with extended interest in theoretical physics and mathematics

Form of Testing and Examination:
Requirements for the module examination (written examination): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
Introduction to modern methods and developments in Theoretical Physics in regard to current research

Contents of the Course:
Selected Topics in Modern Theoretical Physics for example:
Anomalies
Solitons and Instantons
Quantum Fluids
Bosonization
Renormalization Group
Bethe Ansatz
Elementary Supersymmetry
Gauge Theories and Differential Forms
Applications of Group Theory

Recommended Literature:
M. Nakahara; Geometry, Topology and Physics (Institute of Physics Publishing, London 2nd Ed. 2003)
R. Rajaraman; Solitons and Instantons, An Introduction to Solitons and Instantons in Quantum Field Theory (North Holland Personal Library, Amsterdam 3rd reprint 2003)
A. M. Tsvelik; Quantum Field Theory in Condensed Matter Physics (Cambridge University Press 2nd Ed. 2003)
A. Zee; Quantum Field Theory in a Nutshell (Princeton University Press 2003)

Module No.: astro810
Credit Points (CP): 12
Category: Required
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Compulsory Astrophysics I

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Stars and Stellar Evolution or specific: Stellar Structure and Evolution	astro811	6	Lect. + ex.	180 hrs	WT
2.	Cosmology	astro812	6	Lect. + ex.	180 hrs	WT

Requirements:

Preparation:

Content:
The module represents the fundamentals of the phases of stars and stellar evolution and the knowledge about our cosmological model

Aims/Skills:
The student shall acquire deeper understanding of the workings of stars and their evolution, in particular of important transitory phases of evolution, and shall be able to understand the origin of stars related with the location of their parameters in the HRD.
The student shall acquire deep understanding of the foundation of our world models and of their consequences, with special emphasis on the formation of structures in the universe and its physical and observational consequences

Form of Testing and Examination:
Requirements for the submodule examination (written or oral examination): successful work with the exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Compulsory Astrophysics I

Module No.: astro810

Course: Stars and Stellar Evolution or specific: Stellar Structure and Evolution

Course No.: astro811

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Students will acquire sufficient knowledge to understand stars and their evolution. Study of radiation transport, energy production, nucleosynthesis and the various end phases of stellar evolution shall lead to appreciation for the effects these processes have on the structure and evolution of galaxies and of the universe

Contents of the Course:
Historical introduction, measuring quantities, the HRD. Continuum and line radiation (emission and absorption) and effects on the stellar spectral energy distribution. Basic equations of stellar structure. Nuclear fusion. Making stellar models. Star formation and protostars. Brown Dwarfs. Evolution from the main-sequence state to the red giant phase. Evolution of lower mass stars: the RG, AGB, HB, OH/IR, pAGB, WD phases. Stellar pulsation. Evolution of higher mass stars: supergiants, mass loss, Wolf-Rayet stars, P-Cyg stars. Degenerate stars: White Dwarfs, Neutron Stars, Black Holes. Supernovae and their mechanisms. Binary stars and their diverse evolution (massive X-ray binaries, low-mass X-ray binaries, Cataclysmic variables, etc.). Luminosity and mass functions, isochrones. Stars and their influence on evolution in the universe

Recommended Literature:
Lecture notes on "Stars and Stellar Evolution" (de Boer & Seggewiss)

Module: Compulsory Astrophysics I

Module No.: astro810

Course: universitätbonn Cosmology

Course No.: astro812

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Introductory astronomy

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The student shall acquire deep understanding of the foundation of our world models and of their consequences, with special emphasis on the formation of structures in the universe and its physical and observational consequences. The lecture shall enable the student to read and understand original literature in astrophysical cosmology, but also to see the direct connection between the fundamental problems in cosmology and particle physics, such as the nature of dark matter and dark energy

Contents of the Course:
Kinematics and dynamics of cosmic expansion, introduction to General relativity, Friedmann equations and classification of world models, flatness and horizon problem; thermal history of the big bang, decoupling, WIMPS, nucleosynthesis, recombination and the CMB; gravitational light deflection, principles and applications of strong and weak gravitational lensing; structure formation in the Universe, perturbation theory, structure growth and transfer function, power spectrum of cosmic fluctuations, spherical collapse model, Press-Schechter theory and generalizations, cosmological simulations, cosmic velocity fields; principles of inflation; lensing by the large-scale structure, cosmic shear; anisotropies of the CMB, determination of cosmological parameters

Recommended Literature:
J. A. Peacock; Cosmological Physics (Cambridge University Press 1998)
P. J. E. Peebles; Principles of Physical Cosmology (Princeton University Press 1993)
Handout of the Transparencies

Module No.: astro820
Credit Points (CP): 12
Category: Required
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Compulsory Astrophysics II

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Astrophysics of Galaxies	astro821	6	Lect. + ex.	180 hrs	ST
2.	Physics of the Interstellar Medium	astro822	6	Lect. + ex.	180 hrs	ST

Requirements:

Preparation:

Content:
This module presents both, theoretical aspects, as well as the detailed properties of the major building blocks of cosmic structure, viz. galaxies. The fundamentals of the physics of the interstellar medium are conveyed, along with the tools used to study its properties

Aims/Skills:
The student shall acquire knowledge about the properties of galaxies, including their formation and their evolution, based on knowledge of the constituent matter (stars, gas, dark matter). The fundamentals of stellar dynamics are also conveyed. Physical processes relevant for the study of the interstellar medium have to be understood including the basic methods of measurements and their interpretation of the fundamental phases of the ISM

Form of Testing and Examination:
Requirements for the submodule examination (written or oral examination): successful work with the exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Compulsory Astrophysics II

Module No.: astro820

Course: Astrophysics of Galaxies

Course No.: astro821

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Introductory astronomy as well as a good understanding of stars and their evolution as well as of the interstellar medium

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
The student shall acquire deep knowledge of the structure of the Milky Way and of other galaxies including their evolution.
This must enable them to understand and evaluate new publications in the field. It should provide the student a quick entry into the research phase of the study programme

Contents of the Course:
Review of stars and stellar evolution, review of the interstellar medium. Solar neighbourhood: observables, differential galactic rotation, Hyades, Goulds Belt, Local Bubble. The Galaxy: size, dynamics of objects, rotation curve, disk and z-distribution. Stellar dynamics: Boltzmann, Jeans drift, Schwarzschild ellipsoid, scale length and height, density wave, mass distribution, age of populations, dark matter concept, evolution. Satellites: the Magellanic Clouds, their structure and evolution, Magellanic Stream, Dwarf spheroidals, Local Group galaxies. Star clusters: stellar dynamics, binary and multiple stars, energy exchange, star-cluster birth and death, origin of galactic field population. Active galactic nuclei: observables, jets, accretion, black holes. Structure and shape of spirals and ellipticals, surface brightness, globular cluster systems. Galaxy clusters: distances, statistics, luminosity function, X-ray halos, virial theorem. Galaxy evolution: chemical enrichment, galactic winds, infall, observables. Galaxy collisions: relaxation, mergers, birth of dwarf galaxies

Recommended Literature:
J. Binney; B. Merrifield; Galactic Astronomy (Princeton University Press 1998)
J. Binney, S. Tremaine; Galactic Dynamics (Princeton University Press 1988)
L. S. Sparke; J. S. Gallagher; Galaxies in the Universe (Cambridge University Press, 2000)
Write-up of the class

Module: Compulsory Astrophysics II

Module No.: astro820

Course: Physics of the Interstellar Medium

Course No.: astro822

Category	Type	Language	Teaching hours	CP	Semester
Required	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Introductory astronomy

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The student shall acquire a good understanding of the physics and of the phases of the ISM. The importance for star formation and the effects on the structure and evolution of galaxies is discussed.

Contents of the Course:
Constitutens of the interstellar medium, physical processes, radiative transfer, recombination, HI 21cm line, absorption lines, Stroemgren spheres, HII regions, interstellar dust, molecular gas and clouds, shocks, photodissociation regions, energy balances, the multi-phase ISM, gravitational stability and star formation.

Recommended Literature:
B. Draine; The Physics of the Interstellar and Intergalactic Medium (Princeton Univ. Press 2010)
J. Lequeux; The Interstellar Medium (Springer 2005)

Module No.: astro830
Credit Points (CP):
Category: Elective
Semester: 7.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Elective Advanced Lectures

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Observational Astronomy						
1.	Selected 84* courses from catalogue	astro84*	3-6	see catalogue	90-180 hrs	WT/ST
Modern Astrophysics						
1.	Selected 85* courses from catalogue	astro85*	3-6	see catalogue	90-180 hrs	WT/ST
Research Internship						
1.	Internships in the Research Groups	astro831	4	internship		WT/ST
Cologne Courses						
1.	Astrophysics Courses from Cologne	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
1.	Also possible classes from M.Sc. in Physics					

Requirements:

Preparation:

Content:
This module comprises a catalogue of special topics in theoretical and observational astrophysics, which supplements the compulsory courses such as to provide the students with a thorough understanding of modern astrophysics

Aims/Skills:
The student has the opportunity to gain insight into specialized fields of modern theoretical and observational astrophysics, in addition to the compulsory courses, by selecting one such course out of the catalogue offered

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the module examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

The students must obtain 18 CP in all out of the modules astro830, -840, -850.

Module: Elective Advanced Lectures

Module No.: astro830

Course: Internships in the Research Groups

Course No.: astro831

Category	Type	Language	Teaching hours	CP	Semester
Elective	Research Internship	English		4	WT/ST

Requirements:
Students are asked to contact one of the BCGS lecturers prior to the start of their internship. Lecturers provide help if needed to find a suitable research group and topic. Not all groups may have internships available at all times, thus participation may be limited.

Preparation:
A specialization lecture from the research field in question or equivalent preparation.

Form of Testing and Examination:
A written report or, alternatively, a presentation in a meeting of the research group.

Length of Course:
4-6 weeks

Aims of the Course:
Students conduct their own small research project as a part-time member of one of the research groups in Bonn. The students learn methods of scientific research and apply them to their project.

Contents of the Course:
One of the following possible items:
- setting up a small experiment,
- analyzing data from an existing experiment,
- simulating experimental situations,
- numerical or analytical calculations in a theory group.

Recommended Literature:
provided by the supervisor within the research group.

Module No.: astro840
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Observational Astronomy

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 84* courses from catalogue	astro84*	3-6	see catalogue	90-120 hrs	WT/ST
2.	Astrophysics Courses from Cologne marked "OA"	see catalogue	4	see catalogue	120 hrs	WT/ST
3.	Also possible classes from M.Sc. in Physics					

Requirements:

Preparation:

Content:
This module covers all observational tools used in modern astronomy, over a wide range of the electromagnetic spectrum

Aims/Skills:
Observational astronomy shall be conveyed to the students by teaching the fundamentals of observational astronomical tools, along with relevant applications. These tools cover essentially the entire electro-magnetic spectrum, from radio wavelengths through X-ray energies. They naturally also encompass a wide range of astrophysical phenomena, including condensed matter (stars, neutron stars), the interstellar and intergalactic medium, galaxies and active galactic nuclei, and clusters of galaxies. Emphasis is also on observational cosmology

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

The students must obtain 18 CP in all out of the modules astro830, -840, -850.

Module No.: astro850
Credit Points (CP):
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Modern Astrophysics

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected 85* courses from catalogue	astro85*	3-6	see catalogue	90-180 hrs	WT/ST
2.	Astrophysics Courses from Cologne marked "MA"	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST
3.	Also possible classes from M.Sc. in Physics					

Requirements:

Preparation:
Adequate preparation in the M.Sc. in Astrophysics programme
Choice of classes to be made with mentor

Content:
This module contains a number of lectures on various astrophysical phenomena, from stars to the largescale structure of the universe

Aims/Skills:
The student shall acquire deeper knowledge of a variety of astrophysical phenomena, from stars through large-scale structure to cosmological aspects. The physical mechanisms and mathematical tools required to understand these phenomena shall be conveyed, complementing what is being treated in the compulsory astrophysics courses

Form of Testing and Examination:
If the lecture is offered with exercises: requirements for the submodule examination (written or oral examination): successful work with exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

The students must obtain 18 CP in all out of the modules astro830, -840, -850.

Module No.: astro890
Credit Points (CP): 4
Category: Elective
Semester: 8.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Seminar

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Seminar on Cosmology	astro891	4	seminar	120 hrs	WT/ST
2.	Seminar on Radio Astronomy	astro892	4	seminar	120 hrs	WT/ST
3.	Seminar on Stellar Systems: "Star Clusters and Dwarf Galaxies"	astro893	4	seminar	120 hrs	WT/ST
4.	Specialized Seminars	astro894	4	seminar	120 hrs	WT/ST

Requirements:

Preparation:

Content:
Modern developments in astrophysics are discussed using recent literature

Aims/Skills:
These seminars will introduce the student for the first time into professional research in astrophysics.
Active participation will furnish the student with the skill to read and present modern research topics

Form of Testing and Examination:
Talk

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module: Seminar

Module No.: astro890

Course: Seminar on Cosmology

Course No.: astro891

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
astro812 (Cosmology)

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
The students will be introduced to the newest state of knowledge in cosmology. They will familiarize themselves with open questions and acquire knowledge on the newest methods in research

Contents of the Course:
The newest literature (in particular using papers from the astro-ph preprint server) relevant to the research on cosmology will be presented in short talks and will be reviewed

Recommended Literature:

Module: Seminar

Module No.: astro890

Course: Seminar on Radio Astronomy

Course No.: astro892

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
astro841 (Radio Astronomy: Tools, Applications, Impacts)

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
The participating students will learn in depth how the radio-astronomical tools can be utilized in practice to scrutinize a wide range of astrophysical phenomena. Technically, this will cover the whole radioastronomical band, from meter-wavelengths to the sub-mm regime

Contents of the Course:
The students will give oral presentations on a selected subject from the recent literature (refereed journals and proceedings). These will cover both, scientific advancements made with radio-astronomical techniques as well as technical developments. The presentations will be prepared by the students with support by the supervisor(s)

Recommended Literature:

Module: Seminar

Module No.: astro890

Course: Seminar on Stellar Systems: "Star Clusters and Dwarf Galaxies"

Course No.: astro893

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
astro811 (Stars and Stellar Evolution), astro821 (Astrophysics of Galaxies)

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
The students will be introduced to the newest state of knowledge in the field of Star Clusters. They will familiarize themselves with open questions and acquire knowledge on the newest methods in research

Contents of the Course:
The newest literature (in particular using papers from the astro-ph preprint server) relevant to the research on stellar populations, star clusters and dwarf galaxies will be presented in short talks and discussed

Recommended Literature:

Module: Seminar

Module No.: astro890

Course: Specialized Seminars

Course No.: astro894

Category	Type	Language	Teaching hours	CP	Semester
Elective	Seminar	English	2	4	WT/ST

Requirements:

Preparation:
Good results in the first Semester of the M.Sc. in Astrophysics programme

Form of Testing and Examination:
Talk

Length of Course:
1 semester

Aims of the Course:
Students will gain insight in special fields and their most recent developments. Knowledge about the newest methods and newest results will be acquired

Contents of the Course:
The newest literature from preprints, reviews and other up-to-date material on specialised topics, chosen based on the most recent developments in special areas of astrophysics, will be presented in short talks and discussed. The main theme will vary from semester to semester

Recommended Literature:

Module No.: astro940
Credit Points (CP): 15
Category: Required
Semester: 9.

Fachgruppe Physik und Astronomie Universität Bonn

Module: Scientific Exploration of the Master Thesis Topic

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Scientific Exploration of the Master Thesis Topic	astro941	15		450 hrs	WT

Requirements:
Successful completion of 40 credit points from the first year of the Master phase, including the base modules physics600 and physics605 and the compulsory modules astro810 and astro820

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall explore the science field, read the relevant recent literature, and perhaps participate in further specialised classes and in seminars. The student shall write an essay about the acquired knowledge, which may serve as the introduction part of the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the scientific question to be studied in the Master Thesis

Form of Testing and Examination:
Essay

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.:	astro950
Credit Points (CP):	15
Category:	Required
Semester:	9.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Methods and Project Planning

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Methods and Project Planning	astro951	15		450 hrs	WT/ST

Requirements:
Successful completion of 40 credit points from the first year of the M.Sc. phase, including the base modules physics600 and physics605 and the compulsory modules astro810 and astro820

Preparation:

Content:
Under guidance of the supervisor of the planned Master Thesis topic, the student shall acquire knowledge about the methods required to carry out the Master Thesis project. This may include the participation in specialised seminars or specialised classes for the Master programme. The student shall plan the steps needed to successfully complete the Master Thesis

Aims/Skills:
The student shall demonstrate to have understood the methods to be used in the Master Thesis research. The project plan has to be presented

Form of Testing and Examination:
Short proposal for Master Thesis

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Module No.: astro960
Credit Points (CP): 30
Category: Required
Semester: 10.

Fachgruppe
Physik und Astronomie
Universität Bonn

Module: Master Thesis

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Master Thesis	astro960	30	Thesis	900 hrs	WT/ST

Requirements:
Successful completion of the preparatory phase for the Master Thesis (astro940 and astro950)

Preparation:

Content:
Under guidance of the supervisor of the Master Thesis topic, the student shall carry out the research of the Master Thesis project

Aims/Skills:
The student shall identify and work out the science question to be tackled in the Master Thesis

Form of Testing and Examination:
Master Thesis and oral presentation

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure:
s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Catalogue of 84* and 85* courses

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Radio Astronomy: Tools, Applications, Impacts

Course No.: astro841

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	WT

Requirements:

Preparation:
Good knowledge of electrodynamics, atomic physics, and astronomy

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
An introduction to modern radio astronomy, its history, methods, and research potentials is given. The goals are to equip the student with the background and know-how to analyze and interpret data from modern single-dish and interferometer radio telescopes, and to enable them to motivate and write radioastronomical observing proposals. Aperture synthesis techniques are explained at some depth. The lecture is furnished with numerous examples demonstrating the versatility and power of radioastronomical tools

Contents of the Course:
Radiation: processes, propagation; Signal detection; Radio telescopes: properties, types; Receivers: heterodyne, bolometers; Backends: continuum, spectroscopy, pulsars; Interferometers: Fourier optics, aperture synthesis; imaging; Future: APEX, ALMA, LOFAR.

Recommended Literature:
B. F. Burke; F. Graham-Smith, An Introduction to Radio Astronomy (Cambridge University Press 2002)
T. L. Wilson; C. Rohlfs; Tools of Radio Astronomy (Springer, Heidelberg 4. rev. und erw. Ed. 2006)
J. D. Kraus; Radio Astronomy (Cygnus-Quasar Books, Durham 2. Aufl. 1986)
R.A. Perley; F. R. Schwab, A.H. Bridle; Synthesis Imaging in Radio Astronomy, 3rd NRAO Summer School 1988 (Astronomical Society of the Pacific Conference Series, 1989)
A. R. Thompson, J. M. Moran, G.W. Swenson, Interferometry and Synthesis in Radio Astronomy (Wiley & Sons, Weinheim 2. Aufl. 2001)
Lecture Notes (U. Klein)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Submillimeter Astronomy

Course No.: astro842

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:
Basic astronomy knowledge

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Students with B.Sc. in Physics will be introduced to astronomy in the submillimeter wavelength range, one of the last spectral regions to be explored with new high-altitude ground-based or airborne telescopes, and from space

Contents of the Course:
The basic concepts of emission/excitation mechanisms from interstellar dust and molecules are discussed as well as the properties of the observed objects: the dense interstellar medium, star forming regions, circumstellar environments. Star formation near and far is a central focus of submillimeter astronomy and will thus be introduced in depth. Telescopes, instrumentation, and observational techniques will be described in the course

Recommended Literature:
Contemporary review articles

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Astronomical Interferometry and Digital Image Processing

Course No.: astro843

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Students learn the basics required to carry out research projects in the field of wave optics and astronomical infrared interferometry

Contents of the Course:
Statistical optics; Wave optics; image detectors; resolution enhancement by digital deconvolution; interferometric imaging methods in optical astronomy; Theory of photon noise; iterative image reconstruction methods; astronomical applications

Recommended Literature:
J. W. Goodman; Introduction to Fourier Optics (Roberts & Company Publishers 3. Aufl. 2004)
Lecture Notes

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: universitätbonn Observational Cosmology

Course No.: astro845

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Students with B.Sc. in Physics will be introduced to past and current experiments in cosmology, with some bias toward radio- and submillimeter astronomy

Contents of the Course:
Brief history of cosmology and its initial discoveries: cosmic expansion, cosmic microwave background. Overview of modern cosmological experiments, their major aims and technology. Aims: constraints on Big Bang and dark energy, CMB power spectrum and polarization, Sunyaev-Zeldovich effect, Supernova Ia distance measures, structure /cluster /galaxy formation, epoch of reionization, high-redshift galaxies and quasars. Experiments: APEX, LOFAR, Planck, Herschel, ALMA, SKA. Techniques: bolometer, HEMT

Recommended Literature:
B. F. Burke; F. Graham-Smith, An Introduction to Radio Astronomy (Cambridge University Press 2002)
J. A. Peacock; Cosmological Physics (Cambridge University Press 1998)
Contemporary Review Articles

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Wave Optics and Astronomical Applications

Course No.: astro846

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Acquire the fundamentals necessary to carry out research projects in the field of wave optics and astronomical infrared interferometry

Contents of the Course:
Fundamentals of wave optics; Fourier mathematics; digital image processing; Michelson interferometry; speckle interferometry; speckle holography; Knox-Thompson method; bispectrum-speckle interferometry; interferometric spectroscopy; infrared-long-baseline interferometry; optical phase-closure method; infrared interferometry of young stars and stars in late evolutionary stages and in nuclei of galaxies

Recommended Literature:
Lecture Notes
J. W. Goodman; Introduction to Fourier Optics (Roberts & Company Publishers 3rd edition, 2004)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Optical Observations

Course No.: astro847

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Astronomy introduction classes

Form of Testing and Examination:
Requirements for the examination (written or oral exam): successful work with exercises

Length of Course:
1 semester

Aims of the Course:
The students should get familiar with major aspects of optical astronomical observations, data reduction, and image analysis.

Contents of the Course:
Optical CCD and near infrared imaging, data reduction, catalogue handling, astrometry, coordinate systems, photometry, spectroscopy, photometric redshifts, basic weak lensing data analysis, current surveys, how to write observing proposals.
Practical experience is gained by obtaining and analysing multi-filter CCD imaging observations using the 50cm telescope on the AIfA rooftop, as well as the analysis of professional data from the archive.

Recommended Literature:
Provided upon registration

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Galactic and Intergalactic Magnetic Fields

Course No.: astro848

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Good knowledge of electrodynamics and astronomy

Form of Testing and Examination:
Requirements for examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The students shall become familiar with relativistic plasmas in astrophysics. They shall comprehend the origin and significance of magnetic fields in diffuse astrophysical media. The potential role of magnetic fields in the evolution of the universe will be discussed. The detection and quantitative measurements of magnetic fields in the ISM and IGM shall be conveyed, along with a description of the current and future observational facilities.

Contents of the Course:
Introduction: magnetism, physical quantities, history, observational evidence; radiation processes: radiation transport, free-free radiation, synchrotron radiation, inverse-Compton radiation, propagation effects; diagnostics: optical polarisation, synchrotron radiation, Faraday rotation, Zeeman effect; radio continuum observations: total and polarised intensity, rotation measure, RM synthesis, telescopes; Milky Way: diffuse ISM, molecular clouds and star-forming regions, supernova remnants, diffusive shock acceleration, cosmic rays, origin and maintenance of magnetic fields, galactic dynamo; external galaxies: spiral galaxies, dwarf irregular galaxies, elliptical galaxies, origin of magnetic fields; active galactic nuclei: radio galaxies, quasars, Seyfert galaxies, origin of magnetic fields; intergalactic magnetic fields: clusters of galaxies, radio halos, radio relics, mini-halos, magnetisation of the IGM, cosmological shocks; cosmological magnetic fields

Recommended Literature:
M.S. Longair: High Energy Astrophysics, Vol. 1+2 (Cambridge University Press, 2008)
S. Rosswog, M. Brüggen: Introduction to High-Energy Astrophysics (Cambr. Univ. Press 2009)
L. Spitzer: Physics of Fully Ionized Gases (Dover Publications , 2006)
Lecture Notes (U. Klein)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Multiwavelength Observations of Galaxy Clusters

Course No.: astro849

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Introductory Astronomy lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
To introduce the students into the largest clearly defined structures in the Universe, clusters of galaxies. In modern astronomy, it has been realized that a full understanding of objects cannot be achieved by looking at just one waveband. Different phenomena become apparent only in certain wavebands, e.g., the most massive visible component of galaxy clusters - the intracluster gas - cannot be detected with optical telescopes. Moreover, some phenomena, e.g., radio outbursts from supermassive black holes, influence others like the X-ray emission from the intracluster gas. In this course, the students will acquire a synoptic, mulitwavelength view of galaxy groups and galaxy clusters.

Contents of the Course:
The lecture covers galaxy cluster observations from all wavebands, radio through gamma-ray, and provides a comprehensive overview of the physical mechanisms at work. Specifically, the following topics will be covered: galaxies and their evolution, physics and chemistry of the hot intracluster gas, relativistic gas, and active supermassive black holes; cluster weighing methods, Sunyaev-Zeldovich effect, gravitational lensing, radio halos and relics, and the most energetic events in the Universe since the big bang: cluster mergers.

Recommended Literature:
Lecture script and references therein

Modules:	astro830 **Elective Advanced Lectures** astro840 **Observational Astronomy**

Course: Introduction to Hydro- and Magnetohydrodynamics

Course No.: astro8401

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

Requirements:

Preparation:
Revision of vectors and vector calculus, electromagnetism, basic thermodynamics

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The students will become familiar with the basic laws of hydrodynamics and magnetohydrodynamics and will understand their universal applicability and importance in many varied contexts. As well as learning about the basic phenomena such as waves and compressible flow, several particular contexts (mainly in astrophysics and atmospheric physics) will be examined in detail using analytical tools which the students will then learn to apply in other, new situations and contexts. By doing this the students will develop abilities to tackle and interpret any hydrodynamical phenomenon they encounter.

Contents of the Course:
The fluid approximation, Euler equations, ideal fluids, viscous fluids, diffusion of heat, sound waves, hydrostatics, flow around an object, the Bernoulli equation, the Reynolds number and other dimensionless parameters used to describe a flow, compressible and incompressible flow, supersonic and subsonic flow, shock waves (with example: supernovae), surface gravity waves, internal gravity waves, waves in a rotating body of fluid (example: earth's atmosphere), stability analysis (examples: convection, salt fingers in ocean), the magnetohydrodynamics equations, Alfven waves, flux conservation, flux freezing, magnetic pressure and tension, force-free fields, reconnection (with example: solar corona), angular momentum transport and the magneto-rotational instability (example: astrophysical discs).

Recommended Literature:
E.Landau & E.Lifshitz, Fluid mechanics (Pergamon Press 1987)
S.Shore; Astrophysical hydrodynamics: an introduction (Wiley-VCH, 2007)
Lecture notes at http://www.astro.uni-bonn.de/~jonathan/misc/astroMHDnotes.pdf

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: X-Ray Astronomy

Course No.: astro8402

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Introductory astronomy lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The student shall be familiarized with X-ray observations as a powerful tool to study almost all astrophysical objects in ways not possible in other wavebands.

Contents of the Course:
History, space-based instruments, radiation processes, solar system objects, isolated compact objects, binaries with compact objects, supernova remnants, interstellar medium, Galactic center, normal galaxies, galaxy clusters, superclusters, intergalactic medium, active galactic nuclei.

Recommended Literature:
Lecture notes will be provided

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Hydrodynamics and astrophysical magnetohydrodynamics

Course No.: astro8403

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Revision of elementary thermodynamics, vector calculus and electromagnetism. Please note that although this course is designed mainly with astrophysics in mind, no knowledge of astrophysics is assumed. Students of other branches of physics are welcome.

Form of Testing and Examination:
Exercises throughout the semester, and an oral examination at the end of the course.

Length of Course:
1 semester

Aims of the Course:
Almost the entire universe is fluid and so an understanding of many phenomena is impossible without a proper grasp of fluid dynamics. This course introduces the field, drawing on examples from astrophysics as well as atmospheric physics to illustrate the principles. The aim is for the students to develop an intuitive understanding of underlying principles. Roughly the last quarter of the course is an introduction to magnetohydrodynamics; here the emphasis is on astrophysical applications (rather than laboratory/plasma physics).

Contents of the Course:
The fluid approximation, Euler equations, ideal fluids, viscous fluids, diffusion of heat, sound waves, hydrostatics, flow around a solid body, the Bernoulli equation, the Reynolds number and other dimensionless parameters used to describe a flow, compressible and incompressible flow, supersonic and subsonic flow, shocks (with example: supernovae), surface & internal gravity waves, vortices and vorticity, waves in a rotating body of fluid (example: earth's atmosphere), stability analysis (examples: convection, shear instability), the magnetohydrodynamics equations, Alfven waves, flux conservation, flux freezing, magnetic pressure and tension, force-free fields, reconnection (with example: solar corona), angular momentum transport and the magneto-rotational instability (example: astrophysical discs).

Recommended Literature:
E.Landau & E.Lifshitz, "Fluid mechanics" Pergamon Press 1987
S.Shore, "Astrophysical hydrodynamics: an introduction", Wiley-VCH 2007
A. Choudhuri, "The physics of fluids and plasmas", Cambridge 1998
Lecture notes at http://www.astro.uni-bonn.de/~jonathan/misc/Hydro_astroMHD.pdf

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Radiointerferometry: Methods and Science

Course No.: astro8404

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+2	4	ST

Requirements:

Preparation:
Einführung in die Radioastronomie (astro123), Radio Astronomy (astro841)

Form of Testing and Examination:
Requirements for the examination (written or oral): Successful participation in the exercise sessions

Length of Course:
1 semester

Aims of the Course:
Basics of radiointerferometric observations and techniques; review of science highlights; use of common data analysis packages.

Contents of the Course:
Principles of interferometry, aperture synthesis, calibration, continuum and spectral line imaging, zero spacing, VLBI, use of AIPS and CASA, ALMA and VLA proposal writing, LOFAR and SKA, science highlights.

Recommended Literature:
"Synthesis Imaging in Radio Astronomy II" (ASP Conference Series, V. 180, 1998), Editors: Taylor, Carilli, Perley
Interferometry and Synthesis in Radio Astronomy (Wiley 2001), by Thompson, Moran, Swenson

On-line material

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: universitätbonn Stellar and Solar Coronae

Course No.: astro851

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
The student shall gain thorough knowledge of activity phenomena exhibited by the sun and other stars

Contents of the Course:
Sunspots and solar corona; Solar cycle; The Dynamo theory; Emission mechanism; Coronal loops; Magnetic reconnection; Flares; Magnetic stellar activity; Mapping star-spots: Doppler imaging; Radio coronae

Recommended Literature:
Literature references will be provided during the course

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Gravitational Lensing

Course No.: astro852

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
After learning the basics of gravitational lensing followed by the main applications of strong and weak lensing, the students will acquire knowledge about the theoretical and observational tools and methods, as well as about the current state of the art in lensing research. Strong emphasis lies on weak lensing as a primary tool to study the properties of the dark-matter distribution and the equation of state of dark energy

Contents of the Course:
The detection of the deflection of light in a gravitational field was not only one of the crucial tests of Einstein's Theory of General Relativity, but has become in the past two decades a highly valuable tool for astronomers and cosmologists. It is ideally suited for studying the mass distribution of distant objects, search for compact objects as a potential constituent of the Galactic dark matter, provide powerful (and cheap) 'natural telescopes' to take a deeper look into the distant Universe, to measure the mass distribution in clusters and on larger spatial scales, and to study the relation between luminous and dark matter in the Universe. Principles and methods are described in detail and the applications will be presented

Recommended Literature:
P. Schneider, C. Kochanek, J. Wambsganss; Gravitational Lensing: Strong, Weak and Micro: Saas-Fee Advanced Course 33. Swiss Society f Astrophysics and Astronomy (Springer, Heidelberg 2006)
P. Schneider, J. Ehlers, E. F. Falco; Gravitational Lenses (Springer, Heidelberg 1992)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: The Physics of Dense Stellar Systems as the Building Blocks of Galaxies

Course No.: astro8531

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	6	WT

Requirements:

Preparation:
Participation in the lecture course and in the exercise classes and reading

Form of Testing and Examination:
A final two hour written exam on the contents of the course

Length of Course:
1 semester

Aims of the Course:
The students are taught the fundamentals of collisional stellar dynamics and of the emergence of stellar populations from galactic building blocks

Contents of the Course:
Fundamentals of stellar dynamics: distribution functions, generating functions, collisionless Boltzmann equation, Jeans equations, Fokker-Planck equation, dynamical states, collisional dynamics and relaxation, formal differentiation between star clusters and galaxies, mass segregation, evaporation, ejection, star-cluster evolution, the form, variation and origin of the stellar initial mass function, stellar populations, their evolution and their properties, binary stars as energy sinks and sources, the distribution functions of binary stars and the evolution of these distribution functions, star-cluster birth, violent relaxation, birth of dwarf galaxies.

The lecture course covers a broad range of topics related to the emergence of stellar populations from their molecular cloud cores. It provides a Bonn-unique synthesis on the one hand side between observationally and theoretically derived distribution functions, which describe stellar populations, and on the other hand side the temporal evolution of these distribution functions, such that a comprehensive mathematical formulation of stellar populations in galaxies becomes possible with this knowledge.

Recommended Literature:
Lecture notes
Galactic Dynamics by J.Binney and S.Tremaine (1987, Princeton University Press)
Dynamics and Evolution of Galactic Nuclei by D.Merritt (2013, Princeton University Press)
Dynamical Evolution of Globular Clusters by Lyman Spitzer, Jr. (1987, Princeton University Press)
The Gravitational Million-Body Problem by Douglas Heggie and Piet Hut (2003, Cambridge University Press)
Gravitational N-body Simulations: Tools and Algorithms by Sverre Aarseth (2003, Cambridge University Press)
Initial Conditions for Star Clusters by Pavel Kroupa (2008, Lecture Notes in Physics, Springer)
The stellar and sub-stellar IMF of simple and composite populations by Pavel Kroupa (2013, Stars and Stellar Systems Vol.5, Springer)
The universality hypothesis: binary and stellar populations in star clusters and galaxies by Pavel Kroupa

(2011, IAUS 270, p.141)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Numerical Dynamics

Course No.: astro854

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:

Form of Testing and Examination:
Requirements for the examination (written): successful work with exercises and programming tasks

Length of Course:
1 semester

Aims of the Course:
The students will have to familiarize themselves with the various numerical recipes to solve the coupled 2nd-order differential equations as well as with the limitations of these methods

Contents of the Course:
The two-body problem and its analytical solution. Ordered dynamics: integration of planetary motion, solar system, extra-solar planets. Collisional dynamics: integration of stellar orbits in star clusters, star-cluster evolution. Collisionless dynamics: integration of stellar orbits in galaxies, cosmological aspects

Recommended Literature:
Write-up of the class;
S. J. Aarseth; Gravitational N-body simulations: Tools and Algorithms (Cambridge University Press, 2003)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Quasars and Microquasars

Course No.: astro856

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

Requirements:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The phenomenon of quasars and their energy production shall be studied from the smallest (stellar binaries) to the largest (active galactic nuclei) scales

Contents of the Course:
Microquasars and Quasars; X-ray binaries; Accretion; Neutron stars; Black holes; X-ray observations; Spectral states; Radio observations; Doppler boosting; Energy losses; Magneto-hydrodynamic production of jets; Gamma-ray observations; Review of Microquasars; Quasi periodic oscillations (QPO)

Recommended Literature:
Literature references will be provided during the course

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Star Formation

Course No.: astro857

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
An introduction to basic concepts, modern theories, and the current observational basis of star formation.

Contents of the Course:
The structure and evolution of the interstellar medium in relation to Star Formation: molecular excitation, interstellar chemistry; the star formation process: conditions, cloud collapse, protostellar evolution; low mass vs. massive star formation; related phenomena: jets and outflows, protostellar disks, shocks, photodissociation regions; the initial mass function, global star formation, starbursts, the star formation history of the Universe, the very first stars.

Recommended Literature:
Stahler, Palla: The Formation of Stars (Wiley-VCH, 2004)
Additional literature will be given during the course

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Nucleosynthesis

Course No.: astro858

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements:

Preparation:
Introduction to Astronomy, Stars and Stellar Evolution

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
Obtain an overview of the different nucleosynthesis processes in the universe, an understanding of how they work, and where they work.

Contents of the Course:
Basic: Thermonuclear reactions
Big Bang nucleosynthesis
Overview of stellar evolution
Hydrostatic Nucleosynthesis I: Hydrogen burning
Hydrostatic Nucleosynthesis II: Helium burning and beyond
Hydrostatic Nucleosynthesis III: The s-process
Hydrostatic Nucleosynthesis IV: s-process components
Explosive Nucleosynthesis I: Core-collapse supernovae
Explosive Nucleosynthesis II: r-process and p-process
Explosive Nucleosynthesis III: Thermonuclear supernovae
Cosmic ray nucleosynthesis
Chemical Evolution of galaxies

Recommended Literature:
Lecture script
C.E.Rolfs, W.S.Rodney: Cauldrons in the Cosmos (ISBN 0-226-45033-3), not compulsary
D.D. Clayton: Physics of Stellar Evolution and Nucleosynthesis (ISBN 0-226-10953-4), not compulsary

Modules:	astro830 **Elective Advanced Lectures** astro850 **Modern Astrophysics**

Course: The cosmic history of the intergalactic medium

Course No.: astro859

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:
Basic atomic physics (hydrogen atom) and basic thermodynamics. No previous knowledge of astrophysics is required.

Form of Testing and Examination:
Written or oral examination

Length of Course:
1 semester

Aims of the Course:
The aim of this course is to familiarize students with the physics of the intergalactic medium (the material that pervades the vast regions between galaxies) and with its significance for cosmology and the astrophysics of galaxies. Thanks to progress in observations, theoretical modeling, and computational power, our knowledge in this field is growing rapidly. The main questions driving current research will be discussed and new results introduced as they occur.

Contents of the Course:
Basic: Transport of continuum and line radiation, photo-ionizations and radiative recombinations, the cooling function, the expanding universe.

Advanced: Cosmic recombination, the dark ages, hydrogen and helium reionization, 21cm-probes of the dark ages and reionization, quasar absorption systems, the UV background, the warm-hot intergalactic medium, intracluster gas, Lyman-alpha fluorescence.

Recommended Literature:
The study of the intergalactic medium is a young subject. No textbook exists for this topic. Lecture notes will be distributed.

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Binary Stars

Course No.: astro8501

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Introductory astronomy and cosmology lectures, stars and stellar evolution

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The course will provide the necessary understanding of the basic physics of binary stars, in particular orbits, mass-transfer, chemistry and the importance of binary stars and populations of binaries to modern astrophysics.

Contents of the Course:
Most stars are not alone, they orbit a companion in a binary star system. This course will address the evolution of such binary stars and their impact on the Universe. It will start by considering orbital dynamics and observations of binaries, followed by stellar interaction in the form of mass transfer by Roche-lobe overflow and wind mass transfer. The effect of duplicity on chemistry, rotation rates and orbital parameters will be studied with the emphasis on uniquely binary-star phenomena such as type Ia supernovae, thermonuclear novae and gamma-ray bursts. It will conclude with quantitative studies of populations of binary stars.

Recommended Literature:
An Introduction to Close Binary Stars - Hildtich - Cambridge University Press ISBN 0-421-79800-0
Interacting Binary Stars - Pringle and Wade - CUP (Out of print but you can find cheap second-hand copies on www.amazon.com) ISBN 0-521-26608-4
Evolutionary Processes in Binary and Multiple Stars - Eggleton - CUP ISBN 0-521-85557-8

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Physics of Supernovae and Gamma-Ray Bursts

Course No.: astro8502

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:
Introductory astronomy and cosmology lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The student will learn basic physics on supernova and gamma-ray burst, and will have an overview on their applications to various fields of astrophysics.

Contents of the Course:
Basic physics on stellar hydrodynamics, radiation processes, and stellar death.
Type Ia supernova: observations and theory. Application to cosmology
Core collapse supernova: observations and theory
Gamma-ray bursts: observations and theory.
Implications for massive star population and star-formation history
Supernova nucleosynthesis and chemical evolution of galaxies
Explosions of the first generations of stars
Some related issues: supernova remnants, neutrinos, shock break-out, etc.

Recommended Literature:
Lecture notes with key references for each topic will be provided.

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Radio and X-Ray Observations of Dark Matter and Dark Energy

universitätbonn

Course No.: astro8503

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:
Introductory astronomy and cosmology lectures

Form of Testing and Examination:
Written or oral examination, successful exercise work

Length of Course:
1 semester

Aims of the Course:
The student will learn how the phenomena of dark matter and dark energy are explored using radio and X-ray observations, from the largest down to galaxy scales.

Contents of the Course:
Introduction into the evolution of the Universe and the theoretical background of dark matter and dark energy tests, dark matter associated with galaxies, dark matter associated with galaxy clusters and superclusters, the cosmic microwave background (CMB), epoch of re-ionization, low-frequency radio astronomy, high-z supernovae, cosmic infrared background (CIB), precise distance measurements at cosmological distances, observational evidence for hierarchical structure formation, MOND vs. dark matter cosmology.

Recommended Literature:
Lecture notes will be provided

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Lecture on Advanced Topics in Modern Astrophysics

Course No.: astro8504

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT/ST

Requirements:

Preparation:
Theoretical courses at the Bachelor degree level

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
This course is to allow the students to have deeper insight into a specialised subject of astrophysics that is not covered in the astrophysics curriculum otherwise. The content of the course depends on the lecturer’s expertise and may vary from time to time.

Contents of the Course:
See detailed announcements ("kommentiertes Vorlesungsverzeichnis")

Recommended Literature:

Cologne Courses in

Astrophysics

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Astrophysics II (MA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+1	8	WT

Requirements:

Preparation:
Astrophysics I

Form of Testing and Examination:
written test

Length of Course:
1 semester

Aims of the Course:
The student will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable him to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepares the students towards their own research activity within the master thesis.

Contents of the Course:
Based on the introductory course 'Astrophysics I' in the Bachelor program this course deepens the understanding in selected topical areas of relevance. These are:
Interstellar medium: molecular clouds, HII regions, photon dominated regions, shock waves, radiation processes, radiative transfer, astrochemistry
Star formation (low mass and high mass), planetary system formation
Galaxies: galactic structure, morphology, dynamics, chemical evolution, nuclei of active galaxies
Large scale structure of the universe: intergalactic distance ladder, galaxy clusters, dark matter, gravitational lenses, experimental cosmology

Recommended Literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einfhrung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Star Formation (MA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2	3	WT

Requirements:

Preparation:
Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts of star formation in a variety of environments.

Contents of the Course:
The lecture introduces the basic aspects of Star Formation:
Physical Processes in the ISM, Interstellar Chemistry, ISM and Molecular Clouds, Equilibrium Configurations and Collapse, Protostars, Formation of High Mass Stars, Jets, Outflows, Disks, Pre-main sequence stars, Initial Mass Function, Structure of the Galaxy, Starburst Galaxies, Star Formation in the early Universe

Recommended Literature:
Palla and Stahler, Formation of Stars (Wiley)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Spitzer, Physical Processes in the Interstellar Medium (Wiley)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)

Modules:

astro830 **Elective Advanced Lectures**
astro850 **Modern Astrophysics**

Course: Galaxy Dynamics (MA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	WT

Requirements:

Preparation:
Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts of stellar and galaxy dynamics.

Contents of the Course:
The lecture introduces to basic aspects of stellar and galaxy dynamics: Multiple stellar systems, dynamics of open and compact stellar clusters, elliptical, disk and barred spiral galaxies, gas kinematics, galaxy evolution in galaxy clusters, gravitational friction, violent relaxation, the Hubble fork, galaxy collisions and mergers, cosmological evolution of stellar systems.

Recommended Literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Active Galactic Nuclei (OA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Astrophysics I (Astrophysics II recommended)

Form of Testing and Examination:
Oral examination

Length of Course:
1 semester

Aims of the Course:
Understanding of fundamental concepts and physical radiation mechanisms for active galactic nuclei
Like Seyfert-galaxies, QSOs, quasars, and violently variable objects.

Contents of the Course:
The lecture introduces to basic aspects of active galactic nuclei:
Types of sources HII-galaxies, LINERs, Seyfert I, Seyfert II, QSO I , QSO II, BLLac /OVV-sources
Structure of an active nucleus: Broad line region (BLR), Narrow line region (NLR) and extended narrow line region (ionization cone).
Forbidden and permitted line transitions as density and temperature probes
Continuum emission processes: free-free and synchrotron radiation
Radio galaxies, jets and lobes as well as super luminal motion in jets.

Recommended Literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: Methods of Experimental Astrophysics (OA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Elementary Physics (Bachelor level); Astrophysics I (and II)

Form of Testing and Examination:
Exercise and written test; or oral examination

Length of Course:
1 semester

Aims of the Course:
Gain insight into which type of instrumentation, based on which principles, is employed for particular astronomical and astrophysical applications; and learn about their practical and fundamental limitations in resolution and sensitivity

Contents of the Course:
- detection of radiation: direct and coherent detection
- Signal/Noise ratio: fundamental and practical limits
- principles of optical instruments: imaging
- principles of optical instruments: spectroscopy
- radio receivers: Local Oscillator, Mixer and Backend-Spectrometers
- calibration: theory and measurement startegies

Recommended Literature:
Rieke: Detection of Light
Kraus: Radioastronomy
Bracewell: The Fourier Transform and its Applications

Modules:

astro830 **Elective Advanced Lectures**
astro840 **Observational Astronomy**

Course: The Fourier-Transform and its Applications (OA)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements:

Preparation:
Elementary Physics (Bachelor level); Elementary QM

Form of Testing and Examination:
Exercise and written test; or oral examination

Length of Course:
1 semester

Aims of the Course:
Strengthen insight into how the mathematical principles of Fourier Theory as a common principle affect many areas of physics (optics: diffraction/interference; QM: Heisenberg principle; statistics of noise and drifts; data acquisition: sampling) and other applications (data compression, signal processing).

Contents of the Course:
- introduction to the principles of Fourier Transform mathematics
- Delta-function and more general distributions
- diffraction optics and interferometry
- uncertainty principle in QM as application of FT
- theory of noise, drifts and their statistics
- intro to wavelet analysis and data compression

Recommended Literature:
Bracewell: The Fourier Transform and its Applications

Lehrveranstaltungen für andere Fächer

SS 2024

Inhaltsverzeichnis: Lehrveranstaltungen für andere Fächer

physik010 Physik-Lehrveranstaltungen für Nebenfachstudierende 1
physik011 Physik für Naturwissenschaftler I 2
physik012 Physik für Naturwissenschaftler II 3
physik013 Physikalisches Anfängerpraktikum für Naturwissenschaftler 4
physik014 Praktische Übungen in Physik für Geodäten 5
physik021 Physik für Mediziner, Pharmazeuten und Geodäten 6
physik041 Physik für Ernährungs- und Lebensmittelwissenschaften, Agrarwissenschaft 7
physik051 Physikalische Anwendungen in der Medizin 8
astro080 Astronomie für Nebenfächler 9
astro081 Astronomie für Einsteiger I 10
astro082 Astronomie für Einsteiger II 11
astro121 Einführung in die Astronomie 12
astro122 Einführung in die extragalaktische Astronomie 13
astro123 Einführung in die Radioastronomie 14
astro811 Stars and Stellar Evolution or specific: Stellar Structure and Evolution 15
astro822 Physics of the Interstellar Medium 16

Modul-Nr.: physik010
Leistungspunkte: 3-17
Kategorie: Wahl
Semester: 1.-4.

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Physik für Naturwissenschaftler I	physik011	*	Vorl. + Üb.	150 Std.	WS
2.	Physik für Naturwissenschaftler II	physik012	*	Vorl. + Üb.	120 Std.	SS
3.	Physikal. Anfängerprakt. für Naturwiss.	physik013	*	Praktikum	120 Std.	WS/SS
4.	Prakt. Üb. in Physik für Geodäten	physik014	5	Praktikum	150 Std.	WS/SS
5.	Physik für Mediziner, Pharmazeuten und Geodäten	physik021	*	Vorl. + Üb.		WS/SS
6.	Physik für Ernährungs- , Lebensmittel- und Agrarwissenschaften	physik041	6	Vorl. + Üb.	180 Std.	SS
7.	Physikalische Anwendungen in der Medizin	physik051	*	Vorlesung	90 Std.	WS/SS

Zulassungsvoraussetzungen:
Die Teilnahmevoraussetzungen richten sich nach dem Nebenfach.

Empfohlene Vorkenntnisse:

Inhalt:
Physikvorlesungen und Praktika für Nebenfachstudierende. Lehrveranstaltungen können auf verschiedene Arten kombiniert werden (auch LP-Unterschiede). Der erfolgreiche Abschluss von Vorlesungen kann Vorbedingung für Teilnahme an Praktika sein (siehe LV-Beschreibungen).

Lernziele/Kompetenzen:
siehe Teilmodule

Prüfungsmodalitäten:
siehe Teilmodule

Dauer des Moduls: 1-2 Semester

Max. Teilnehmerzahl:

Anmeldeformalitäten:

* Wird in der Bachelor-Prüfungsordnung des importierenden Faches festgelegt.

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modul-Nr.: physik010

Lehrveranstaltung: Physik für Naturwissenschaftler I

LV-Nr.: physik011

Kategorie	LV-Art	Sprache	SWS	LP	Semester
fachspezifisch	Vorlesung mit Übungen	deutsch	4+1	*	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
nützlich: Vertrautheit mit mathematischen Methoden der SEK II (Vektorrechnung, trigonomische Funktionen, Differentiation, Integration)
nützlich: Vorkurs Mathematik für Naturwissenschaftler

Studien- und Prüfungsmodalitäten:
Klausur

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Erarbeitung von Physikalischen Grundkenntnissen und Ihre Anwendung auf die rechnerische oder phänomenologische Lösung von naturwissenschaftlichen Problemstellungen.
Vorbereitung auf die Durchführung eigener praktischer Experimente im physikalischen Praktikum.

Inhalte der LV:
Grundlagen (Größen, Einheiten, Statistik und Fehlerrechnung), Bewegung in einer Dimension (Geschwindigkeit, Beschleunigung, diffenzieren, integrieren), Bewegung in zwei Dimensionen (Vektoren, Wurfbahnen), Newton'sche Gesetze (Kraftgesetze, Bewegungsgleichungen, Lösung in einfachen Fällen), Erhaltungssätze (Arbeit, Energie, Impuls, Stoßprozesse), Rotationen und Kreisbewegungen (Vektorprodukt, Drehmoment, Drehimpuls,Trägheitsmoment),Gravitation (Gravitationsgesetz, Kepler'sche Gesetze), Rotierende Bezugssysteme (Zentrifugalkraft, Corioliskraft), Schwingungen (einfach, gedämpft, erzwungen, Resonanz), Elastische Eigenschaften von Festkörpern (Kompressionsmodul, Schermodul), Wellen (mechanisch, akustisch), Fluide (Druck, Auftrieb, Strömungen, Bernoulli).

Literaturhinweise:
W. Bauer, W. Benenson G. Westfall : CliXX Physik CD-Rom (Harri Deutsch, Frankfurt am Main 2004)
E.W. Otten: Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Tipler, Dransfeld-Kienle, Orear, Metzler (Physik , Oberstufe)

* Wird in der Bachelor-Prüfungsordnung des importierenden Faches festgelegt.

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modul-Nr.: physik010

Lehrveranstaltung: Physik für Naturwissenschaftler II

LV-Nr.: physik012

Kategorie	LV-Art	Sprache	SWS	LP	Semester
fachspezifisch	Vorlesung mit Übungen	deutsch	4+1	*	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
nützlich: Vertrautheit mit mathematischen Methoden der SEK II (Vektorrechnung, trigon. Funktionen, Differentiation, Integration)
nützlich: Vorkurs Mathematik für Naturwissenschaftler
Empfehlung: Kombination der Vorlesung mit den begleitenden Übungen in Gruppen, zur Lösung von naturwissenschaftlichen Problemstellungen und Vorbereitung auf die Klausur.

Studien- und Prüfungsmodalitäten:
zweistündige Klausur am Ende des Semesters.

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Erarbeitung von Physikalischen Grundkenntnissen und Ihre Anwendung auf die rechnerische oder phänomenologische Lösung von naturwissenschaftlichen Problemstellungen.
Vorbereitung auf die Durchführung eigener praktischer Experimente im physikalischen Praktikum.

Inhalte der LV:
Wärmelehre (Temperatur, Wärme, Thermodynamik, Zustandsänderungen, Kreisprozesse) , Elektrostatik (Ladung, Coulomb-Gesetz, elektrisches Feld, Dipol, Kondensator, Kapazität, Dielektrika) Elektrische Leitung (Leitungsmechanismen, Stromdichte, Ladungserhaltung, Ohm'sches Gesetz, Stromkreise) Magnetismus (Ströme als Ursache, Felder, magn. Dipol, Spule, Materie in magnetischen Feldern) Veränderliche Ströme (Induktion, Transformator, Wechselstromkreis, Schwingkreis) Elektromagnetische Wellen (Hertz'scher Dipol, Polarisation, Wärmestrahlung) Ursprünge der Quantentheorie (Photonen, Atomaufbau, Spektrallinien, Kernspinresonanz), Kern-und Teilchenphysik (Kernzerfälle, Aufbau der Materie, fundamentale Wechselwirkungen), Optik (Wellenoptik und Photonen, Interferenz an Spalt und Gitter, Auflösungsvermögen, Strahlenoptik, Linsen und optische Instrumente).

Literaturhinweise:
W. Bauer, W. Benenson G. Westfall : CliXX Physik CD-Rom (Harri Deutsch, Frankfurt am Main 2004)
E.W. Otten: Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Tipler, Dransfeld-Kienle, Orear, Metzler (Physik, Oberstufe)

* Wird in der Bachelor-Prüfungsordnung des importierenden Faches festgelegt.

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modul-Nr.: physik010

Lehrveranstaltung: Physikalisches Anfängerpraktikum für Naturwissenschaftler

LV-Nr.: physik013

Kategorie	LV-Art	Sprache	SWS	LP	Semester
fachspezifisch	Praktikum	deutsch	4	*	WS/SS

Zulassungsvoraussetzungen:
Erdwissenschaften: bestandene Klausur physik021, Chemie: bestandene Klausur physik012
Andere Fächer: siehe jeweilige Bachelor-Prüfungsordnung

Empfohlene Vorkenntnisse:
Erdwissenschaften: physik021, Chemie: physik011 und physik012
Andere Fächer: siehe jeweilige Bachelor-Prüfungsordnung

Studien- und Prüfungsmodalitäten:
Studienmodalität: Vorbereiten auf physikalische Grundlagen, Durchführen und Auswerten von Experimenten in kleinen Gruppen. Prüfungsmodalität: mündliche Abschlussprüfung

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten

Inhalte der LV:
10 Versuche im Praktikum zur Mechanik, Wärmelehre, Elektromagnetismus und Optik
Auswahl: Einführungsversuch "Was ist ein Praktikum", Elastizitätskonstanten, Biegung und Knickung, Schwingungen, freie und erzwungene Schwingungen, Trägheitsmoment und physisches Pendel, spezifische Wärmekapazität, Adiabatenkoeffizient, statistische Schwankungen. Gleichströme, Spannungsquellen, Widerstände, elektrolytischer Trog, Fadenstrahlrohr, Linsen und optische Instrumente, Beugung und Interferenz. 2 begleitende Seminare inkl. Einführungsversuch

Literaturhinweise:
W. Walcher; Praktikum der Physik (Teubner, Wiesbaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999),
E.W. Otten: Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Tipler, Dransfeld-Kienle, Orear, Metzler (Physik , Oberstufe); Mills: Arbeitsbuch zu Tipler/Mosca Physik

max. Teilnehmerzahl: 80 pro Kurs
weitere Informationen: http://pi.physik.uni-bonn.de/~aprakt/
* Wird in der Bachelor-Prüfungsordnung des importierenden Faches festgelegt.

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modul-Nr.: physik010

Lehrveranstaltung: Praktische Übungen in Physik für Geodäten

LV-Nr.: physik014

Kategorie	LV-Art	Sprache	SWS	LP	Semester
fachspezifisch	Praktikum	deutsch	4	5	WS/SS

Zulassungsvoraussetzungen:
Teilnahme an Klausur zu physik021

Empfohlene Vorkenntnisse:
physik021

Studien- und Prüfungsmodalitäten:
Studienmodalität: Vorbereiten auf physikalische Grundlagen, Durchführen und Auswerten von Experimenten in kleinen Gruppen
Prüfungsmodalität: mündliche Abschlussprüfung

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Praktische Erfahrungen zum zielgerichteten Experimentieren und Auswerten

Inhalte der LV:
8 Versuche im Praktikum zur Mechanik, Elektromagnetismus und Optik

Einführungsversuch "Was ist ein Praktikum"; Auswahl: Schwingungen, freie und erzwungene Schwingungen, Trägheitsmoment und physisches Pendel, statistische Schwankungen, RC-Glieder und Schwingkreise, Gleichströme, Spannungsquellen, Widerstände, Linsen und optische Instrumente, Beugung und Interferenz.

1 begleitendes Seminar inkl. Einführungsversuch

Literaturhinweise:
W. Walcher; Praktikum der Physik (Teubner, Wiesbaden 8. Aufl. 2004)
D. Geschke; Physikalisches Praktikum (Teubner, Wiesbaden 12. Aufl. 2001)
V. Blobel; Statistische und numerische Methoden der Datenanalyse (Teubner, Wiesbaden 1. Aufl. 1999),
E.W. Otten: Repetitorium Experimentalphysik (Springer, Heidelberg 2. Aufl. 2002)
Tipler, Dransfeld-Kienle, Orear, Metzler (Physik, Oberstufe)
Mills: Arbeitsbuch zu Tipler/Mosca Physik

max. Teilnehmerzahl: 80 pro Kurs
weitere Informationen: http://pi.physik.uni-bonn.de/~aprakt/

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modul-Nr.: physik010

Lehrveranstaltung: Physik für Mediziner, Pharmazeuten und Geodäten

LV-Nr.: physik021

Kategorie	LV-Art	Sprache	SWS	LP	Semester
fachspezifisch	Vorlesung mit Übungen	deutsch	3+1	*	WS/SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematische Grundkenntnisse

Studien- und Prüfungsmodalitäten:
Abschlussklausur, falls in der Prüfungsordnung vorgesehen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Studierenden anderer Studiengänge soll grundlegendes Wissen der Physik vermittelt werden.
Vorbereitung für ein Physikalisches Praktikum.

Inhalte der LV:
Sehr kompakte Einführung in die Experimentalphysik:

- Physikalische Größen und Einheiten
- Mechanik: Statik und Kinematik starrer Körper
- Kondensierte Materie: Aggregatzustände, Verformungen
- Flüssigkeiten und Gase: Hydrostatik, Grenzflächen, Hydrodynamik, Reale/ideale Gase, Wärme und Temperatur
- Elektrizität und Magnetismus: Widerstand und Ohmsches Gesetz, Kapazität, Wechselspannung, Elektrisches Feld, Materie im elektrischen Feld, Magnetostatik, Elektromagnetismus
- Schwingungen und Wellen: mechanisch / elektromagnetisch, Wellen-ausbreitung und -überlagerung
- Optik: Geometrische Optik, Optische Instrumente, Wellenoptik, Elektronenoptik, Röntgenstrahlen
- Atomphysik: Aufbau des Atoms, Bohr'sches Atommodell, Absorption und Strahlung
- Kern und Elementarteilchenphysik: Aufbau und Bindungsenergie der Kerne, radioaktiver Zerfall

Literaturhinweise:
U. Harten, "Physik für Mediziner"
H. A. Stuart, G. Klages, "Kurzes Lehrbuch der Physik"

* Wird in der Bachelor-Prüfungsordnung des importierenden Faches festgelegt.

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modul-Nr.: physik010

Lehrveranstaltung: Physik für Ernährungs- und Lebensmittelwissenschaften, Agrarwissenschaften

LV-Nr.: physik041

Kategorie	LV-Art	Sprache	SWS	LP	Semester
fachspezifisch	Vorlesung mit Übungen	deutsch	3+1	6	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Mathematische Grundkenntnisse

Studien- und Prüfungsmodalitäten:
Abschlussklausur

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Studierenden anderer Studiengänge soll grundlegendes Wissen der Physik vermittelt werden.
Vorbereitung für ein Physikalisches Praktikum.

Inhalte der LV:
Sehr kompakte Einführung in die Experimentalphysik:

- Physikalische Größen und Einheiten
- Mechanik: Statik und Kinematik starrer Körper
- Kondensierte Materie: Aggregatzustände, Verformungen
- Flüssigkeiten und Gase: Hydrostatik, Grenzflächen, Hydrodynamik, Reale/ideale Gase, Wärme und Temperatur
- Elektrizität und Magnetismus: Widerstand und Ohmsches Gesetz, Kapazität, Wechselspannung, Elektrisches Feld, Materie im elektrischen Feld, Magnetostatik, Elektromagnetismus
- Schwingungen und Wellen: mechanisch / elektromagnetisch, Wellen-ausbreitung und -überlagerung
- Optik: Geometrische Optik, Optische Instrumente, Wellenoptik, Elektronenoptik, Röntgenstrahlen
- Atomphysik: Aufbau des Atoms, Bohr'sches Atommodell, Absorption und Strahlung
- Kern und Elementarteilchenphysik: Aufbau und Bindungsenergie der Kerne, radioaktiver Zerfall

Literaturhinweise:
U. Harten, "Physik für Mediziner"
H. A. Stuart, G. Klages, "Kurzes Lehrbuch der Physik"

Modul: Physik-Lehrveranstaltungen für Nebenfachstudierende

Modul-Nr.: physik010

Lehrveranstaltung: Physikalische Anwendungen in der Medizin

LV-Nr.: physik051

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlfach	Vorlesung	deutsch	2	*	WS/SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
physik021: Physik für Mediziner oder vergleichbare Grundlagenkenntnisse

Studien- und Prüfungsmodalitäten:
benotete Leistungsüberprüfung

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis der physikalischen Grundlagen medizinischer Geräte und Verfahren, physikalische Grenzen von Analyseverfahren, Auflösung, Genauigkeiten.

Inhalte der LV:
Einordnung physikalischer Verfahren in der Medizin: Mechanisch, optisch, elektromagnetisch, Strahlungsbasiert, in Bildgebung, anatomischer und funktionaler Diagnose, Therapie; physikalische Grundlagen, Auflösung verschiedener Verfahren, Anwendungsgebiete und Grenzen, Apparate.

Literaturhinweise:
Werden in der Vorlesung bekannt gegeben

* Wird in der Bachelor-Prüfungsordnung des importierenden Faches festgelegt.

Modul-Nr.: astro080
Leistungspunkte: 2-18
Kategorie: Wahl
Semester:

Fachgruppe
Physik und Astronomie
Universität Bonn

Modul: Astronomie für Nebenfächler

Modulbestandteile:

Nr.	LV Titel	LV Nr	LP	LV-Art	Aufwand	Sem.
1.	Astronomie für Einsteiger I	astro081	1	Vorlesung	30 Std.	WS
2.	Astronomie für Einsteiger II	astro082	1	Vorlesung	30 Std.	SS
3.	Einführung in die Astronomie	astro121	4	Vorl. + Üb.	120 Std.	WS
4.	Einführung in die extragalaktische Astronomie	astro122	4	Vorl. + Üb.	120 Std.	SS
5.	Einführung in die Radioastronomie	astro123	4	Vorl. + Üb. + Pr.	120 Std.	SS
6.	Stars and Stellar Evolution or specific: Stellar Structure and Evolution	astro811	6	Lect. + ex.	180 hrs	WT
7.	Physics of the Interstellar Medium	astro822	6	Lect. + ex.	180 hrs	ST

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Keine, außer denen, die vom Hauptfach verlangt werden

Inhalt:
Einführung in die Astronomie sowie weiterführende Vorlesungsinhalte.
Für Außenseiter: astro081+astro082.
Für Naturwissenschaftler astro121+astro122 und die vertiefenden LVn

Lernziele/Kompetenzen:
Die einführenden Vorlesungen vermitteln den Studierenden die Grundlagen der Astronomie.
Die weiterführenden Vorlesungen dienen der Vertiefung

Prüfungsmodalitäten:

Dauer des Moduls:

Max. Teilnehmerzahl:

Anmeldeformalitäten:

Modul: Astronomie für Nebenfächler

Modul-Nr.: astro080

Lehrveranstaltung: Astronomie für Einsteiger I

LV-Nr.: astro081

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlfach	Vorlesung	deutsch	1	1	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Die Vorlesung versteht sich als Anfängervorlesung, ist aber gedacht für alle, die sich für Astronomie interessieren, aber bisher noch keine Vorkenntnisse haben.

Studien- und Prüfungsmodalitäten:
Mündliche Prüfung.

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Den Studierenden wird ein grundlegendes astronomisches Weltbild vermittelt. Sie werden in die Lage versetzt, einfache astronomische Zusammenhänge zu verstehen und zu beschreiben.

Inhalte der LV:
Astronomische Beobachtung am Himmel, Sternbilder, das Planetensystem, Kometen und Asteroiden; die Milchstrasse; Lebensweg eines Sterns; Galaxien und Quasare, Schwarze Löcher.

Mit Exkursion zum Observatorium Hoher List, die Aussenstelle der Sternwarte.

Literaturhinweise:
Himmelsjahr, von H.U. Keller (Kosmos)
Astronomie für Dummies, von S.P. Maran (Wiley VCH) 2. Auflage ISBN 3826631277
Atlas für Himmelsbeobachter, von E. Karkoschka (Kosmos) ISBN 3-440-08826-X.

Modul: Astronomie für Nebenfächler

Modul-Nr.: astro080

Lehrveranstaltung: Astronomie für Einsteiger II

LV-Nr.: astro082

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlfach	Vorlesung	deutsch	1	1	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Die Vorlesung versteht sich als Anfängervorlesung, ist aber gedacht für alle die sich für Astronomie interessieren aber die bisher noch keine weiteren Vorkenntnisse haben, als aus der Vorlesung "Astronomie für Einsteiger I".

Studien- und Prüfungsmodalitäten:
Mündliche Prüfung.

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden lernen grundlegende astronomische Messverfahren kennen. Sie werden in die Lage versetzt, einfache astronomische Zusammenhänge zu verstehen und zu beschreiben.

Inhalte der LV:
Helligkeit der Himmelsobjekte, Farben, Bewegungen, Geschwindigkeiten, Entfernungen, Variabilität, Teleskope und Satelliten.

Literaturhinweise:
Himmelsjahr, von H.U. Keller (Kosmos)
Astronomie für Dummies, von S.P. Maran (Wiley VCH) 2. Auflage ISBN 3826631277
Atlas für Himmelsbeobachter, von E. Karkoschka (Kosmos) ISBN 3-440-08826-X.

Modul: Astronomie für Nebenfächler

Modul-Nr.: astro080

Lehrveranstaltung: Einführung in die Astronomie

LV-Nr.: astro121

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlfach	Vorlesung mit Übungen	deutsch	2+1	4	WS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Die Studierenden werden an die stellare Astronomie herangeführt. Sie lernen die Probleme der Entfernungsbestimmung in der Astronomie kennen und erwerben Kenntnisse über Sterne und Sternentwicklung, einschließlich Phänomene in den Endphasen, wie Planetarische Nebel, Supernovaexplosionen und Schwarze Löcher. Man wird in die Lage versetzt, die Grundlagen der stellaren Astronomie einem Laien zu erklären

Inhalte der LV:
Teleskope, Instrumente, Detektoren; Himmelsmechanik; Himmel, Planetensystem, Kometen, Meteore; Sonne und Erdklima; Planck-Funktion, Photometrie, Sterne, Entfernungsbestimmung der Sterne, Hertzsprung-Russell-Diagramm; Sternatmosphäre; Sternaufbau und Sternentwicklung, Kernfusionsprozesse; Variable Sterne; Doppelsterne; Sternhaufen und Altersbestimmung; Endstadien der Sterne; Messgeräte der anderen Wellenlängenbereiche; Interstellares Medium, ionisiertes Gas, neutrales Gas und Molekülwolken mit Sternentstehung, heiße Phase

Literaturhinweise:
Skriptum zur Vorlesung; Astronomie (PAETEC Verlag, ISBN 3-89517-798-9)

Modul: Astronomie für Nebenfächler

Modul-Nr.: astro080

Lehrveranstaltung: Einführung in die extragalaktische Astronomie

LV-Nr.: astro122

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlfach	Vorlesung mit Übungen	deutsch	2+1	4	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Einführung in die Astronomie

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Studierende sollen die extragalaktische Astronomie in ihrer Breite kennen lernen, werden an die Schwerpunkte der aktuellen Forschung herangeführt und sollen in die Lage versetzt werden, astrophysikalische Zusammenhänge auch für Laien verständlich darzustellen. Durch die Diskussion der Dunklen Materie und der Dunklen Energie werden auch zentrale Fragen der fundamentalen Physik angesprochen

Inhalte der LV:
Struktur der Galaxis: Scheibe, Bulge, Halo; Rotation der Galaxis, Entfernung zum Zentrum; Dunkle Materie; Spiralgalaxien und ihre Strukturen; Elliptische Galaxien und ihre stellare Populationen; Aktive Galaxien; Quasare; Galaxienhaufen, großskalige Strukturen im Universum; Gravitationslinsen; Bestimmung des Anteils an Dunkler Materie; Kosmologie, Expansion des Universums, Bestimmung der Entfernungen weit entfernter Objekte; Urknall, Kosmische Hintergrundstrahlung, kosmologische Parameter

Literaturhinweise:
Skriptum zur Vorlesung
P. Schneider, Einführung in die Extragalaktische Astronomie und Kosmologie (Springer Verlag, Heidelberg 2005)

Modul: Astronomie für Nebenfächler

Modul-Nr.: astro080

Lehrveranstaltung: Einführung in die Radioastronomie

LV-Nr.: astro123

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Wahlpflicht	Vorlesung mit Übungen und Praktikum	deutsch	2+1	4	SS

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Einführung in die Astronomie I + II (astro121, 122), Physik I-III (Physik 110, 210, 310)

Studien- und Prüfungsmodalitäten:
Voraussetzung zur Teilnahme an der Prüfung (mündliche Prüfung oder Klausur): erfolgreiche Teilnahme an den Übungen

Dauer der Lehrveranstaltung:
1 Semester

Lernziele der LV:
Verständnis der Grundlagen der radioastronomischen Beobachtungstechnik und der wesentlichen astrophysikalischen Prozesse

Inhalte der LV:
Vorlesung:
Radioastronomische Empfangstechnik (Teleskope, Empfänger und Detektoren), atmosphärische Fenster, Strahlungstransport, Radiometergleichung, statistische Prozesse in der Signalerkennung, interstellares Medium, HI 21-cm Linienstrahlung, Sternentstehung in Molekülwolken, kontinuierliche Strahlungsprozesse, Maser, Radiogalaxien, Entwicklung der Galaxien im Universum, Pulsare, Physik in starken Gravitationsfeldern, Epoche der Re-Ionisation, frühes Universum, Zukunftsprojekte der Radioastronomie

Ergänzendes, optionales Praktikum (1 bis 2 tägig am Observatorium):
Eichung eines radioastronomischen Empfängers, Messung der HI 21-cm Linienstrahlung, Ableitung der Spiralstruktur der Milchstraße, Messung der kontinuierlichen Strahlung der Milchstraße, Messung und Analyse eines Pulsarsignals

Literaturhinweise:
Folien der Vorlesung werden zur Verfügung gestellt.

On-line material: http://www.cv.nrao.edu/course/astr534/ERA.shtml

Dieses Modul kann anstelle von astro122 anerkannt werden.

Modul: Astronomie für Nebenfächler

Modul-Nr.: astro080

Lehrveranstaltung: Stars and Stellar Evolution or specific: Stellar Structure and Evolution

LV-Nr.: astro811

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Required	Lecture with exercises	English	3+1	6	WT

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:

Studien- und Prüfungsmodalitäten:
Requirements for the examination (written or oral): successful work with the exercises

Dauer der Lehrveranstaltung:
1 semester

Lernziele der LV:
Students will acquire sufficient knowledge to understand stars and their evolution. Study of radiation transport, energy production, nucleosynthesis and the various end phases of stellar evolution shall lead to appreciation for the effects these processes have on the structure and evolution of galaxies and of the universe

Inhalte der LV:
Historical introduction, measuring quantities, the HRD. Continuum and line radiation (emission and absorption) and effects on the stellar spectral energy distribution. Basic equations of stellar structure. Nuclear fusion. Making stellar models. Star formation and protostars. Brown Dwarfs. Evolution from the main-sequence state to the red giant phase. Evolution of lower mass stars: the RG, AGB, HB, OH/IR, pAGB, WD phases. Stellar pulsation. Evolution of higher mass stars: supergiants, mass loss, Wolf-Rayet stars, P-Cyg stars. Degenerate stars: White Dwarfs, Neutron Stars, Black Holes. Supernovae and their mechanisms. Binary stars and their diverse evolution (massive X-ray binaries, low-mass X-ray binaries, Cataclysmic variables, etc.). Luminosity and mass functions, isochrones. Stars and their influence on evolution in the universe

Literaturhinweise:
Lecture notes on "Stars and Stellar Evolution" (de Boer & Seggewiss)

Modul: Astronomie für Nebenfächler

Modul-Nr.: astro080

Lehrveranstaltung: Physics of the Interstellar Medium

LV-Nr.: astro822

Kategorie	LV-Art	Sprache	SWS	LP	Semester
Required	Lecture with exercises	English	3+1	6	ST

Zulassungsvoraussetzungen:

Empfohlene Vorkenntnisse:
Introductory astronomy

Studien- und Prüfungsmodalitäten:
Requirements for the examination (written or oral): successful work with the exercises

Dauer der Lehrveranstaltung:
1 semester

Lernziele der LV:
The student shall acquire a good understanding of the physics and of the phases of the ISM. The importance for star formation and the effects on the structure and evolution of galaxies is discussed.

Inhalte der LV:
Constitutens of the interstellar medium, physical processes, radiative transfer, recombination, HI 21cm line, absorption lines, Stroemgren spheres, HII regions, interstellar dust, molecular gas and clouds, shocks, photodissociation regions, energy balances, the multi-phase ISM, gravitational stability and star formation.

Literaturhinweise:
B. Draine; The Physics of the Interstellar and Intergalactic Medium (Princeton Univ. Press 2010)
J. Lequeux; The Interstellar Medium (Springer 2005)