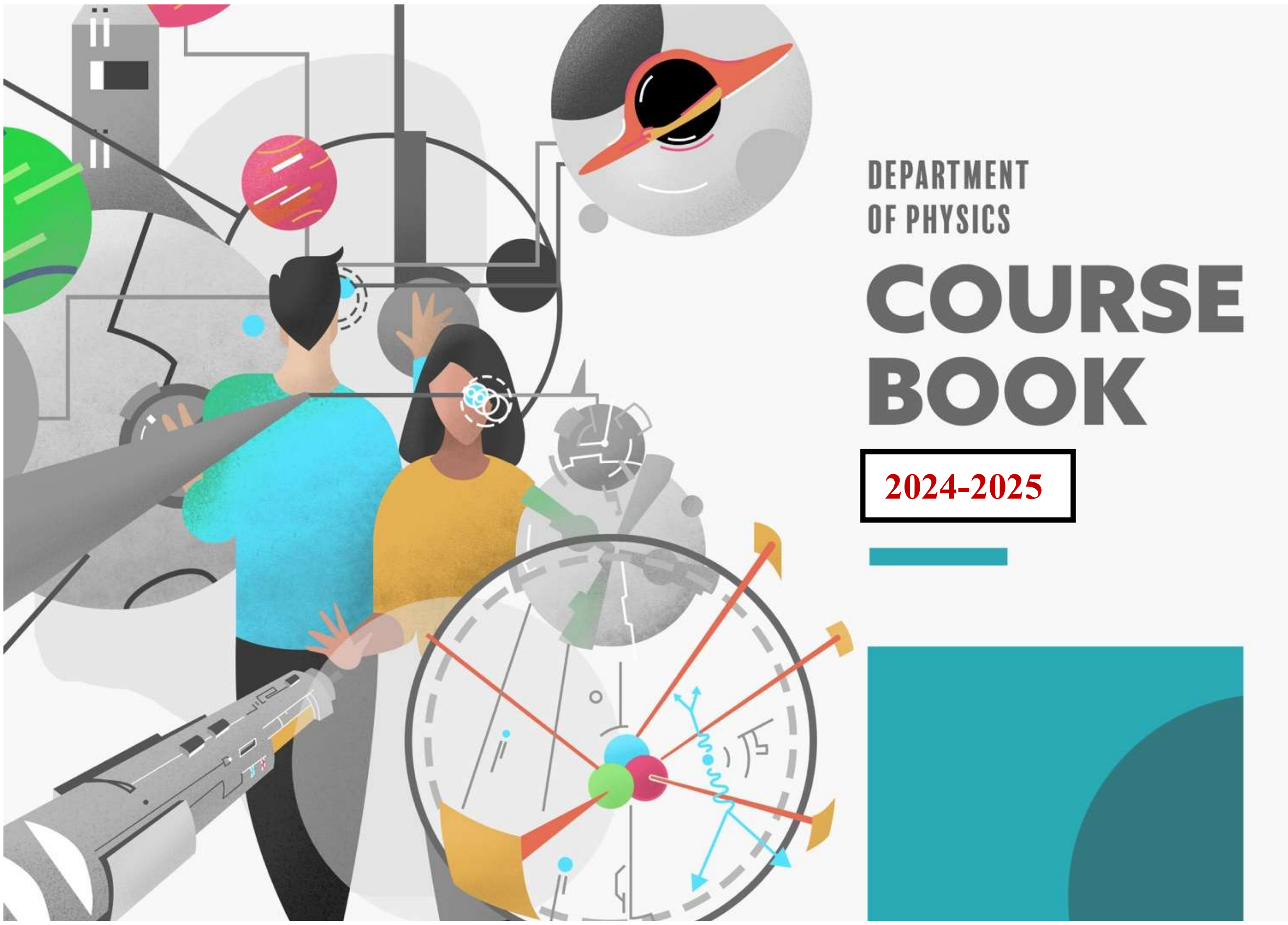

July 2024

Message from the Head of the Department:

At the outset, let me extend my heartiest congratulations to you on successfully qualifying to become a student of IITB. I understand the amount of hard work and dedication that you have put in to achieve this and I am sure that you will continue to put the same for achieving greater heights during your stay here. As these are difficult times and we are all experimenting with a new mode of education, I am sure you will try your best to adjust to the new world.

Physics department of IITB is one of the oldest departments of the institute and one of the most vibrant Physics departments in the country today. For the last few years, our dept. has been ranked as the number one/two Physics department in India according to the QS ranking. We have 50 faculty members, about 240 B.Tech. students, 120 M.Sc. students and 120 Ph.D. students. There are about 25 Post-Doctoral fellows, working in different groups. We also have support staff of about 25 people. We have all modern teaching laboratories and a well-equipped department library. A computer lab only meant for students is also available for you.

This booklet also contains the curriculum and the course contents that you have to follow. You may note that in the final year, there are a few core courses that are common for B.Tech. and M.Sc. Also, almost all elective courses are common and taught in the same class. Ph.D. students have to take some of the M.Sc. core or elective courses as indicated later.

The main areas of research in the department are (i) Condensed Matter Physics, (ii) Astrophysics/Cosmology/Gravity, (iii) High Energy Physics, (iv) Photonics and Spectroscopy (v) Statistical Physics/Bio Physics/Soft Matter Physics/Non-linear Dynamics. In almost all these areas, both theoretical as well as experimental research is going on. There is ample scope for you to interact with the faculty members to get involved in the research activities, in addition to your normal academic work. I encourage you to take up such assignments and get more exposure.

Many of our alumni (B.Tech., M.Sc. and Ph.D.) have performed very well in their career and are in leading positions in academia/industry/civil services/corporate sector in India or abroad. With the training that you get here, I am sure you will all be able to rise to such levels of excellence. Please make use of every opportunity and facility that are available in the department and in the institute to achieve this, develop your personality and come out in flying colours.

Let's together meet the new challenges and transform them into opportunities….

With best wishes,

[S. Dhar]

List of Faculty Members			
No.	**Name**	**No.**	**Name**
1	P. P. Singh	26	Archana Pai
2	Raghav Varma	27	Mithun K. Mitra
3	S. Umasankar	28	Kumar Rao
4	A. V. Mahajan	29	Vikram Rentala
5	T. Kundu	30	Raghunath C
6	M. Senthil Kumar	31	Amitabha Nandi
7	K. G. Suresh	32	Sai V
8	Alok Shukla	33	Gopal Dixit
9	B. K. Nandi	34	Soumya Bera
10	P. Ramadevi	35	Sumiran Pujari
11	A. Sain	36	Varun Bhalerao
12	Dibyendu Das	37	Sunita Srivastava
13	Asmita Mukherjee	38	Anshuman Kumar
14	Punit Parmananda	39	Pramod Kumar
15	S. Dhar	40	Hridis Kumar Pal
16	M. Aslam	41	Nitin Kumar
17	Pragya Das	42	M. Maniraj
18	K. Das Gupta	43	Himadri Dhar
19	Parinda Vasa	44	Siddhartha Santra
20	Dinesh Kabra	45	Sayantika Bhowal
21	Pradeep Sarin	46	Uditendu Mukhopadhyay
22	Sadhana Dash	47	Rahul Kashyap
23	Aftab Alam	48	Prashant Kumar
24	S. Mahapatra		
25	S. Shankaranarayanan		

List of faculty advisers of current batches

B.Tech. (2020)	Mithun K. Mitra
B.Tech. (2021)	Hridis Pal
B.Tech. (2022)	Siddhartha Santra
B.Tech. (2023)	Sumiran Pujari
M. Sc. (2023)	Pramod Kumar
B.Tech. (2024)	**Amitabha Nandi**
M.Sc. (2024)	**Sunita Srivastava**
Ph.D. (2024)	**Raghunath Chelakot**

Minimum Credits required

Degree	Credits
B. Tech. Engineering Physics	265
B. Tech. Engineering Physics (with Honors)	265+24=289 (4 years)
Minor - Engineering Physics	30
B. Tech.-M.Tech. Dual Degree*	265+126=391 (5 years)
Integrated M.Sc. (B.Tech. to M.Sc.)**	265+96=361 (5 years)
M. Sc.	145
M.Sc. to M.Sc.-Ph.D.***	145+34 (5 semesters)
Ph.D.	34 (for students with M.Sc.) 16 (for students with M.Tech./M.E. 44 (for students with B.Tech./B.E./B.S.) **[PH 899 communications skills (Pass/No Pass course) and a 4-credit Seminar are compulsory for all. The latter can be taken in the first or second semester.**

*subject to the interest by a B.Tech. student AND the approval of the Dept. (minimum CPI required =7.5 at the end of the third year)

**Subject to the interest by a B. Tech. student AND the approval of the Dept. (minimum CPI required =7.5 at the end of the third year)

*** subject to the interest by a M.Sc. student AND the approval of the Dept. (minimum CPI required =6.5 at the end of the third semester, without any backlog)

Department Academic Mentorship Program (DAMP)

The Department Academic Mentorship Program works to provide assistance to students of the department, with two primary aims:

1. Providing the freshers with a smooth transition into the department in their second year
2. Enabling academically weak students to get back on track

With these broad aims, our activities can be put into the following categories:

1. Student mentorship:
    a. Freshman year has common courses for all departments, except a Department Introductory Course. From the second year onwards, there are more of department specific courses and electives, and all sophomore students are assigned a DAMP mentor to help them manoeuvre their way through these.
    b. Mentors are also assigned to all third/fourth year students having a large number of backlog courses to aid them in clearing their backlogs and improving their academic standing.

Faculty Interaction: We strive to improve the level of interaction between the faculty and the students of the department, through a number of events conducted throughout the year. With regards to improving the feedback from the students, we carry out a midsem course review every semester to identify any general problems that the students might be facing and convey them to the respective course instructor. We also keep in touch with the course instructors throughout the semester and communicate their feedback about students who are falling behind to the corresponding DAMP mentors.

Support and Outreach:

. We have a DAMP blog which is run by students of the department, hosting content such as reviews of elective courses, internship experiences, AMAs with professors, and frequently asked questions (FAQs).

a. We conduct help sessions for the students, based on feedback from the class and the instructor, especially before the major exams.

b. We organize various knowledge-sharing sessions for the students, with seniors sharing their experience on minors and elective courses, internships, graduate school applications, and non-core career opportunities to name a few.

Students Association Physics Department (SAPD):

SAPD handles the informal side of the physics department. SAPD organizes events such as Freshmen Introduction, Department Trips and Kurta Days. SAPD is responsible for designing cool Department of Physics T-shirts every year.

Curricula and Course Contents

of

B.Tech.

M.Sc.

And

Ph.D.

B. Tech.
(Engineering Physics)

2022 batch

Year/Sem	*Course code*	*Course Title*	*Category*	*Credits*
	BB 101	Biology	Basic Sciences and Mathematics	2-1-0-6
	MS 101	Makerspace	Engineering Sciences and skills	8
	CH 105	Organic and Inorganic Chemistry	Basic Sciences and Mathematics	3-1-0-4 (half sem)
	CH 107	Physical Chemistry	Basic Sciences and Mathematics	3-1-0-4 (half sem)
I Year I Sem	PH 109	Fundamental Themes in Physics (DIC 1)	Dept. core	2-1-0-6
	MA 109	Calculus I	Basic science and maths	3-1-0-4 (half sem)
	MA 111	Calculus II		3-1-0-4 (half sem)
	CH 117	Chemistry lab	Basic Sciences and Mathematics	0-0-3-3
	NOCS 01	NCC/NSS/NSO	Non - Credited compulsory Courses	
	GC 101	Gender sensitization course	Non - Credited compulsory Courses	
	TA 101	TA Course	Non - Credited compulsory Courses	
				Total credits: 39
I Year II Sem	CS 101	Computer programming	Engineering Sciences and skills	2-1-0-6
	MA 106	Linear Algebra	Basic Sciences and Mathematics	3-1-0-4 (half sem)
	MA 108	Differential Equations	Basic Sciences and Mathematics	3-1-0-4 (half sem)
	PH 111	Introduction to classical physics	Basic Sciences and Mathematics	3-1-0-4 (half sem)
	PH 112	Introduction to quantum physics	Basic Sciences and Mathematics	3-1-0-4 (half sem)
	PH 113	Oscillations and Waves (DIC 2)	Department Core	2-1-0-3(half sem)
	PH 114	Thermal Physics (DIC 2)	Department Core	2-1-0-3 (half sem)
	PH 117	Physics lab	Basic Sciences and Mathematics	0-0-3-3

	HSS/IDC/ENT	Introduction to HASMED	HASMED Core	3-1-0-8
	NOCS 02	NCC/NSS/NSO	Non - Credited compulsory Courses	
				Total credits: 39

Year/ Sem	***Course code***	***Course Title***		
II Year I Sem	EC 101	Economics	HASMED Core	2-1-0-6
	PH 217	Classical Mechanics	Department Core	2-1-0-6
	PH 223	Complex Analysis and Integral Transforms	Department Core	2-1-0-6
	MM 225	AI and Data Science	Engineering Sciences and skills	2-1-0-6
	PH 225	Quantum Mechanics I	Department Core	2-1-0-6
	PH 221	Analog Electronics	Department Lab (core)	1.5-0-3-6
				Total credits=36
II Year II Sem	DE 250	Design Thinking	HASMED Core	2-1-0-6
	PH 307	Introduction to Numerical Analysis	Department Core	2-1-0-6
	PH 423	Quantum Mechanics II	Department Core	3-1-0-8
	PH 438	Statistical Mechanics	Department Core	2-1-0-6
	PH 222	Digital Electronics and Microprocessors (lecture + lab)	Department Lab (core)	1.5-0-3-6
	PH 232	General Physics Lab	Department Lab (core)	0-0-3-3
				Total credits=35

Year/Sem	*Course code*	*Title*		*Credits*
	PH 312	Electromagnetic Theory	Department Core	3-1-0-8
III Year I Sem	PH 436	Introduction to Condensed Matter Physics	Department Core	2-1-0-6
	PH 446	Solid State Physics + Nuclear Physics Lab	Department Lab (core)	0-1-3-3
	ES 250 & HS 250	Environmental Science	Basic Sciences and Mathematics	2-1-0-6
		HASMED elective 1	HASMED Elective	2-1-0-6
		Honors course (must for DD students)		2-1-0-6
				Total credits: 29
III Year II Sem	PH 314	Molecular spectroscopy and optical physics	Department Core	3-1-0-8
		STEM elective 1	STEM Elective	2-1-0-6
		Department elective 1	Department Elective	2-1-0-6
		HASMED elective 2	HASMED Elective	2-1-0-6
		BTP 1 or equivalent elective	Department Elective	2-1-0-6
	PH 447	Optics + Spectroscopy Lab	Department Lab (core)	0-0-3-3
		Honors Course (must for DD students)	Department Elective	2-1-0-6
				Total credits: 35 (without honors)

Year/Sem	*Course code*	*Title*		*Credits*
IV Year I Sem		Department elective 2	Department Elective	2-1-0-6
		BTP 2/Equivalent elective	BTP/ Equivalent Elective	2-1-0-6
		STEM elective 2	STEM Elective	2-1-0-6

		Flexible elective 1	Flexible Elective	2-1-0-6
		Flexible elective 2	Flexible Elective	2-1-0-6
		Honors Course (must for DD students)	Department Elective	2-1-0-6
				Total credits: 30 (without honors)
IV Year II Sem		BTP 3/Equivalent elective	BTP/ Equivalent Elective	2-1-0-6
		Flexible elective 3	Flexible Elective	2-1-0-6
		Flexible elective 4	Flexible Elective	2-1-0-6
		Flexible elective 5	Flexible Elective	2-1-0-6
		Department elective 3	Department Elective	2-1-0-6
		Honors Course (must for DD students)	Department Elective	
				Total credits: 30 (without honors)

ONLY FOR DD STUDENTS

Year/Sem	***Course code***	***Title***		***Credits***
V Year I Sem	PH 575	Nanoscience: Fundamentals to Fabrication	Department Core for DD	2-1-0-6
	PH 570	Advanced Laboratory Techniques in Nanoscience	Department Core for DD	2-1-0-6
	PH 591	Dual degree project I (DDP I)	Department core for DD	30
				Total credits: 42
	PH 576	Nanoscale Quantum Transport	Department Core for DD	2-1-0-6
	PH 578	Nanodevices and Applications	Department Core for DD	2-1-0-6
	PH 592	Dual degree project II (DDP II)	Department core for DD	42
				Total credits: 54

In addition, the DD students need to take 4 electives of their choice plus Supervised Learning Project (SLP) of 6 credits

Total credits (minimum) for 4 Year B. Tech. = 265

Total credits (minimum) for 5 Year B. Tech-M.Tech. = 265+ 126

B. Tech.
(Engineering Physics)

2023 batch onwards

Year/Sem	*Course code*	*Course Title*	*Category*	*Credits*
I Year I Sem	BB 101	Biology	Basic Sciences and Mathematics	2-1-0-6
	MS 101	Makerspace	Engineering Sciences and skills	8
	MA 105	Calculus	Basic science and maths	3-1-0-8
	PH 109	Fundamental Themes in Physics (DIC 1)	Dept. core	2-1-0-6
	CH 117	Chemistry lab	Basic Sciences and Mathematics	0-0-3-3
	NOCS 01	NCC/NSS/NSO	Non - Credited compulsory Courses	0
	GC 101	Gender sensitization course	Non - Credited compulsory Courses	0
				Total credits: 31
	CS 101	Computer programming	Engineering Sciences and skills	2-1-0-6
I Year II Sem	MA 110	Linear Algebra and Differential Equations	Basic Sciences and Mathematics	3-1-0-8
	PH 110	Introduction to classical physics and Quantum mechanics	Basic Sciences and Mathematics	3-1-0-8
	HSS/IDC/ENT	Introduction to HASMED	HASMED Core	3-1-0-8
	PH 117	Physics lab	Basic Sciences and Mathematics	0-0-3-3
	NOCS 02	NCC/NSS/NSO	Non - Credited compulsory Courses	
				Total credits: 33

Year/ Sem	*Course code*	*Course Title*		
	EC 101	Economics	HASMED Core	2-1-0-6
	PH 113	Oscillations and Waves (DIC-2, Part-I)	Department Core	2-1-0-3 (half semester)
	PH 114	Thermal Physics (DIC-2, Part-II)	Department Core	2-1-0-3 (half semester)
II year	PH 217	Classical Mechanics	Department Core	2-1-0-6

I sem	PH 223	Complex Analysis and Integral Transforms	Department Core	2-1-0-6
	PH 227	AI and Data Science	Engineering Sciences and skills	2-1-0-6
	PH 221	Analog Electronics	Department Lab (core)	1.5-0-3-6
				Total credits=36

Year/ Sem	***Course code***	***Title***		
II Year II Sem	PH 216	Statistical Mechanics	Department Core	2-1-0-6
	PH 225	Quantum Mechanics I	Department Core	2-1-0-6
	DE 250	Design Thinking and innovation	HASMED Core	2-1-0-6
	PH 312	Electromagnetic theory	Department core	3-1-0-8
	PH 222	Digital Electronics and Microprocessors (lecture + lab)	Department Lab (core)	1.5-0-3-6
	PH 232	General Physics Lab	Department Lab (core)	0-0-3-3
				Total credits=35

Year/Sem	***Course code***	***Title***		***Credits***
III Year I Sem	ES 250 & HS 250	Environmental Science	Basic Sciences and Mathematics	2-1-0-6
	PH 307	Introduction to Numerical Analysis	Department Core	2-2-0-6
	PH 309	Quantum Mechanics II	Department Core	3-1-0-8
	PH 436	Introduction to Condensed Matter Physics	Department Core	2-1-0-6
		HASMED elective 1	HASMED Elective	2-1-0-6
	PH-446	Solid State Physics + Nuclear Physics Lab	Department Lab (core)	0-1-3-3

		Honors course (must for DD students)		2-1-0-6
				Total credits: 35
III Year II Sem	PH 314	Molecular spectroscopy and optical physics	Department Core	3-1-0-8
		STEM elective 1	STEM Elective	2-1-0-6
		Department elective 1	Department Elective	2-1-0-6
		HASMED elective 2	HASMED Elective	2-1-0-6
	PH 447	Optics + Spectroscopy Lab	Department Lab (core)	0-0-3-3
		BTP 1 or equivalent elective	BTP/ Department Elective	2-1-0-6
		Honors Course (must for DD students)	Department Elective	2-1-0-6
				Total credits: 35 (without honors)

Year/Sem	***Course code***	***Title***		***Credits***
IV Year I Sem		Department elective 2	Department Elective	2-1-0-6
		BTP 2/Equivalent elective	BTP/ Equivalent Elective	2-1-0-6
		Flexible elective 1	Flexible Elective	2-1-0-6
		Flexible elective 2	Flexible Elective	2-1-0-6
		Flexible elective 2	Flexible Elective	2-1-0-6
		Honors Course (must for DD students)	Department Elective	2-1-0-6
				Total credits: 30 (without honors)
IV Year II Sem		BTP 3/Equivalent elective	BTP/ Equivalent Elective	2-1-0-6
		Flexible elective 3	Flexible Elective	2-1-0-6

		Flexible elective 4	Flexible Elective	2-1-0-6
		Flexible elective 5	Flexible Elective	2-1-0-6
		Department elective 3	Department Elective	2-1-0-6
		Honors Course (must for DD students)	Department Elective	
				Total credits: 30 (without honors)

ONLY FOR DD STUDENTS

Year/Sem	***Course code***	***Title***		***Credits***
V Year I Sem	PH 575	Nanoscience: Fundamentals to Fabrication	Department Core for DD	2-1-0-6
	PH 570	Advanced Laboratory Techniques in Nanoscience	Department Core for DD	2-1-0-6
	PH 591	Dual degree project I (DDP I)	Department Core for DD	30
				Total credits: 42
V Year II Sem	PH 576	Nanoscale Quantum Transport	Department Core for DD	2-1-0-6
	PH 578	Nanodevices and Applications	Department Core for DD	2-1-0-6
	PH 592	Dual degree project II (DDP II)	Department Core for DD	42
				Total credits: 54

In addition, the DD students need to take 4 electives of their choice plus Supervised Learning Project (SLP) of 6 credits

Total credits (minimum) for 4 Year B. Tech. = 265

Total credits (minimum) for 5 Year B. Tech-M.Tech. = 265+ 126

List of Electives for ODD (AUTUMN)) semester

Number	Title	Number	Title
PH 505	Introduction to Nuclear and Particle Physics	PH 567	Nonlinear Dynamics
PH 517	Methods in Analytical Techniques	PH 569	Applied Solid State Physics
PH 523	Quantum Mechanics III	PH 575	Nanoscience: Fundamentals to Fabrication
PH 543	Advanced Statistical Mechanics	PH 813	Advanced Topics in Astro-Particle Physics
PH 549	Physics of Biological Systems	PH 815	Standard Model of Particle Physics
PH 557	Theoretical Condensed matter physics	PH 817	Specialized Topics in QFT and Beyond Standard Model Physics
PH 561	Ultrafast Sciences	PH 819	Advanced Astrophysics
PH 563	Group Theory Methods in Physics	PH 821	Gravitational Wave Physics and Astronomy
PH 565	Semiconductor Physics	PH 534	Quantum Information and Computing

List of Electives for EVEN (SPRING) semester- Open to all

PH 500	Thin film Physics and Technology	PH 564	Methods in Experimental Nuclear and Particle Physics
PH 530	Light Matter Interaction – core for MSc.	PH 566	Advanced Simulation Techniques in Physics
		PH 572	Special Topics in Elementary Particle Physics
PH 540	Elementary Particle Physics	PH574	Physics of Semiconductor Devices
PH 544	General Theory of Relativity	PH 576	Nanoscale Quantum Transport
PH 546	Quantum Optics	PH 578	Nanodevices and Applications
PH 550	Soft Matter Physics	PH 580	Magnetism and Superconductivity
PH 554	Computational Many Body Physics	PH 601	Advanced Quantum Information and Computation
PH 556	Astrophysics	PH 818	Relativistic Cosmology
PH 562	Continuum Mechanics		

B.Tech. Engineering Physics - Honours

** for the award of Honors, a student should take any 4 courses, completing 24 credits*.

Sl. No.	*Course code*	*Title*	*Credits*
1	**PH 303**	**Supervised Learning (runs in both semesters)**	**2-1-0-6**
2	PH 523	Quantum Mechanics III	2-1-0-6
3	PH 534	Quantum Information and Computing	2-1-0-6
4	PH 563	Group Theory Methods in physics	2-1-0-6
5	PH 565	Semiconductor Physics	2-1-0-6
6	PH 567	Non linear Dynamics	2-1-0-6
7	PH 562	Continuum Mechanics	2-1-0-6
8	PH 540	Elementary Particle Physics	2-1-0-6
9	PH 557	Theoretical Condensed matter physics	2-1-0-6
10	PH 544	General Theory of Relativity	2-1-0-6
11	PH 554	Computational Many Body Physics	2-1-0-6
12	PH 564	Methods in Exp. Nuclear and Particle Physics	2-1-0-6
13	PH 580	Magnetism and Superconductivity	2-1-0-6
14	PH 587	B.Tech. Project I	2-1-0-6
15	PH 588	B.Tech. Project II	2-1-0-6

B.Tech. Engineering Physics - Minor

* *for the award of minor, a student should take any 5 courses, completing 30 credits*.

Sl. No.	*Course code*	*Title*	*Credits*
1	PH 251	Classical Mechanics	3-1-0-8
2	PH 252	Introduction to Quantum Mechanics	2-1-0-6
3	PH 253	Thermal and Statistical Physics	2-1-0-6
4	PH 352	Introduction to Condensed Matter Physics	2-1-0-6
5	PH 353	Light Matter Interaction	2-1-0-6

Out of the required 5, Classical Mechanics, Quantum mechanics and Thermal & Statistical Phys. are compulsory. The remaining 2 can be taken from the list of department electives as well.

Integrated M. Sc. (4 year EP B.Tech. to 5 year integrated M.Sc.)

In addition to the courses/credits required by the B.Tech. EP program, a student needs to complete the following courses: (Credits: 6x6+30+30=96)

Semester	**Course**	**Credits**
VII	Extra dept. elective–I	2-1-0-6
VIII	Extra dept. elective -2	2-1-0-6
IX	Extra dept. elective –3	2-1-0-6
	Extra dept. elective -4	2-1-0-6
	Integrated M.Sc. Project I (PH 593)	30
X	Extra dept. elective –5	2-1-0-6
	Extra dept. elective -6	2-1-0-6
	Integrated M.Sc. Project II (PH 594)	30
Total Credits		**96**

M.Sc. Physics

Year/Sem	*Course code*	*Course Description*	*Credits*
I Year I Semester	PH 401	Classical Mechanics	3-1-0-8
	PH 403	Quantum Mechanics I	3-1-0-8
	PH 405	Electronics	2-1-0-6
	PH 407	Mathematical Physics I	3-1-0-8
	PH 434	Programming Lab	1-0-3-5
	PH 443	Electronics Lab	0-0-3-3
			Total credits: 38

Year/Sem	*Course code*	*Course Description*	*Credits*
I Year II Semester	PH 408	Mathematical Physics II	3-1-0-8
	PH 410	Statistical Physics	2-1-0-6
	PH 418	Introduction to Condensed Matter Physics	2-1-0-6
	PH 422	Quantum Mechanics II	2-1-0-6
	PH 424	Electromagnetic Theory I	2-1-0-6
	PH 441	General Physics Lab	0-0-3-3
			Total credits: 35

Year/Sem	*Course code*	*Course Description*	*Credits*
II Year I Semester	PH 505	Introduction to Nuclear and Particle Physics	2-1-0-6
	PH 515	Introduction to Atomic and Molecular Physics	2-1-0-6
	PH 512	Physics Lab (Optics and Spectroscopy)	0-0-3-6
	PH 595	M.Sc. Project stage I	0-0-3-6
		Or Departmental Elective X	2-1-0-6
		Departmental Elective I	2-1-0-6
		Department Elective II	2-1-0-6
			Total credits: 36

II Year II Semester	PH 510	Electromagnetic Theory II	2-1-0-6
	PH 530	Light Matter Interaction	2-1-0-6
	PH 527	Physics Lab (SSP and NP)	0-0-3-6
	PH 596	M.Sc. Project stage II	0-0-3-6
		Or Elective XX	2-1-0-6
		Departmental Elective III	2-1-0-6
		Departmental Elective IV	2-1-0-6
			Total credits: 36

Total Credits: 145

No. of Dept. electives required: 6 (including Projects)

For MSc.-PhD students only

III Year I Semester		Extra elective 1	2-1-0-6
		Extra elective 2	2-1-0-6
	PH 555	M.Sc. Project stage III	24
			Total credits: 36

III Year II Semester	PH 899	Communications skills	P/NP

List of prescribed courses under Electives X, I, II (odd semester)

Number	Title	Number	Title
PH 517	Methods in Analytical Techniques	PH 567	Nonlinear Dynamics
PH 523	Quantum Mechanics III	PH 569	Applied Solid State Physics
PH 543	Advanced Statistical Mechanics	PH 575	Nanoscience: Fundamentals to Fabrication
PH 549	Physics of Biological Systems	PH 813	Advanced Topics in Astro-Particle Physics
PH 557	Theoretical Condensed matter physics	PH 815	Standard Model of Particle Physics
PH 561	Ultra-fast Sciences	PH 817	Specialized Topics in QFT and Beyond Standard Model Physics
PH 563	Group Theory Methods in Physics	PH 819	Advanced Astrophysics
PH 565	Semiconductor Physics	PH 821	Gravitational Wave Physics and Astronomy
PH 534	Quantum Information and Computing		

List of prescribed courses under Elective XX, III, IV (even semester)

PH 500	Thin film Physics and Technology	PH 564	Methods in Experimental Nuclear and Particle Physics
		PH 572	Special Topics in Elementary Particle Physics
PH 540	Elementary Particle Physics	PH 574	Physics of Semiconductor Devices
PH 544	General Theory of Relativity	PH 576	Nanoscale Quantum Transport
PH 546	Quantum Optics	PH 578	Nanodevices and Applications
PH 550	Soft Matter Physics	PH 580	Magnetism and Superconductivity
PH 554	Computational Many Body Physics	PH 601	Advanced Quantum Information and Computation
PH 556	Astrophysics	PH 818	Relativistic Cosmology
PH 562	Continuum Mechanics		

Ph.D. courses (Jan 2019 onwards)

Group A	Group B
ODD SEMESTER (July)	**ODD SEMESTER (July)**
Physics of Semiconductor Devices - PH 574	Methods in Analytical Techniques – PH 517
Mathematical Physics- I – PH 407 (8 credits)	Advanced Statistical Mechanics – PH 543
Quantum Mechanics III -PH 523	Applied Solid State Physics – PH 569
Non-linear Dynamics – PH 567	Ultrafast Sciences - PH 561
Introduction to Atomic and Molecular Physics - PH 515	Group Theoretical Methods in Physics- PH 563
Introduction to Nuclear and particle Physics- PH 505	Physics of Biological Systems - PH 549
Theoretical Condensed Matter Physics- PH 557	Data Analysis and Interpretation- PH 219
Methods in Analytical Techniques – PH 517	Advanced Topics in Astro-particle Physics- PH 813
	Standard Model of Particle Physics- PH 815
	Specialized Topics in QFT and Beyond Standard Model Physics – PH 817
	Advanced Astrophysics – PH 819
	Gravitational Wave Physics and Astronomy- PH 821
	Quantum Information and Computing – PH 534
EVEN SEMESTER (January)	**EVEN SEMESTER (January)**
Introduction to Condensed Matter Physics – PH 418	
Quantum Mechanics II – PH 422	Physics of Quantum Devices – PH 536
Electromagnetic Theory II -PH510	Elementary Particle Physics – PH 540
Mathematical Physics II - PH 408 (8 credits)	
Laboratory Techniques- PH 804 (8 credits)	Methods in Experimental Nuclear and Particle Physics- PH 564
Astrophysics – PH 556	Thin film Physics and Technology – PH 500
Programming Lab- PH 434 (5 credits)*	
Light Matter Interaction – PH 530	Special topics in Elementary Particle Physics -PH 572
	Computational Many Body Physics- PH 554
Continuum Mechanics -PH 562	Soft Matter Physics – 550

Statistical Physics - PH 410	General Theory of Relativity- PH 544
Advanced Simulation Techniques in Physics- PH 566*	Quantum Optics – PH 546
	Magnetism and Superconductivity- PH 580
	Advanced Quantum Information and Computation – PH 601
	Relativistic Cosmology – PH 818

*You can take either one of these two.

PhD students with M.Sc. have to complete 34 credits. This includes 4 credits of a seminar course (PHS 801/802). Regarding the theory courses, you have to take at least 2 from each of the two groups. One course can be taken from outside the dept. In addition, all Ph.D. students should pass HS 791+PH 792 in their first year. Those with M.Tech./M.E need to do only 16 credits, while those with B.Tech./B.E./B.S. need to do 44 credits. The credits requirements for PMRFs are the same as those of other students.

B. Tech. Course Contents

First Year, First Semester

Course Name	Biology
Course Code	**BB 101**
Total Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Half Semester	N
Description	Quantitative views of modern biology. Importance of illustrations and building quantitative/qualitative models. Role of estimates. Cell size and shape. Temporal scales. Relative time in Biology. Key model systems - a glimpse. Management and transformation of energy in cells. Mathematical view - binding, gene expression and osmotic pressure as examples. Metabolism. Cell communication. Genetics. Eukaryotic genomes. Genetic basis of development. Evolution and diversity. Systems biology and illustrative examples of applications of Engineering in Biology.
Text Reference	Physical Biology of the Cell, R. Phillips, J. Kondev and J. Theriot. Garland science publishers. 2008. 1st edition. Campbell Biology, J. B. Reece, L. A. Urry, M. L. Cain, S. A. Wasserman, P. V. Minorsky, R. B. Jackson. Benjamin Cummings publishers. 2010. 9th edition.

Course Name	Calculus
Course Code	**MA 105**
Total Credits	8
Type	T
Lecture	3
Tutorial	1
Practical	N
Half Semester	N

Description	Review of limits, continuity, differentiability. Mean value theorem, Taylors Theorem, Maxima and Minima. Riemann integrals, Fundamental theorem of Calculus, Improper integrals, applications to area, volume. Convergence of sequences and series, power series. Partial Derivatives, gradient and directional derivatives, chain rule, maxima and minima, Lagrange multipliers. Double and Triple integration, Jacobian and change of variables formula. Parametrization of curves and surfaces, vector Fields, line and surface integrals. Divergence and curl, Theorems of Green, Gauss, and Stokes.
Text Reference	1. Hughes-Hallett et al., Calculus - Single and Multivariable (3rd Edition), John-Wiley and Sons (2003). 2. James Stewart, Calculus (5th Edition), Thomson (2003). 3. T. M. Apostol, Calculus, Volumes 1 and 2 (2nd Edition), Wiley Eastern 1980. 4. G. B. Thomas and R. L. Finney, Calculus and Analytic Geometry (9th Edition), ISE Reprint, Addison-Wesley, 1998.

Course Name	**Fundamental Themes in Physics (DIC 1)**
Course Code	**PH 109**
Total Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	N
Half Semester	N
Description	Physics of Ancient Times: Laws of lever, Archimedean screw, Archemedes principle, Spherical shape of earth, Determination of radius of earth, Planets vs stars, distances to planets 2. Heliocentric Theory: Copernicus model, Kepler's laws, Newton's law of universal gravitation 3. Newtonian Mechanics: Newton's laws of motion, Application to rigid bodies, Application to continuous systems, Mechanical view of universe 4. Thermodynamics: Energy conservation and first law of thermodynamics, One way flow of heat and second law of thermodynamics 5. Field Point of View: The development of the concept of field, Faraday's law of induction, Maxwell's equations and the unification of electricity, magnetism and optics. Man-made electromagnetic waves, wireless communication and development of electronics, Path to special relativity 6. Quantum Ideas: Early radiation theories and ultraviolet catastrophe, Planck radiation formula, photoelectric effect and photon hypothesis, Bohr atom and de Broglie hypothesis
Text Reference	

Course Name	Chemistry Lab
Course Code	**CH 117**
Total Credits	3
Type	T
Lecture	0
Tutorial	0
Practical	3
Half Semester	N
Description	1. Electrochemical Cell (A) To measure the standard electrode potential of Zn2+ / Zn couple. (B) To determine the concentration of Fe2+ by potentiometric titration. 2. Chemical kinetics To determine the rate constant for the inversion of sucrose using a polarimeter. 3. Estimation of Iron To estimate the amount of ferrous and ferric ion in a solution containing both. 4. Oscillatory Chemical Reactions a) To introduce the students to a fascinating example of an oscillating chemical reaction. b) To introduce the concept of non-equilibrium thermodynamics. c) To speculate on the possible causes and applications of oscillating chemical phenomena. 5. Electrolytic Conductance (A) To determine the ionization constant of weak monobasic acid. (B) To determine the solubility of a sparingly soluble salt. 6. Colorimetric Analysis To determine the equilibrium constant of a reaction with the help of a colorimeter. 7. Complexometric Titration Determination of total hardness of water using complexometric titration with Ethylenediaminetetraacetic Acid (EDTA). 8. Thin Layer Chromatography (A) To prepare a fluorescent dye in microscale using a one pot sequential amide formation – nucleophilic aromatic substitution reactions. (B) To understand the principles and application of Thin Layer Chromatography. (C) Analysis of TLC using ‘ImageJ’.
Text Reference	1. Lab Manual

First Year, Second Semester

Course Name	**Computer Programming**
Course Code	**CS 101**
Total Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	2
Half Semester	N
Description	This course provides an introduction to problem solving with computers using a modern language such as Java or C/C++. Topics covered will include: * Utilization: Developer fundamentals such as editor, integrated programming environment, Unix shell, modules, libraries. * Programming features: Machine representation, primitive types, arrays and records, objects, expressions, control statements, iteration, procedures, functions, and basic i/o. * Applications: Sample problems in engineering, science, text processing, and numerical methods. Hours: 2 lectures (55 minutes each), 2 hours of laboratory time which will include practice on computers. Description: This course provides an introduction to problem solving with computers using a modern language such as Java or C/C++. Topics covered will include: A. Utilization: Developer fundamentals such as editor, integrated programming environment, Unix shell, modules, libraries. B. Programming features: Machine representation, primitive types, arrays and records, objects, expressions, control statements, iteration, procedures, functions, and basic i/o. C. Sample problems in engineering, science, text processing, and numerical methods.
Text Reference	1.* C++ Program Design: An introduction to Programming and Object-Oriented Design, 3rd Edition, by Cohoon and Davidson, Tata McGraw Hill. 2003. Other references (Not required reading)* 2. Thinking in C++ 2nd Edition by Bruce Eckel (available online)*G. Dromey, 3. How to Solve It by Computer, Prentice-Hall, Inc., Upper Saddle River, NJ, 1982.* Polya, G., 4. How to Solve _It (2nd ed.), Doubleday and co. (1957) * 5. Let Us C. Yashwant Kanetkar. Allied Publishers, 1998* 6. The Java Tutorial, Sun Microsystems. Addison-Wesley, 1999 7. C++ Program Design: An introduction to Programming and Object-Oriented Design, 3rd Edition, by Cohoon and Davidson. Tata McGraw Hill. 2003. 8. A First Book of C++, 2nd Ed, by Gary Bronson, Brooks/Cole, Thomson Learning

Course Name	Linear Algebra and Differential Equations
Course Code	**MA 110**
Total Credits	8
Type	T
Lecture	3
Tutorial	1
Practical	0
Half Semester	N
Description	Vectors in S mathbb R nS, linear independence and dependence, linear span of a set of vectors, vector subspaces of S mathbb R n S, basis of a vector subspace. Systems of linear equations, matrices and Gauss elimination, row space, null space, and column space, rank of a matrix. Determinants and rank of a matrix in terms of determinants. Abstract vector spaces, linear transformations, matrix of a linear transformation, change of basis and similarity, rank-nullity theorem. Inner product spaces, Gram-Schmidt process, orthonormal bases, projections and least squares approximation. Eigenvalues and eigenvectors, characteristic polynomials, eigenvalues of special matrices (orthogonal, unitary, hermitian, symmetric, skew-symmetric, normal), algebraic and geometric multiplicity, diagonalization by similarity transformations, spectral theorem for real symmetric matrices, application to quadratic forms. Exact equations, integrating factors and Bernoulli equations. Orthogonal trajectories. Lipschitz condition, Picard`s theorem, examples of non-uniqueness. Linear differential equations generalities. Linear dependence and Wronskians. Dimensionality of space of solutions, Abel-Liouville formula. Linear ODE with constant coefficients, characteristic equations. Cauchy-Euler equations. Method of undetermined coefficients. Method of variation of parameters. Laplace transform generalities. Shifting theorems.
Text Reference	1. H. Anton, Elementary Linear Algebra with Applications (8th Edition), John Wiley, 1995. 2. G. Strang, Linear Algebra and its Applications (4th Edition), Thomson, 2006. 3. S. Kumaresan, Linear algebra - A Geometric Approach, Prentice Hall of India, 2000. 4. E. Kreyszig, Advanced Engineering Mathematics (8th Edition), John Wiley, 1999. 5. W. E. Boyce and R. DiPrima, Elementary Differential Equations (8th Edition), John Wiley, 2005. 6. T. M. Apostol, Calculus, Volume 2 (2nd Edition), Wiley Eastern, 1980

Course Name	Introduction to Classical and Quantum Physics
Course Code	**PH 110**
Total Credits	8
Type	T
Lecture	3
Tutorial	1

Practical	0
Half Semester	N
Description	Dynamics with plane polar coordinates, Dynamics in rotating frames, Special theory of relativity, de Broglie hypothesis, Fourier analysis, Heisenberg Uncertainty Principle, Schrodinger equation in one dimension, infinite potential well and other bound state problems, scattering in one dimension and tunneling.
Text Reference	1. Modern Physics -- R.A. Serway, C. J. Moses and C. A. Moyer (third edition, 2005) Thomson Learning 2. Introduction to Mechanics by D. Kleppner and R.J.Kolenkow, (2007) Tata McGraw Hill

Course Name	**Physics Lab**
Course Code	**PH 117**
Total Credits	3
Type	T
Lecture	0
Tutorial	0
Practical	3
Half Semester	N
Description	1. Laser diffraction 2. Thermal conductivity 3. LCR bridge 4. Determination of e/m of electron 5. Grating Spectrometer 6. Fresnel's Bi-prism 7. Measurement of centrifugal force 8. Torque on a current loop 9. Hydrogen spectrum
Text Reference	1. Lab Manual 2. Advanced Practical Physics, Worsnop and Flint

Second Year, First Semester

Course Name	**Economics**
Course Code	**EC 101**
Total Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Half Semester	N

Description	Basic economic problems. resource constraints and Welfare maximizations. Nature of Economics : Positive and normative economics; Micro and macroeconomics, Basic concepts in economics. The role of the State in economic activity; market and government failures; New Economic Policy in India.Theory of utility and consumer"s choice. Theories of demand, supply and market equilibrium. Theories of firm, production and costs. Market structures. Perfect and imperfect competition, oligopoly, monopoly.An overview of macroeconomics, measurement and determination of national income. Consumption, savings, and investments. Commercial and central banking. Relationship between money, output and prices. Inflation - causes, consequences and remedies. International trade, foreign exchange and balace payments, stabilization policies : Monetary, Fiscal and Exchange rate policies.
Text Reference	P. A. Samuelson & W. D. nordhaus, Economics, McGraw Hill, NY, 1995. A. Koutsoyiannis, Modern Microeconomics, Macmillan, 1975. R. Pindyck and D. L. Rubinfeld, Microeconomics, Macmillan publishing company, NY, 1989. R. J. Gordon, Macroeconomics 4th edition, Little Brown and Co., Boston, 1987. William F. Shughart II, The Organization of Industry, Richard D. Irwin, Illinois, 1990.

Course Name	**Oscillations and waves (DIC 2 PART 1)**
Course Code	**PH 113**
Total Credits	3
Type	T (half semester)
Lecture	2
Tutorial	1
Practical	0
Half Semester	Y
Description	Waves & Oscillations: Simple Harmonic motion, damped SHM, critical damping, Sustaining oscillations in a damped oscillator. Driven oscillation, resonance, damped-driven oscillator and its resonance, Q-factor, Vanderpol oscillator, non-linear feedback for sustained oscillations. SHM in 2-dim, dependence on initial conditions, Lissajous figures, condition for closed orbits, SHM in 3-dim. Oscillations of two particle systems, symmetric and asymmetric modes, general solution to the problem. Driven oscillations of two particle system. Oscillations of \`n\` particle systems, normal modes, Formulation of the general problem, eigenvalues and eigenvectors of normal modes, general solution for arbitrary initial conditions. Driven oscillations. Example of a linear triatomic molecule. Longitudinal and transverse oscillations, modding out the zero frequencies. Oscillations of a chain of \`n\` atoms. Continuum limit, vibrational modes of a string of constant density. Equation of Motion for waves, Standing waves and travelling waves in 1

	dimensions. Properties of waves in two and three dimensions Harmonics, Linear superposition of harmonics, odd harmonics, construction of pulse shapes. Fourier components of a periodic pulse, Fourier analysis and Fourier coefficients. Fourier analysis of arbitrary functions, Fourier Coefficients, Properties of Fourier transform.
Text Reference	1. Berkeley Physics Course (Vol 3) 2. Waves by Frank S. Crawford 3. Introduction to Mechanics by D. Kleppner and R. J. Kolenkow (for topics 1 and 2) 4. Introduction to Non-linear Dynamics by Steven Strogatz (for topics 3) 5. Mechanics, Landau and Lifshitz (for topics 4 to 7) 6. Mathematical Methods for Physicists, G. Arfken and Weber (for topics 11 to 13)

Course Name	**Thermal Physics (DIC 2 PART 2)**
Course Code	**PH 114**
Total Credits	3
Type	T (half semester)
Lecture	2
Tutorial	1
Practical	0
Half Semester	Y
Description	Thermal equilibrium, zeroth law and concept of temperature. First law and its consequences, reversible, irreversible and quasi-static processes. Second law: heat engines, concept of entropy and its statistical interpretation. Thermodynamic potentials, Maxwell's relations. Joule Kelvin effect. Phase transitions, order of phase transitions, order parameter, critical exponents and the Clausius-Clapeyron equation. Applications to magnetism, superfluidity and superconductivity.
Text Reference	1. An Introduction to Thermal Physics: D.V. Schroeder, Addison Wesley 1999, 2nd Edition. 2. Heat and Thermodynamics: M.W.Zemansky and R.H.Dittman, McGraw Hill 1997, 7th edition. 3.Equilibrium Thermodynamics: C.J.Adkins, Cambridge University Press, 1983, 3rd edition.

Course Name	**Classical Mechanics**
Course Code	**PH 217**
Total Credits	6
Type	T
Lecture	2

Tutorial	1
Practical	0
Half Semester	N
Description	Review of Newton`s laws of motion, frames of reference, rotating frames, centrifugal and Coriolis forces. Free and constrained motion, D`Alemberts principle and Lagrange`s equation of first kind. Lagrangian formulation, Hamilton's equation of motion. Variational principles. Canonical transformation and Poisson Bracket. Hamilton Jacobi theory and action angle variables. Periodic motion, small oscillations, normal coordinates, Central force, Kepler`s Laws and Rutherford scattering.
Text Reference	1. H. Goldstein, Classical Mechanics, Addison Wesley 1980 2. N. C. Rana and P. S. Joag, Classical Mechanics, Tata McGraw Hill 1991 3. L. D. Landau and E. M. Lifshitz, Pergamon Press 1960 4. V. I. Arnold, Mathematical Methods of Classical Mechanics, Springer Verlag 1981 5. S. N. Biswas, Classical Mechanics 1998

Course Name	**Complex Analysis and Integral Transforms**
Course Code	**PH 223**
Total Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Half Semester	N
Description	Part A (60% of the course): Complex analysis 12) Complex numbers z. Complex plane. Triangle inequalities. 13) Continuity, Differentiability, Continuity and existence of partial derivatives, Cauchy-Riemann conditions, pure complex function of z. 14) Analyticity. Single value. Cauchy's theorem. Complex Taylor Series. Convergence and domains of analyticity. Order of zeros. 15) Cauchy integral formula, and derivation of Laurent Series. Calculation of Residues. 16) Meromorphic functions and order of poles, Branch singularities, Essential singularities. 17) Residue theorem. Cauchy's argument principle. 18) Various types of contour integrals — semicircles, rectangular, conical. Case of poles on real line. 19) Branch Points and branch cuts. Integrals involving branch singular integrands. 20) Shapes of complex functions and Saddles. Darboux's inequality. Proofs of impossibility of local maxima and minima. Impossibly of entire & bounded function. 21) Asymptotic analysis: Laplace's method, stationary phase, and method of steepest descent. 22) Conformal Mapping and properties. Linear and Inversion map and their geometric effects on lines and circles. Application to 2d electrostatics. Logarithmic map. Homographic transformations and cross-ratio preservation. Part B (40% of the course): Function spaces, Integral transforms and

	some Differential equations 7. Infinite dimensional vector spaces or function spaces. Inner product, and weight function. The problem of completeness. Riemann to Lebesgue integrals, and Lebesgue space. Reisz-Fisher theorem. Bessel inequality, and Perseval's equality. Hilbert space. 8. Weierstrass's theorem and polynomial basis. Orthonormalization of polynomials using Schmidt method. Generalized Rogrigues's formula and 3 classes of classical polynomials. 9. Good, fairly good, and generalized distributions (namely, Dirac delta). Continuous index basis and use of Dirac delta. Identity operator and completeness relation of polynomials. 10. Fourier series as a basis expansion. Fourier cosine and sine series. Fourier transforms. Plancherel-Parseval relations. Meaning of Fourier transforms of generalized functions like Dirac delta where Parseval relation fails. 11. Examples of Fourier transform calculations — reminding complex analysis. Transforms of derivatives and derivatives of transforms. Solving linear ODEs, and PDEs (like diffusion equation) using Fourier transform. Convolution theorem. 12. Laplace transforms. Examples. Derivatives of transforms and transforms of derivatives. Shifting properties. Solution of linear ODEs and PDEs. Convolution theorem. Inverse Laplace transforms, Bromwich integrals and contour integration.
Text Reference	Mathematics for Physicists P. Dennery and A. Krzywicki, Dover Books Mathematical Methods for Physicists G. B. Arfken and H. J. Weber, Elsevier Press

Course Name	**AI and Data Science**
Course Code	**PH 227**
Total Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Half Semester	N
Description	**Data Science:** Introduction to data driven systems and examples. Bayesian vs. Frequentist statistics. Random variables, probability distribution with continuous and discrete outcomes, common distribution functions. Moments and moment generating function. Central limit theorem, parameter Inference: maximum likelihood method and confidence interval. Hypothesis testing: Test statistic, chi-squared test, p-value test. Introduction to linear models, simple and multiple linear regression, logistic regression. **Machine Learning:** What is learning? Learning objective, data needed. Introduction to supervised learning, training validation and testing (including loss function) - (i) Decision trees and support vector machines (SVM), classification and regression trees (CART) – growing trees, variable importance measure (ii) Random Forests - separating hyperplane, maximum margin classifier, support vector classifier. (iii) Introduction to deep learning: Definition and types of neurons, neural network architecture, cost function, feed forward neural network, back propagation algorithm. Artificial Neural networks (ANN), Deep

	Neural Networks, Convolution Neural Networks (CNN). Applications of neural networks (deep learning) in optimization, regression and model building. Multivariate analysis and dimension reduction. Singular Value Decomposition (SVD), Principal Component Analysis (PCA) etc.
Text Reference	Introduction to Statistics and Data Analysis for Physicists by Gerhard Bohm and Gunter Zech (URL : https://s3.cern.ch/inspire-prod-files-d/da9d786a06bf64d703e5c6665929ca01) Introduction to Probability and Statistics for Engineers and Scientists by Sheldon M. Ross (URL: https://minerva.it.manchester.ac.uk/~saralees/statbook3.pdf) Pattern Recognition and Machine Learning by C. M. Bishop (URL: https://readyforai.com/download/pattern-recognition-and- machine-learning-pdf/) Neural Networks and deep learning, Web book (URL: http://neuralnetworksanddeeplearning.com/index.html)

Course Name	**Analog Electronics**
Course Code	**PH 221**
Total Credits	6
Type	L
Lecture	1
Tutorial	0
Practical	2
Half Semester	N
Description	1. Fundamentals of semiconductor of device physics 2. Electronic signal transmission in circuits in time and frequency domain 3. Operational characterization of diodes and transistors performance. 4. Use of a transistor as a switch 5. Study linear amplification mode of transistor with some applications including: a. voltage amplification b. power amplification 6. Opamps – Design characteristics 7. Typical opamp application circuits including: a. Inverting, Non-inverting voltage amplification b. Transimpedance amplifiers to measure signals from typical transducers like photo-diodes, thermocouples etc c. Instrumentation amplifier and/or Lock-in amplifier Feedback control circuit using the PID (Proportional-Integrative-Differential) algorithm
Text Reference	Microelectronics, Jacob Millman and Arvin Grabel, McGraw-Hill Education, 2nd edition Building Scientific Apparatus John H. Moore and Cristopher C. Davis, Cambridge University Press011

Second Year, Second Semester

Course Name	**Statistical Physics**
Course Code	**PH 216**
Total Credits	6
Type	L
Lecture	2
Tutorial	1
Practical	0
Half Semester	N
Prerequisite	Nil
Description	1)Random walk, gaussian statistics and diffusion.2) Statistical ensembles: a) phase space, ergodicity, microcanonical ensemble, Liouville`s theorem, Ideal-gas. b) canonical ensemble, partition function c) grand-canonical ensemble, equivalence of ensembles, 3) Quantum statistical Mechanics: density matrix, Boltzmann, Bose & Fermi statistics.4) Fermi gas: high and low temp limits, electrons in magnetic field, para and diamagnetism.5) Bose gas: black body radiation, phonons, B.E. condensation.
Text Reference	1. K. Huang, Statistical Mechanics, John Wiley 1987 2. R. K. Pathria, Statistical Mechanics, Butterworth Heinemann 1996 3. J. Bhattacharjee, Statistical mechanics, Allied Publishers 1996

Course Name	**Quantum Mechanics 1**
Course Code	**PH 225**
Total Credits	8
Type	T
Lecture	3
Tutorial	1
Practical	0
Half Semester	N
Description	Review quantum ideas using wavefunction formalism; Linear vector spaces and Dirac bra(ket) notation; Operators, state vector approach of harmonic oscillator; Hydrogen atom; angular momentum, spin, addition of angular momentum, Clebsch-Gordan coefficients.
Text Reference	1. Principles of Quantum Mechanics, R. Shankar, 2. Introduction to Quantum Mechanics by Griffiths, Modern Quantum

	3. Mechanics, J. J. Sakurai 4. Quantum Mechanics by C. Cohen-Tannoudji and F. Lalö e for reference material. 5. L. D. Landau and E. M. Lifshitz, Pergamon Press 1965

Course Code:	**PH 312**
Title:	**Electromagnetic Theory**
Credits:	8
Type	T
Lecture	3
Tutorial	1
Practical	0
Half semester	N
Description:	Divergence and curl of the electrostatic field. Electrostatic potential, Laplace and Poisson's equation. Solving Laplace's equation in Cartesian and Spherical Polar (revision only). Solution in cylindrical co-ordinates with examples. Use of Bessel functions. Uniqueness and mean value theorems. Boundary value problems, Green's function. Solving Green's functions with images, eigenfunction expansion of Dirac delta function. Multipole moment upto dipole and quadrupole potentials. Interaction energy of a charge distribution with an external field. Dielectrics and polarization, E, P and D vectors. Boundary conditions. Magnetic fields and vector potential, induced currents, magnetic materials, B,H and M vectors. Electromagnetic induction, Faraday's laws and Maxwell's correction to ampere's law. Maxwell's equations. Energy of the EM field, Poynting theorem and energy transport. Momentum transport, Electromagnetic stress tensor. Electromagnetic waves. Reflection and refraction of EM waves at boundaries of dielectrics and metals. Derivation of the laws of reflection and refraction. Quantitative calculation of the reflected and transmitted intensities. Total internal reflection and evanescent waves. Radiation pressure. Electrodynamics, gauge freedom, derivation of the retarded potentials via Green's function. Lenard-Wiechart potentials of a moving point charge. Electric and magnetic fields of a moving charge. Equivalence with Lorenz transformation/ Special relativity. Electromagnetic radiation due to oscillating electric dipole. The near and far fields and their relevance. Magnetic dipole radiation. Radiation due to accelerating point charge, Brehmstralung and energy loss. Radiation retardation and its relevance
Text/Reference	**Introduction to Electrodynamics**

	D. J. Griffiths, 4th edition Prentice Hall India Pvt Ltd **Feynman Lectures vol II** R. P. Feynman, R. B. Leighton, M. Sands Narosa Publishing House **Classical Electricity and Magnetism** W.K.H. Panofsky, M. Philips Dover Books (2012) **Modern Electrodynamics** A. Zangwill Cambridge University Press (2020) **Electricity and Magnetism** A.S. Mahajan and A.A. Rangwala McGraw Hill Education (2017) **Foundations of Electromagnetic Theory** J.R. Reitz, F.J. Milford and R.W. Christy Addison-Wesley/ Narosa Publishing House (1992)

Course Name	**Digital Electronics and Microprocessors (lecture + lab)**
Course Code	**PH 222**
Total Credits	3
Type	L
Lecture	1
Tutorial	0
Practical	2
Half Semester	N
Description	Digital electronics: Theory includes (1) Boolean algebra Basic gates (2) Combinational logic (3) Sequential logic (4) Finite State Machines (5) Karnaugh maps. Laboratory: Each of the theory topics is developed in a lab assignment Microprocessors: (1) Architecture of microprocessors, with focus on the hardware design and application to control of physics experiments (2) Digital input/output systems (3) analog-to-digital and digital-to-analog conversion (4) Interrupts. Each of these concepts is developed using laboratory assignments on the Arduino microcontroller platform. Course project: Culminates in a student ideated project that combines concepts of digital electronics and microprocessors to build an

	electronic instrumentation system that demonstrates some physics concept, or is useful for a research experiment.
Text Reference	1. Digital Electronics: Principles and Applications 9th editionRoger Tokheim Wiley, McGraw-Hill Higher Education, 2022ISBN 9781259872983 2. Digital Electronics: Principles, Devices and Applications Anil K. Maini. Wiley (2007) ISBN 978-0-470-03214-5 3. Foundations of Analog and Digital Electronic Circuits. Agarwal, Anant, and Jeffrey H. Lang. Elsevier, July 2005. ISBN: 9781558607354 4. Digital Integrated ElectronicsH. Taub and D. Schilling, McGraw-Hill ISBN: 0070629218 5. Arduino: A Technical Reference: A Handbook for Technicians, Engineers, and Makers J. M. Hughes O302222Reilly (2016) ISBN: 978-1491921760

Course Name	**General Physics Lab**
Course Code	**PH 232**
Total Credits	3
Type	L
Lecture	0
Tutorial	0
Practical	3
Half Semester	N
Description	1. Photoelectric Effect 2. Frank-Hertz Experiment 3. Elastic Constant by Cornu's Method 4. Dielectric Constant 5. Viscosity by Stokes' Method 6. Thermal conductivity by Forbes' Method 7. Magnetic Susceptibility Gouy's Method 8. Potential Energy of a Magnet
Text Reference	Lab manual

Third Year, First Semester

Course Name	**Environmental Science**
Course code	**ES 200 & HS 200**
Total Credits	6
Type	T
Lecture	2
Tutorial	1

Practical	0
Half Semester	N
Prerequisite	Nil
Description	
Text Reference	

Course Name	**Introduction to Numerical Analysis**
Course code	**PH 307**
Total Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Half Semester	N
Prerequisite	Nil
Description	1. Basics: Errors, binary representation of numbers. 2. Solutions of algebraic equations: bisection method, false-position method, modified false-position method, Newton-Rapson method both for one and many variables 3. Interpolation and extrapolation: forward, backward, and divided differences and the corresponding Newton's interpolation formulas. Lagrange formula for interpolation. 4. Numerical integration: finite differences based approaches such as trapezoidal rule, Simpson rule, and Romberg integration. Gaussian quadrature. 5. Solutions of ordinary differential equations: Euler method and improved Euler method, Runge-Kutta class of methods up to fourth order. Predictor-Corrector methods 6. Solutions of Partial Differential Equations: Mainly finite difference approaches, spectral methods employing the basis-set expansion techniques. 7. Matrix Algebra: Solution of systems of linear equations using Gaussian Seidel and Gaussian elimination approaches. LU factorization. Iterative approaches to systems of linear equation. Diagonalization of matrices using Jacobi rotation, power method, Rayleigh quotient approach, and inverse iteration mehod. Inverse of a matrix using different methods such as Fadeev-Leverrier method 8. Random Number generation and Monte Carlo Methods for calculations of integrals. Metropolis algorithm. Kinetic Monte Carlo Method. 9. Fast Fourier transform (FFT): Fourier transform of discretely sampled data, FFT for real functions, Sine

	and Cosine functions. Convolution and deconvolution using FFT, correlation and auto-correlation using FFT
Text Reference	1. Introduction to numerical analysis, by F.B. Hilderbrand, Dover Publications (1974). 2. Numerical Methods for Scientists and Engineers, by R.W. Hamming, Dover Publications (1973). 3. Numerical Mathematics and Computing, by W. Cheney and D. Kincaid, Thomson (Brooks/Cole) (1999). 4. Numerical Recipes: The art of scientific computing (3rd edition) by W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery Cambridge University Press (2007) 5. Numerical Python by R. Johansson, Springer (2019)

Course Name	**Quantum Mechanics II**
Course code	**PH 309**
Total Credits	8
Type	T
Lecture	3
Tutorial	1
Practical	0
Half Semester	N
Prerequisite	Nil
Description	Addition of angular momentum, Clebsch-Gordan coefficients, Tensor operators, Wigner Eckart theorem. Approximation methods in Quantum Mechanics: (i) Variational principle, (ii) WKB method, (iii) time-independent and (iv) time dependent perturbation theory. Must include applications in atomic physics: Hydrogen atom Fine structure -Relativistic effect, spin orbit coupling, Darwin term, Lamb shift, hyperfine interaction. Stark, Zeeman and Paschen-Back effects. The ground and excited states of helium, direct and exchange terms. Time-dependent electromagnetic interaction, transition probabilities and selection rules. Scattering theory- Born approximation. If time permits partial wave analysis and a brief exposure on Klein-Gordan and Dirac equation.
Text Reference	1. Principles of Quantum Mechanics by R. Shankar. 2. Introduction to Quantum Mechanics by Griffiths.

	3. Modern Quantum Mechanics by J. J. Sakurai 4. Quantum Mechanics by C. Cohen-Tannoudji and F. Lalo¨e for reference material. 5. L. D. Landau and E. M. Lifshitz, Pergamon Press 1965 6. W. Greiner, Quantum Mechanics: An introduction 7. Atomic Physics by C.J. Foot, Oxford Master Series in Physics, Oxford University Press 8. Physics of atoms and molecules, Bransden and Joachain, Pearson 2003

Course Name	**Introduction to Condensed Matter Physics**
Course Code	**PH 436**
Total Credits	6
Type	T
Lecture	2
Tutorial	0
Practical	1
Prerequisite	Nil
Description	Crystal structures, reciprocal lattice, X-ray and electron diffraction. Lattice vibrations, Einstein and Debye models, phonons. Drude and Sommerfeld models. Bloch theorem, Empty lattice and nearly free electron model, tight-binding model, Density of states and Fermi surfaces. Semi classical model of electron dynamics. Concept of Effective mass.
Text Reference	1. N. Ashcroft and N.D. Mermin, Solid state physics 2. C. Kittel, Introduction to solid state physics, 7th ed., John Wiley 1997. 3. J. R. Christman, Fundamentals of Solid State Physics. John Wiley 1988 4. Ibach and Luth, Solid State Physics, Springer Verlag 2009

Course Name	**Physics Lab (Solid State Physics and Nuclear Physics)**
Course Code	**PH 446**
Total Credits	3
Type	L
Lecture	0
Tutorial	0
Practical	3
Prerequisite	Nil

Description	**SSP:** 1) g value using ESR spectrometer, 2) spin-lattice relaxation time using NMR spectrometer, 3) energy gap of a semiconductor using four-probe method, 4) carrier concentration using Hall measurement, 5) wave length of microwaves. **NP:** 1) Absorption coefficient of gamma-rays in Aluminium. 2) Low and high counting statistics using G. M. Counter. 3) Gamma-ray spectrometry using NaI(Tl) scintillator. 4) Compton scattering of gamma-ray using 137Cs source. 5) Coincident study of annihilation photons using 22Na source. 6) Rutherford scattering of alpha particles in gold.
Text Reference	Lab manuals of SSP and NP.

Third Year, Second Semester

Course Name	**Molecular spectroscopy and optical physics**
Course code	**PH 530**
Total Credits	8
Type	T
Lecture	3
Tutorial	1
Practical	0
Prerequisite	Nil
Description	Part-I Molecular Spectroscopy (Half-semester) Born-Oppenheimer approximation, Rotational structure of diatomic molecules and extension to linear, symmetric/spherical top molecules, vibrational structure of diatomic molecules and extension to triatomic molecules, Rotational-vibrational spectrum of diatomic molecules, Electronic structure of diatomic molecules and extension to simple polyatomic molecules, Selection rules for rotational, vibrational and electronic transitions, Franck-Condon principle, Raman effect. X-ray and photoelectron spectroscopy. Part-II Optical Physics (Half-semester) Linear optical response on the basis of Lorentz oscillator model, photonic crystals-an introduction to their band structure, introduction to plasmonics and applications, non-linear optical response of the medium, origin of the optical non-

	linearities (second and third order susceptibilities), classical and quantum pictures, a synopsis of nonlinear optical processes, second and third order optical processes and applications, phase matching considerations, stimulated Raman and Brillouin scatterings, intense field effects.
Text Reference	Part-I Molecular Physics 1. 'Physics of atoms and molecules' by Bransden and Joachain, Pearson 2003 2. 'Atoms, Molecules and Photons: An Introduction to Atomic-, Molecular- and Quantum Physics' by Wolfgang Demtröder, Springer (2010). 3. 'Fundamentals of Molecular Spectroscopy' by C.N. Banwell and E.M. McCash, Tata-McGraw-Hill (1995). 4. 'Spectra of Atoms and Molecules' by Peter F. Bernath, Oxford University Press (2005). Part-II Optical Physics 1. M. Born and E. Wolf, Principles of Optics, McMillan,1974. 2. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade, Photonic Crystals: Molding the Flow of Light (2ed) Princeton University Press (2007) 3. Stefan Maier, Plasmonics: Fundamental and Applications, Springer (2007) 4. R. W. Boyd, Nonlinear optics, academic press, 2003

Course Name	**Physics Lab (Optics and Spectroscopy)**
Course code	**PH 447**
Total Credits	3
Type	L
Lecture	0
Tutorial	0
Practical	3
Prerequisite	Nil
Description	**<u>Optics</u>** Spatial Filtering Spatial Coherence

	Mach-Zehnder Interferometer Nonlinear Optics / Z Scan CdS Nanoparticles (Theory) **Spectroscopy** Spin Orbit Coupling of Cu Absorption Spectrum of Iodine Rotation Spectrum of CN
Text Reference	Lab manuals

Fourth year has only electives

Minor in Engineering Physics

Course Code:	**Classical Mechanics**
Title:	**PH 251**
Credits:	6
Pre-requisite:	Nil
Description:	Review of Newton's laws of motion. Hamilton's principle, variational method and Lagrange's equations with and without constraints. Central force, Kepler's laws. Hamilton's equations, canonical transformation, Poisson brackets. Periodic motion, small oscillations, normal coordinates. Rigid body dynamics, moment of inertia tensor, Euler equations, motion of asymmetric top. Frames of reference, rotating frames, centrifugal and Coriolis forces.
Text/References:	1. H. Goldstein, Classical Mechanics, Addison Wesley 1980

	2. N. C. Rana and P. S. Joag, Classical Mechanics, Tata McGraw Hill 1991 3. S. N. Biswas, Classical Mechanics 1998

Course Name	**Introduction to Quantum Mechanics**
Course Code	**PH 252**
Total Credits	6
Prerequisite	Nil
Description	Basic Ideas and Origin of Quantum Mechanics, Various Experiments, which led to the birth of Quantum Mechanics, Wave Particle Duality Schrodinger Equation and Interpretation of Wave functions, Elementary Ideas of Operators, Eigenvalue problem, Various boundary value Problems, Bound States, Harmonic Oscillator problem (1-dimension), Derivation of Hermite polynomial. Creation and Annihilation Operators, Higher Dimensional Problems, Degeneracy, Hydrogen atom problem in some detail, Many Body Theory , Going beyond Hydrogen atom problem(Helium, Lithium), Many Body Hamiltonian, Born -Oppenheimer Approximation, Tight - binding Approximations, Few simple problems, Introduction to Hartree and Hartree-Fock Theory. Perturbation Theory (Time independent), Derivation of 1^{st} order and 2^{nd} order correction to eigen energy and eigenstate, Various Problems.
Text Reference	1. Principles of Quantum Mechanics by R. Shankar, 2. Introduction to Quantum Mechanics by Griffiths,

Course Name	**Thermal and Statistical Physics**
Course Code	**PH 253**
Total Credits	6
Prerequisite	Nil
Description	Review of thermodynamics: notion of equilibrium, equation of state, first and second laws of thermodynamics, thermodynamic potentials and Maxwell`s relations. Phase space, ergodicity, Liouville's theorem, microcanonical, canonical and grand canonical ensembles, Boltzmann statistics and its applications to ideal gas. Bose-Einstein and Fermi-Dirac statistics, and their applications.
Text Reference	1. K. Huang, Statistical Mechanics, 2nd ed., John Wiley, 1987. 2. H.B. Callen, Thermodynamics and an Introduction to Thermostatistics, 2nd edn, John Wiley, 1985 3. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill, 1965.

Text Reference

Course Code:	**Introduction to Condensed Matter Physics**
Title:	**PH 352**
Credits:	6
Pre-requisite:	Nil
Description:	Crystal structures, reciprocal lattice, X-ray and electron diffraction. Lattice vibrations, Einstein and Debye models, phonons. Drude and Sommerfeld models. Block theorem, Empty lattice and nearly free electron model, tight-binding model, Density of states and Fermi surfaces. Semi classical model of electron dynamics. Concept of Effective mass.
Text/References:	1. N. Ashcroft and N.D. Mermin, Solid State Physics, Holt Finehart & Winston 1976 2. C. Kittel, Introduction to solid state physics, 7th ed., John Wiley 1997. 3. J.R. Christman, Fundamentals of Solid State Physics. John Wiley 1988

Course Code:	**Light matter Interactions**
Title:	**PH 353**
Credits:	6
Pre-requisite:	
Description:	Maxwell's equations and propagation of light, Fourier analysis, Lorentz model of optical response, optical response of various natural and artificial materials, metamaterials, photonic crystals, polarization of light, scattering phenomena, lasers, nonlinear light-matter interaction, ultrafast phenomena, strong light-matter interaction, plasmonics, and few applications of light-matter interactions like photovoltaics and optical switching.
Text/References:	1. Optics by Eugene Hecht 2. Introduction to Nonlinear Optics by Robert Boyd 3. Femtosecond Laser Pulses: Principles and Experiments by Claude Rullière

M.Sc.

First Year, First Semester

Course Code:	**PH 401**
Title:	**Classical Mechanics**
Credits:	8
Type	T
Lecture	3
Tutorial	1
Description:	1. A short revision of elementary Newtonian mechanics - Forces, Torques, Rotational motion, Sliding friction, Rolling friction as a constraint, Oscillations of single degrees of freedom, Energy conservation, Energy non-conservation and inelasticity. 2. Lagrangian formalism (i) Generalised Kinetic energy, Potential energy, Symmetries leading to Lagrangian of a free particle in non-relativistic and relativistic mechanics. (ii) Hamilton's principle, Variational method, and Euler-Lagrange equations. (iii) Symmetries and conservation laws — generalised momenta, energy function, and Gauge freedom of Lagrangian. (iv) Lagrangian systems with constraint — Lagrange multipliers, and generalised forces of constraint and virtual work. (v) Particles to fields — derivation of 1-dimensional wave equation, and electromagnetic Lagrangian to Lorentz force law and Maxwell's equations. 3. Coupled Oscillators and small oscillations Lagrangian formulation of linearly coupled systems — normal modes and normal frequencies. Examples. 4. Hamiltonian formulation (i)Derivation of the Hamilton's equations of motion. Hamiltonian of certain

<table>
<tr><td></td><td>systems, specially of a particle in an electromagnetic field.
(ii) Phase space flows in second-order autonomous systems. Special case of Classical Hamiltonian systems — comparison to incompressible fluids. Examples of Hamiltonian phase space flows — elliptic and hyperbolic fixed points.
(iii) Gauge freedom of the Lagrangian and corresponding changes in the Hamiltonian.

5. Central forces

(i)Differential and integral equations of orbit.
(ii)Conditions for bounded orbits or/and closed orbits. Precession of the axis of ellipse.

6. Canonical Transformations

(i)Motivation, condition for canonical transformation, and types of generating functions.
(ii) Symplectic criterion for Canonical Transformations.
(iii) Infinitesimal Canonical transformations, Generators.
(iv) Poisson bracket invariance, and Jacobi's identity.
(v) Phase space volume conservation, and Liouville's Theorem. Hamilton's Jacobi equation. Discuss the quantum to classical limit.

7. Rigid bodies

(i)Frames of reference — accelerating and rotating frames and pseudo-forces.
(ii)Rigid body motion with one point fixed. The orthogonal rotation matrix — its components, determinant, and eigenvalues. Euler's theorem. Finite rotation formula. Infinitesimal rotation matrix, and concept of angular velocity.
(iii) Velocity of different points of a rigid body. Motion split into that of the Centre of mass, and about the Centre of mass — angular momentum, and kinetic energy formulas. The inertia tensor. Its components related to the symmetries of the rigid body. Parallel axis theorem.
(iv) The body frame, Euler angles and Euler equations.
(v) The symmetric top — force and torque free motion, and motion under constant gravity.</td></tr>
<tr><td>Text/References:</td><td>6. H. Goldstein, Classical Mechanics, Addison Wesley 1980
7. N. C. Rana and P. S. Joag, Classical Mechanics, Tata McGraw Hill 1991
8. L. D. Landau and E. M. Lifshitz, Pergamon Press 1960
9. V. I. Arnold, Mathematical Methods of Classical Mechanics, Springer Verlag 1981
10. S. N. Biswas, Classical Mechanics 1998</td></tr>
</table>

	11. Percival & Richards, Introduction to Dynamics, Cambridge

Course Code:	**PH 403**
Title:	**Quantum Mechanics I**
Credits:	8
Type	T
Lecture	3
Tutorial	1
Description:	1. Experimental Motivation, Future of Quantum Mechanics. Axioms of QM. 2. Mathematical Preliminaries: Linear Algebra (esp. trace, partial trace, tensor products. . .), Hilbert Space, Orthogonal Polynomials, Rotations &Unitaries. 3. Quantum States & Density Matrices. 4. Schr¨odinger's equation, Schr¨odinger's equation for Unitaries, Schr¨odinger, Heisenberg & Interaction Pictures. 5. Simple Problems in One Dimension, Preview of Selection Rules. 6. Harmonic Oscillators, Uncertainty Principle, Ladder Operators. 7. Spin-1/2: Qubit states, Bloch Sphere Representation, Transitions, Rabi Oscillations. . . 8. Coupled Quantum Systems. . . 9. Central Force Problems, Rigid Rotor. . . 10. Hydrogen Atom, Angular Momentum Operators, Addition of Angular Momentum.
Text/References:	1. Principles of Quantum Mechanics, R. Shankar, 2. Introduction to Quantum Mechanics, D. J. Griffiths, 3. Modern Quantum Mechanics, J.J. Sakurai 4. Quantum Mechanics, C. Cohen-Tannoudji and F. Lalo¨e for reference material. 5. L. D. Landau and E. M. Lifshitz, Pergamon Press 1965

Course Code:	**PH 405**
Title:	**Electronics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Description:	Semiconductor basics, diodes, transistors, transistor models, biasing, amplifiers (CE, CC, Swamped), Darlington pairs, difference amplifiers, operational amplifiers, feedback, instrumentation amplifier, filters, JFETs and MOSFETs,

	Digital electronics : Logic gates, Boolean algebra, Karnaugh maps, flip flops, shift registers, adders, counters, ADC and DAC.
Text/References:	1. J. Millman and C. Halkias, Integrated Electronics: Analog and Digital Systems, McGraw Hill 1972 2. A. P. Malvino, Electronic Principles, Tata McGraw Hill 1979 3. J. Millman and H. Taub, Pulse and Digital Circuits, McGraw Hill 1956

Course Code:	**PH 407**
Title:	**Mathematical Physics I**
Credits:	8
Type	T
Lecture	3
Tutorial	1
Description:	1. Linear Vector space - Scalar product, Metric spaces, Linear operator, Matrix algebra, Eigenvalues and Eigenvector, , Infinite dimensional vector spaces, Introduction to tensors. 2. Theory of analytical functions : Complex analysis - Complex numbers, Cauchy-Riemann condition, Analytic function, Taylor and Laurent series, Classification of singularities, Series, Calculus of residue, Various contour integration, Conformal mapping , Riemann surface, Branch cut integrals, Analytic continuation, Integral approximation.
Text/References:	1. M. R. Spiegel, Vector Analysis, Schaum's Outline Series, Tata McGraw Hill 1979 2. V. Balakrishnan, Mathematical Physics, Ane Books 2017 3. J. W. Brown and R. V. Churchill, Complex Variables and Applications, McGraw Hill International 1996 4. G. B. Arfken and H. J. Weber, Mathematical Methods for Physicists, Academic Press 1995 5. H. A. Hinchey, Introduction to Applicable Mathematics, Part 1, Wiley Eastern, 1980 6. Dennery & Krzywicki, Mathematics for Physicists, Dover, 7. Dender & Orszag, Advanced Math. Methods for scientists & Engineers

Course Code:	**PH 434**

Title:	**Programming Lab**
Credits:	5
Type	T
Lecture	1
Tutorial	1
Practical	3
Description:	Exposure to DOS and Unix environment. Elementary numerical programming using either FORTRAN-77 or C Language.
Text/References:	B. Davis and T.R. Hoffmann, Fortran-77-A Structured Disciplined style, McGraw Hill, Singapore, 1988.

Course Code:	**Electronics Laboratory**
Title:	**PH 443**
Credits:	3
Type	T
Lecture	0
Tutorial	0
Practical	3
Description:	Laboratory techniques-I Laboratory techniques-II I-V characteristics of electronic components Single stage CE amplifier with feedback Introduction to Opamps ---Comparator and Buffer Inverting and Non-inverting amplifier using Opamp Passive and active filters Positive Feedback in Opamp circuits---- Schmitt Trigger Introduction to Digital Electronics ---Comparator and Buffer Sequential circuits using registers
Text/References:	Lab manual

First year, Second Semester

Course Code:	PH 408
Title:	**Mathematical Physics II**
Credits:	8
Type	T
Lecture	2
Tutorial	1
Practical	0

Description:	Partial differential equations and the method of separation of variables. Ordinary differential equations, second order homogeneous and inhomogeneous equations. Wronskian, general solutions, particular integral using the method of variation of parameters. Sturm separation and comparison theorems. Adjoint of a differential equation. Ordinary and singular points. Series solution. Gauss hypergeometric and confluent hyprgeometric equations. Sturm Liouville problem. Legendre, Hermite and the associated polynomials, their differential equations, generating functions. Bessel functions, spherical Bessel equations. Fourier series, Fourier and Laplace transforms with applications. Bromwich integral approach to inverse Laplace transform. Green's function approach to inhomogeneous differential equations.
Text/References:	1. G.F. Simmons, Differential Equations with Applications and Historical notes, 2nd edn, Mc Graw Hill, 1991. 2. H. A. Hinchey, Introduction to Applicable Mathematics Part I, Wiley Eastern, 1980. 3. G.B. Arfken, H.J.Weber, Mathematical Methods for Physicists, 4th ed., Academic Press Prism Books, 1995. 4. P. Morse and H. Feshbach, Methods of Theoretical Physics, Vol.1, McGraw Hill, 1953. 5. V. Balakrishnan, Mathematical Physics, Ane Books 2017

Course Code:	**PH 410**
Title:	**Statistical Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	1. Revision of Thermodynamics: Zeroth law, First law, Second law, Carnot cycle, Claussius theorem, reversible work and heat transfer. Entropy. Extensivity — Euler and Gibbs-Duhem relations. Ideal gas. Response functions. Stability conditions, second law, and positivity of response functions. Thermodynamic potentials. Maxwell's relations. 2. Elementary aspects of probability theory: Empirical versus theoretical probabilities, equal a priori probabilities. Probability distributions functions, and cumulative distribution functions. Characteristic function and moments. Cumulant generating function and cumulants. Transformation of variables and corresponding distributions. Central limit theorem statement and explaining its significance. Problem set should clarify the procedure of attaining the central limit result, starting from various initial distributions, using asymptotic analysis of integrals.

	3. Statistical Ensembles: Microscopic dynamics and Liouville's theorem. Different hypotheses of Boltzmann leading up to the formula of Entropy in terms of number of configurations in an isolated system. Microcanonical ensemble. Example of ideal gas. Entropy of mixing. Canonical Ensemble, and partition sum. Asymptotic analysis and relation to thermodynamic free energy. Fluctuation of energy and fluctuation-response relationship. Ideal gas in canonical ensemble. Gibbs ensemble for fluids. Volume fluctuations. Ideal gas. Gibbs ensemble for a magnetic system. Non-interacting spins. Grand canonical ensemble. Number fluctuations. Ideal gas. Connection of ensembles through inverse transforms. Problem set may clarify ideal gases in various situations including constant gravity, freely jointed polymer chains, magnetic systems, classical oscillators, and hard rods in 1-dimension. 4. Quantum Statistical systems, and quantum gases: Density matrix and its time evolution. Density matrix in energy basis. Density matrix for a single oscillator, a single spin, and a single particle in a box in position basis. Exchange symmetry in many particle system. Fermions and Bosons. Off-diagonal density matrix in position basis, Canonical partition function and Pressure as a series. Grand canonical ensemble. Bose and Fermi distributions. Fermions — pressure, chemical potential, occupancy of levels, energy and specific heat. Bosons — Bose-Einstein condensation. Chemical potential, pressure, energy, specific heat. Vibrations in solids, and blackbody radiation. 5. [If time permits] Fluids of interacting particles: Cluster expansion, Virial coefficients, and Pressure as a series in density. Derivation of Vander Waals equation of state for real gases.
Text/References:	1. Mehran Kardar, Statistical Physics of Particles 2. K. Huang, Statistical Mechanics, John Wiley 1987 3. R. K. Pathria, Statistical Mechanics, Butterworth Heinemann 1996 4. J. Bhattacharjee, Statistical mechanics, Allied Publishers 1996

Course Code:	**PH 418**
Title:	**Introduction to Condensed Matter Physics**
Credits:	6

Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Crystal structures, reciprocal lattice, X-ray and electron diffraction. Lattice vibrations, Einstein and Debye models, phonons. Drude and Sommerfeld models. Block theorem, Empty lattice and nearly free electron model, tight-binding model, Density of states and Fermi surfaces. Semi classical model of electron dynamics. Concept of Effective mass.
Text/References:	1. N. Ashcroft and N.D. Mermin, Solid state physics 2. C. Kittel, Introduction to solid state physics, 7th ed., John Wiley 1997. 3. J.R. Christman, Fundamentals of Solid State Physics. John Wiley 1988 4. Ibach and Luth, Solid State Physics, Springer Verlag 2009

Course Code:	**PH 422**
Title:	**Quantum Mechanics II**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Recapitulation of angular momentum, tensor operators and Wigner-Eckart theorem. Variational principle method and WKB approximation methods and their applications. Formalism of time independent perturbation theory - both non-degenerate and degenerate cases. Techniques and application of time dependent perturbation theory. Scattering theory concepts with particular discussion on Born approximation, partial wave analysis. Brief exposure to relativistic quantum mechanics and solution of Dirac equation.
Text/References:	1. Principles of Quantum Mechanics, R. Shankar 2. Introduction to Quantum Mechanics, D. J. Griffiths, 3. Modern Quantum Mechanics, J.J.Sakurai 4. Quantum Mechanics, C. Cohen-Tannoudji 5. Quantum Mechanics with Basic Field Theory, Bipin R Desai

Course Code:	**PH 424**
Title:	**Electromagnetic Theory I**
Credits:	6
Type	T

Lecture	2
Tutorial	1
Practical	0
Description:	1. Electrostatics Introduction: Coulomb's law, Scalar potential, Electrostatic potential energy, Total energy, electric stress tensor Multipole expansion, Conducting matter, Dielectric Matter 2. Boundary Value Problems Solution of Laplace's equation: Potential theory, Uniqueness, Separation of Variables in different coordinate Systems Solution of Poisson's equation using Green's function. Method of Images 3. Magnetostatics Introduction: Steady currents, Biot – Savart law, Ampere law, Magnetic vector potential, Magnetic multipoles Magnetic Force & Energy Magnetic matter 4. Electrodynamics Dynamic and Quasi – static fields General EMFields Waves in vacuum and dispersive media 5. Special Theory of Relativity Introduction: Galilean relativity, Einstein's relativity Lorentz transformation Four – vectors, Relativistic Kinematics Electromagnetic quantities and Covariant Electrodynamics.
Text/References:	(1) Modern Electrodynamics, A. Zangwill (2) Classical Electrodynamics, J. D. Jackson (3) Introduction to Electrodynamics, D. J. Griffiths (4) Classical Electrodynamics, J. Schwinger

Course Code:	**General Physics Lab**
Title:	**PH 441**
Credits:	3
Type	L
Lecture	0
Tutorial	0
Practical	3
Description:	1. e/m Ratio 2. Photoelectric Effect 3. Frank-Hertz Experiment

	4. Elastic Constant by Cornu's Method 5. Dielectric Constant 6. Linear Expansion of Brass – Fizeau's Method 7. Thermal conductivity by Forbes' Method 8. Magnetic Susceptibility Gouy's Method 9. Potential Energy of a Magnet
Text/References:	Lab manual

Second Year, First Semester

Course Code:	**PH 505**
Title:	**Introduction to Nuclear & Particle Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Basic properties of nuclei and interactions, Nuclear binding energy, Nuclear moments, Nuclear models- independent particle model, shell model, Deuteron problem, Central and tensor forces, Radioactive decay-theory of alpha decay, Fermi theory of beta decay, gamma decay, Nuclear reactions- direct and compound reactions, Elementary particles- classification, symmetries and conserved quantum numbers, quark model
Text/References:	1. S S M Wong, Introductory Nuclear Physics, 2nd Edition, Wiley-VCH Verlag GmbH & Co. 2. B L Cohen, Concepts Of Nuclear Physics, Mc Graw Hill 3. H A Enge, Introduction to Nuclear Physics Addison-Wesley 4. J S Lilley, Nuclear Physics: Principles and Applications, John Wiley and Sons 5. K Hyde, Basic ideas and concepts in nuclear physics, CRC Press 6. W E Burcham, Nuclear and Particle Physics, Addison Wesley 7. G Kane, Modern Elementary Particle Physics, Westview Press 8. D J Griffiths, Introduction to Elementary Particles, John Wiley and Sons

Course Code:	**PH 515**
Title:	**Introduction to Atomic and Molecular Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	***Review of one and two-electron atoms***: Relativistic effects (spin orbit, mass-

	velocity and Darwin terms) in hydrogen and hydrogenic atoms, Lamb shift, ground and excited states of helium, shell structure of alkalis, quantum defect, Rydberg levels. ***Basics of spectroscopy***: Absorption and emission of photons, Transition probabilities and cross-sections, Lifetime, Line broadening mechanisms, Homogenous and in-homogenous broadening. ***Many electron atoms***: Central field approximation, coupled and uncoupled representations, L-S and j-j coupling schemes, Selection rules, Zeeman and Paschen-Back effects, Hyperfine interaction (magnetic dipole and electric quadrupole interactions), Isotope shift (mass shift and volume shift). ***Molecular structure***: Born-Oppenheimer approximation, Rotational structure of diatomic molecules and extension to linear, symmetric/spherical top molecules, vibrational structure of diatomic molecules and extension to triatomic molecules, Rotational-vibrational spectrum of diatomic molecules, Electronic structure of diatomic molecules and extension to simple polyatomic molecules, Selection rules for rotational, vibrational and electronic transitions, Franck-Condon principle, Raman effect. ***Experimental techniques in atomic and molecular physics***: Absorption, Fluorescence, Raman, Two-photon, Doppler-limited and Doppler-free spectroscopy, X-ray and photoelectron spectroscopy, Cooling and trapping of atoms/ions.
Text/References:	1. Atomic Physics by C.J. Foot, Oxford Master Series in Physics, Oxford University Press (2005). 2. Atoms, Molecules and Photons: An Introduction to Atomic-, Molecular- and Quantum Physics by Wolfgang Demtröder, Springer (2010). 3. Fundamentals of Molecular Spectroscopy by C.N. Banwell and E.M. McCash, Tata-McGraw-Hill (1995). 4. Spectra of Atoms and Molecules by Peter F. Bernath, Oxford University Press (2005). 5. Physics of atoms and molecules, Bransden and Joachain, Pearson 2003

Course Code:	**PH 527**
Title:	**Solid State Physics and Nuclear Physics Lab**
Credits:	6
Type	L
Lecture	0
Tutorial	0
Practical	6
Description:	**SSP:** 1. g value using ESR spectrometer, 2. spin-lattice relaxation using NMR spectrometer, 3. Energy gap of a semiconductor using four-probe method, 4. Carrier concentration using Hall measurement, 5. wave length of microwaves.

	NP: 1)Absorption coefficient of gamma-rays in Aluminium. 2) Low and high counting statistics using G. M. Counter. 3) Gamma-ray spectrometry using NaI(Tl) scintillator. 4) Compton scattering of gamma-ray using 137Cs source. 5) Coincident study of annihilation photons using 22Na source. 6) Rutherford scattering of alpha particles in gold.
Text/References:	Lab manuals

Second Year, Second Semester

Course Code:	**PH 510**
Title:	**Electromagnetic Theory II**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Potentials and fields of moving charges (Lienard-Wiechert), radiation basics, radiative transfer, Planck's law, dipole radiation, Thomson scattering, Cyclotron, Synchrotron, Bremmstrahlung, Cherenkov, Compton and inverse Compton, Einstein coefficients, Transmission lines, Waveguides, Antennas and Arrays, detection of radiation - detector physics.
Text/References:	1. Electrodynamics, D. J. Griffiths 2. E. K. Jordan and K. G. Balmain, Electromagnetic Waves and Radiating Systems, Prentice Hall 1971 3. S. S. Puri, Classical Electrodynamics, Tata McGraw Hill 1997 4. J. D. Jackson, Classical Electrodynamics, John Wiley and Sons 1998
Course Code:	**PH 530**
Title:	**Light Matter Interaction**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Interaction of two level atom with incoherent light, Einstein coefficients, multi quantum transitions, interaction of two level atom with resonant coherent light, analogy between two level and spin ½ systems, optical Bloch equations of two level systems-polarization, susceptibility and spontaneous emission, dressed

	states, Rabbi flopping, free precession and photon echoes. Interaction of light with three level system-irradiation of single and two transitions, coherence transfer, three level echoes, quantum beats, Raman excitation, coherent population trapping, electromagnetically induced transparency, over damped systems adiabatic limit, optical pumping, light shift and damping, ground state dynamics.
Text/References:	1. Light-Matter Interaction, Vol.1: Fundamentals, by J. Weiner and P.T. Ho, Willy (2008). This books contains all topics of interest except strong/intense field interactions. 2. Elements of quantum optics, P. Meyster and M. Sargent, Springer Verlag 2001 3. Quantum Optics, M. O. Scully and S. Zubairy, Cambridge university Press 1997 4. Atom-photon interaction: basic principles and applications, Claude Cohen Tonnoudji, J. D. Roc and G. Grynberg, John Wiley and Sons 1998 5. Lectures on Light: Nonlinear and Quantum Optics, by S.C. Rand, Oxford Univ. Press (2010). It treats topics of interest, one needs to subtract the quantum optics part (e.g. Coherent states etc). 6. Atomic Physics, by C.J. Foot, Oxford University Press (2005) Chapters 7,8,9 provide the basic issues in light-matter interaction. 7. Atoms, Solids and Plasmas in super intense laser fields, Ed. D. Batani, C.J. Joachain, S. Martelluci and A.N. Chester, Kluwer/Plenum (2001) 8. Multiphoton ionization of atoms, Ed. S.L. Chin and P. Labropoulos, Elsevier (1984).

Course Code:	**PH 512**
Title:	**Optics and Spectroscopy Lab**
Credits:	6
Type	L
Lecture	0
Tutorial	0
Practical	6
Description:	<u>**Optics**</u> Spatial Filtering Spatial Coherence Mach-Zehnder Interferometer

	Nonlinear Optics / Z Scan CdsNanoparticals (Theory) **<u>Spectroscopy</u>** Spin Orbit Coupling of Cu Absorption Spectrum of Iodine Rotation Spectrum of CN
Text/References:	Lab manuals

Elective Courses (Odd semester) open to all

Course Name	**Methods in Analytical Techniques**
Course code	**PH 517**
Total Credits	6
Type	T
Lecture	2
Tutorial	0
Practical	2
Half Semester	N
Description	Structure and Microstructure analysis by X-ray and electron diffraction, transmission and scanning electron microscopy techniques. Study of molecular structure by resonance techniques like Nuclear magnetic resonance (NMR), Fourier transform NMR (FTNMR) and Electron spin resonance (ESR). Study of molecular structure by Infrared (IR), Fourier transform IR (FTIR) and Raman spectroscopies. Study of electronic structure by Photoelectron Spectroscopy and X-ray absorption techniques. Composition analysis by Energy dispersive X-ray (EDX), Auger Electron Spectroscopy (AES) and Secondary ion mass spectrometry (SIMS). Study of surface morphology and structure by Scanning tunneling and Atomic Force microscopies (STM, AFM). Study of magnetic thin films by Ferromagnetic resonance, vibrating sample and torque magnetometry and Magnetic force microscopy.

Text Reference	1. R.S. Drago, Physical methods, 2nd ed., Saunders College Publishing, 1992. 2. B.G.Yacobi, D.B.Holt and L.L.Kazmerski, Microanalysis of Solids, Plenum Press, 1994.

Course Code:	**PH 523**
Title:	**Quantum Mechanics III**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Relativistic wave equation : (a) Klein-Gordon equation, solution for K-G equation (free spin zero particles), Lagrangian and energy-momentum tensor of K-G field, symmetries and Noether's theorem, conserved charge and current, Interaction of a relativistic spin-zero particle with electromagnetic field, (b) Rotation group and angular momentum, Dirac equation for spin-1/2 particle, covariant form, continuity relation, hole theory, free particle spinors, antiparticles, Lagrangian density and energy-momentum tensor, normalization of spinors and completeness relation, zero mass fermions, (c) Field theory and second quantization: quantization of free scalar field, ground state of the Hamiltonian, normal ordering, Fock space, complex scalar field, propagator of real and complex scalar field, microscopic causality, Quantization of free Dirac field, Fourier decomposition, propagator of Dirac field.
Text/References:	1. Relativistic Quantum Mechanics, Bjorken and Drell 2. Quarks and Leptons : an Introductory course in modern particle physics, Halzen and Martin 3. A first book on quantum field theory, Lahiri and Pal; 4. An introduction to quantum field theory, Peskin and Schroeder.

Course Code:	**PH 534**
Title:	**Quantum information and computing**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Open Systems Theory (N&C, Breuer) Basics : States and measurements in quantum mechanics: Basic quantum mechanics, unitary operators, qubits and single qubit gates, density matrices, evolution equation for density matrices, example: two-level systems, composite systems and tensor products.

	CPTP Maps: CPTP maps, Kraus representation, Stinesping dilation, Choi &Jamiałkowski isomorphism, Information & Computation (ref: N&C, Wilde, Wolf, Hayashi) Entropy, Entanglement & Measures: Entropy, matrix inequalities and monotones, distance measures and their meaning, relative entropy, mutual information. Schmidt rank, concurrence, distance measures, entropic measures. Important Techniques & Algorithms: Dense coding, entanglement distillation and purification, teleportation, Deutsch-Josza, Bernstein-Vazirani, Simon, Grover, quantum Fourier transform, Shor, DQC-1... Paradigms & Implementations of Computing (N&C): circuit-based QC, adiabatic QC, measurement-based QC, topological QC... Experiments: ion traps, linear optics, superconducting qubits... Geometry & Metrology (Extra / Wishlist) (N&C,Bengtsson) Geometry & Correlation Measures :.
Text/References:	[1] Nielsen, Michael A., and Isaac L. Chuang. "Quantum Computation and Quantum Information (Cambridge University Press, Cambridge, 2000)."302240URL https://doi. org/10.1017/CBO9780511976667. [2] Nakahara, Mikio.302240Quantum computing: from linear algebra to physical realizations. CRC press, 2008. [3] Preskill, John. "Lecture notes for physics 229: Quantum information and computation."302240California Institute of Technology30224016, no. 1 (1998): 1-8.

Course Code:	**PH 543**
Title:	**Advanced Statistical Mechanics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	1. Introduction and Overview 2. Probability Theory, A-priori probabilities, Distributions, generating functions (moment and cumulant series expansions) Inter-conversion of probability distributions, Central Limit Theorem 3. Folklore of Phase transitions: exponents and universality Yang-Lee theorem and singularities in phase transition Lattice gas: fluid-magnet analogy 4. Transfer matrices, Ising and Dimer models Duality and exact Tc of 2-d Ising model, Overview of exactly solvable models 5. Master Equation, Two processes in details — Random Walk, and Birth Process

	[method of Lagrange characteristics]. More examples. Waiting times, and continuous time random walk. Theory of W-matrices, Equilibrium versus Non-equilibrium steady states — detailed balance and other balances. Ergodicity, Kinetic Monte-Carlo, and simulation of kinetics of models. Metropolis Monte Carlo — simulations of spin systems, and other equilibrium models. 6. Fokker-Planck and Langevin equations Solutions by various methods, connection between the two approaches. Absorbing boundaries and first passage problem, reflecting boundaries, Kramer's problem, Auto-correlations using Langevin equation — [Wiener, Ornstein-Uhlenbeck, Rouse Polymer (sub-diffusion), Polymer in shear flow (super-diffusion)] 7. Approximate approaches to critical phenomena Mean field theory for magnets: calculation of Exponents Overview of Van der Waal's theory Ginzburg-Landau theory and fluctuations, Gaussian approximation, Calculation of Correlation function, and specific heat. 8. Scaling hypothesis, Renormalisation group (RG) Preliminary examples 9. Vector order parameters — equilibrium versus non-equilibrium XY model, Vicsek model
Text/References:	1. Statistical Physics of Particles (volume I), M. Kardar 2. Statistical Physics of Fields (volume II), M. Kardar 3. Handbook of Stochastic Methods, C.W. Gardiner 4. Stochastic Processes in Physics and Chemistry, N.G. Van Kampen 5. Fokker-Plank Equation, H. Risken 6. Equilibrium Statistical Physics, M. Plischke and B. Bergersen 7. Principles of Condensed matter physics, P.M. Chaikin and T.C. Lubensky 8. Statistical Mechanics, K. Huang 9. Scaling and renormalisation in statistical physics, John Cardy 10. Exactly solved models in Statistical Physics, R. J. Baxter

Course Code:	**PH 549**
Title:	**Physics of Biological Systems**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Numbers and scales in Biology, temporal scales, kinetic processes, model systems. Diffusion in biological systems, Brownian motion, Reynold`s number, intra and intercellular transport. Pattern formation in biology, Turing model, Reaction diffusion systems, mechano-chemical coupling, patterns in development. Cell, cytoskeleton and motors, invitro and invivo measurements, models for filaments and motors, example systems, cell division and active matter. Chromatin structure and function, DNA and genes, nucleosomes and

	epigenetic regulation, higher order structures. Gene expression, Role of noise, transcription and translation. Optional: • Viral infections, lysis, lysogeny, horizontal gene transfer, immune responses. Protein folding and mis-folding, aggregation and amyloids.
Text/References:	1. R. Phillips, J. Kondev, J. Theriot & H. Garcia, Physical Biology of the Cell, Garland Science 2. K. Roberts, D. Bray, J. Lewis, M. Raff, A. Johnson, B. Alberts, Molecular Biology of theCell, Garland Science, 3. P. Nelson, Biological Physics, 4. W.H. Freeman, J. Howard, Mechanics of Motor Proteins and the Cytoskeleton, Sinauer Associates, 5. D. Bray, Cell Movements: From Molecules to Motility, Garland Science, 6. D. Boal, Mechanics of the Cell, Cambridge University Press, 7. H.C. Berg, Random Walks in Biology, Princeton University Press, 1983

Course Code:	**PH 557**
Title:	**Theoretical Condensed Matter Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Elementary theory of groups and their representation, application solid state physics. Electronic state in solids. Hartree and Hartree-Fock approximation. Free electron, exchange, pseudopotential theory. Cohesive energy of simple metals. Energy bands and their symmetries. Magnetism: Heisenberg exchange and magnetic ordering, magnetic resonance and relaxation. Superconductivity: Microscopic theory, Josephson effect, flux quantization.
Text/References:	1. W. Harrison, Solid State Theory Tata McGraw Hill. 2. N. Ashcroft and N.D. Mermin, Solid State Physics, Holt, Rinehart and Winston, 1972. 3. J. Ziman, Principles in the Theory of Solids, Cambridge.

Course Code:	**PH 561**
Title:	**Ultrafast Sciences**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0

Description:	Ultrafast science: Introduction, Spatio-temporal properties of ultrashort pulses Generation of ultra-short pulses, Material dispersion and compensation Nonlinear optics, Ultrashort pulse characterization Pulse propagation through various media, Pulse-shaping and coherent control Applications in atomic and molecular physics, Applications in condensed matter physics and materials science, Applications in bio-photonics and femto-chemistry High power lasers, Extreme nonlinear effects: Experiments and theory Intense field effects and attosecond science (Theory and experiments)
Text/References:	1. Nonlinear Optics by R. Boyd (Elsevier/Academic Press) 2. Ultrafast Optics by A. M. Weiner (Wiley) 3. Ultrashort Laser Pulse Phenomena by J-C Diels and W. Rudolph (Elsevier/Academic Press) 4. Frequency resolved optical gating: The measurement of ultrashort laser pulses by R.Trebino (Springer) 5. Ultrafast Biophotonics by P. Vasa and D. Mathur (Springer) 6. Lectures on Ultrafast Intense Laser Science by K. Yamanuchi (Springer)

Course Code:	**PH 563**
Title:	**Group Theoretical Methods in Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	<u>**Discrete groups and applications**</u>: cyclic groups, permutation groups, point groups, irreducible representations, great orthogonality theorem, character tables. Applications like selection rules, normal modes of molecules possessing symmetry and energy splitting due to symmetry breaking which will highlight the power of group theory tools. <u>**Continuous groups**</u>.: space translations, time translations, rotations and their symmetry properties. A formal introduction of Lie algebras and Lie Groups with particular emphasis on Lie groups SU(2) and SU(3). The applications in quantum mechanical angular momentum and particle physics quark models. Young Tableau approach of understanding tensor product and irreducible representations of SU(N). Lorentz group, dynamical symmetry for appreciating the elegant way of obtaining energy spectrum of hydrogen atom.

Text/References:	1. Group theory and its application to Physical Problems, M. Hammermesh, 1965 Wiley-VCH Verlag GmbH & Co. 2. Lie groups and lie algebras for physicists - Das and Okubo 3. Lie algebras in particle physics - H. Georgi

Course Code:	**PH 565**
Title:	**Semiconductor Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	An introduction to semiconductors, their crystal structure and their band structure. Intrinsic and extrinsic semiconductors, charge carriers and their effective masses. Methods of electronic structure calculations for semiconductors: plane wave methods, pseudo-potential approaches, semi-empirical pseudo-potential method, k.p method, Luttinger Hamiltonian, and the tight-binding approach. Electron-phonon coupling. Optical properties of semiconductors: absorption edges, effective mass approximation, excitons, polaritons. Electron transport properties: high-fieldeffects and magneto-transport.
Text/References:	1. P.Y. Yu and M. Cardona, Fundamentals of Semiconductors, Springer, 1992. 2. K. Seeger, Semiconductor Physics, 9th Edition, Springer 2004. 3. C. Hamaguchi, Basic Semiconductor Physics, Springer 2001. 4. H. Haug and S.W. Koch, Quantum Theory of the optical and electronic Properties of Semiconductors, 4th Edition World Scientific 2004.

Course Code:	**PH 567**
Title:	**Nonlinear Dynamics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Physics of nonlinear systems, dynamical equations and constants of motion, phase space, fixed points, stability analysis, bifurcations and their classifications, Poincar`e section and iterative maps. One dimensional non--invertible maps, simple and strange attractors, period doubling and universality, intermittency,

	invariant measure, Lyapunov exponents. Higher dimensional systems, Henon map, Lorenz equations. Fractal geometry and examples of simple and fat fractals, concept of dimensions. Hamiltonian systems, integrability, Liouville`s theorem, action and angle variables, introduction to perturbation techniques, KAM theorem, area preserving maps, chaos and stochasticity.
Text/References:	1. I. Percival and D. Richards, Introduction to Dynamics, Cambridge University Press, 1982. 2. Steven H. Strogatz, Nonlinear Dynamics and Chaos, Addison Weseley,1994. 3. Edward Ott, Chaos in Dynamical Systems, Cambridge University Press,1993. 4. E. A. Jackson, Perspectives of Nonlinear Dynamics, Vol. 1&2, Cambridge University Press, 1989.

Course Name	**Applied Solid State Physics**
Course Code:	**PH 569**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Boltzmann transport equation, scattering and relaxation time. Optical properties of solids, excitations, concept of plasmons, polarons and polaritons. Dielectric function, dielectric and ferroelectric materials. Band structure of semiconductors, density of states and conductivity effective masses, carrier diffusion processes, excess carrier life time, recombination and trap centres, photo conductivity, electronic properties of surfaces. Dia, para and ferro magnetism, magnetic domains, magnetic materials and application. Magnetic resonance techniques, spin-spin and spin-lattice relaxation. Superconductivity, Meissner effect, tunneling in superconductors, Josephson junctions, squids, superconducting magnets.
Text/References:	1. N. Ashcroft and N.D. Mermin, Solid state physics 2. C. Kittel, Introduction to solid state physics, 7th ed., John Wiley 1997. 3. J. R. Christman, Fundamentals of Solid State Physics. John Wiley 1988 4. Ibach and Luth, Solid State Physics, Springer Verlag 2009

Course Name	**Nanoscience: Fundamentals to Fabrication**
Course Code:	**PH 575**

Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	**Physical Properties of Nanomaterials:** Effect of size on thermal, electrical, mechanical, optical and magnetic properties of nanoscale materials, diffusion properties, dielectric properties, Surface area to aspect ratio, Quantum confinement size effects, bang gap effect at nanoscale. **Synthesis of Nanomaterials** The principles of nucleation and growth, thermodynamics, kinetics, and mechanisms of Nucleation and Growth of nanocrystals, crystallography, surfaces and Interfaces, Applications to growth from solutions, melts and vapors. **NanoFabrication** Introduction to micro/nano fabrication, photolithography, x-ray lithography, e-beam lithography, nanoimprint lithography, stamping techniques for micro/nano fabrication, methods and applications of lithographic techniques, AFM based nanolithography (DPN) and nanomanipulation, self-assembly, template-based growth of nanorod arrays, 3D nanofabrication using focused ion beam (FIB), MEMS and NEMS, nano and micro-structured semiconductor materials for microelectronics.
Text/References:	Frank J. Owens and Charles P.Poole, The Physics and Chemistry of Nano Solids, Wiley-Interscience, 2008. Guozhong Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, World Scientific 2011 Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, John Wiley and Sons 2013 C. N. R. Rao, Achim Mller, A. K. Cheetham, The Chemistry of Nanomaterials: Synthesis, Properties and Applications, John Wiley and Sons 2007 A S Edelstein and R C Cammarata, Nanomaterials Synthesis, Properties and Applications, IOP Publishing Ltd 1996. Stephen A. Campbell: Fabrication Engineering at the Micro- and Nanoscale, 4th

	Edition. Oxford University Press 2012 P. V. Zant, Microchip Fabrication, McGraw-Hill Education; 5 edition 2004 ISBN: 978-0071432412 Ning Xi and King Lai, Nano Optoelectronic Sensors and Devices: Nanophotonics from Design to Manufacturing, Elsevier Inc. 2011, eBook ISBN: 9781437734720. Sam Zhang, Nanostructured thin films and coatings: Mechanical Properties, CRC Press 2010. H. Baltes et al, Enabling technology for MEMS and Nanodevices, Wiley-VCH, 2008

Course Name	**Advanced Topics in Astro-particle Physics**
Course Code:	**PH 813**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	• Recap of Cosmography and the FLRW cosmological models. • Thermal history of the Universe • Non-equilibrium processes -- possible origins of Dark Matter and matter-anti-matter asymmetry. • Phase transitions and cosmological defects. • Inflationary universe models. • Late time cosmology and formation of large scale structures. • Approaches to quantum cosmology • Dark matter experiments
Text/References:	1.011E. Kolb and M. Turner, 302223 The Early Universe.302224, Frontiers in Physics, 19942.011 Lars Bergstr 303266m and Ariel Goobar, 302223Cosmology and Particle Astrophysics302224, Springer Praxis Books, 20063.011Ofer Lahav & Yasushi Suto , 302223Measuring our Universe from Galaxy Redshift Surveys302224, 2004, https://link.springer.com/article/10.12942/lrr-2004-84.011J. Fernando Barbero G. & Eduardo J. S. Villase303261or 302223Quantization of Midisuperspace Models302224, 2010, https://link.springer.com/article/10.12942/lrr-2010-65.011Neal Jackson, 302223The Hubble Constant302224, 2, https://link.springer.com/article/10.1007/lrr-2-26.011Timothy J. Sumner, 302223Experimental Searches for Dark Matter302224, 2002, https://link.springer.com/article/10.12942/lrr-2002-4

Course Name	**Standard Model of Particle Physics**
Course Code:	**PH 815**

Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Symmetries of strong interactions and QCD. Parton model and perturbative QCD. RG analysis of scaling and scaling violations. Operator analysis of e-N scattering. Moments of Structure Functions and Wilson Coefficients. RG Equation for Wilson Coefficients. Spontaneous symmetry breaking (SSB). O(N) models. Goldstone`s theorem. Abelian and Non-abelian Higgs mechanism and SSB in gauge theories. Renormalization of spontaneously broken gauge theories and R-ξ gauge. Goldstone boson equivalence theorem.
Text/References:	1. Paul Langacker, 302223The Standard Model and Beyond302224, CRC Press 20172. 2. John F. Donoghue, Eugene Golowich and Barry R. Holstein,"` Dynamics of the Standard Model", 2nd edition, Cambridge University Press (2014) 3. C. P. Burgess and G. D. Moore, 302223The standard model: A primer302224,Cambridge Univ. Press (2007)4. Palash Pal, 302223An Introductory Course of Particle Physics``,CRC Press;1st edition, 20145. 4. T. P. Cheng and L-F Lee, 302223Gauge Fields and Elementary ParticlePhysics.302224 Oxford Science Publications, 19846. 5. R. K. Ellis, W. J. Stirling and B. R. Webber, 302223QCD and colliderphysics302224. Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology, 19967. 6. Mulders, M. (ed.) ; Duhr, C. (ed.) 302223Proceedings of the 2018 European School of High-Energy Physics302224,https://e-publishing.cern.ch/index.php/CYRSP/issue/view/92, 20188. 7. Yuval Grossman, Philip Tanedo, 302223Just a Taste: Lectures on Flavor Physics``,https://www.classe.cornell.edu/~pt267/files/notes/FlavorNotes.pdf, 2010

Course Name	**Specialized Topics in QFT and Beyond Standard Model Physics**
Course Code:	**PH 817**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0

Description:	Grand Unified Theories: motivation, construction and constraints. Supersymmetry: motivation, construction and constraints. Majorana Neutrinos and challenges in Neutrino mass models. Particle Physics solutions to Dark Matter. QFT at finite temperature. Restoration of spontaneously broken symmetry at finite temperature. Topology of gauge fields, sphalerons, instantons and strong CP problem Chiral Lagrangian and Chiral Perturbation Theory. Models of confinement and large N gauge theories
Text/References:	1. S. Weinberg, 302223Quantum Field Theory302224 vol. II and vol. III, Cambridge University Press, 19982. Mark Srednicki, 302223Quantum Field Theory302224,;Cambridge University Press, 20073. M. Shifman, 302223Advanced Topics in Quantum Field Theory: A Lecture Course302224, Cambridge University Press, 24. Stephen P. Martin, 302223A Supersymmetry Primer302224,https://arxiv.org/abs/hep-ph/97093565. Csaba Csaki, Salvator Lombardo, Ofri Telem, 302223TASI Lectures onNon-Supersymmetric BSM Models302224, https://arxiv.org/abs/1811.042796. Anson Hook, 302223TASI Lectures on the Strong CP Problem and Axions302224,https://arxiv.org/abs/1812.026697. Kai Zuber, "Neutrino Physics", CRC Press, 3nd edition, 20208. Davidson et al., 302223Effective Field Theory in Particle Physics and Cosmology: Lecture Notes of the Les Houches Summer School: Volume 108,July 2017302224., OUP Oxford (2020)

Course Name	**Advanced Astrophysics**
Course Code:	**PH 819**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Stellar evolution: Basic equations of stellar structure, Stellar energy sources, qualitative description of numerical solutions for stars of different mass, homologous stellar models, Evolution in the HR-Diagram, End state of stars, compact objects, Chandrashekhar mass, Compact Binaries: Types, Roche lobe mechanism, Different formation channels, Observational probe Galaxies -- Galaxies as self-gravitating systems, Virial theorem, Potentials, and orbits, Rotation curves Spiral galaxies, spiral structure, The collisionless-Boltzmann equation, Elliptical galaxies, Supermassive black holes in galaxies High energy astrophysics -- Supernova & supernova remnants, neutron stars, pulsars and magnetars, X-ray binaries, gamma-ray bursts & active galactic nuclei, Accretion process in astrophysics, Astrophysical jets - emission from jets, beaming and boosting, superluminal motion, Cosmic rays, Radio emission from the Galaxy.

Text/References:	1. Modern Astrophysics, B. W. Carroll and D. A. Ostlie, Addison -Wesley, 2007. 2. The physical universe, F. Shu, University Science books, 1982. 3. Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press, 2010 4. Theoretical Astrophysics, T. Padmanabhan, Cambridge University Press, 2 011 011011

Course Name	**Gravitational Wave Physics and Astronomy**
Course Code:	**PH 821**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	A brief recap of General Relativity: Einstein's equations, the Newtonian limit of GR, Linearized gravity Gravitational Waves: Description, Propagation, Physical properties, Effects of gravitational waves, Energy and momentum carried by gravitational waves, Gravitational radiation luminosity, Far zone, and Near Zone solutions, and quadrupole formula Sources of Gravitational waves: Estimation from terrestrial sources, coalescing compact binaries, gravitational wave bursts, continuous gravitational waves from pulsars, stochastic gravitational-wave background Detectors: Historical perspective, Laser interferometric detectors; Principle of detection, Ground-based LIGO, Virgo, KAGRA detectors, Space-based LISA, Einstein Telescope; Pulsar timing arrays Astronomy: Discovery of Hulse Taylor Binary pulsar, Gravitational wave discovery of Binary black hole merger, Astrophysics and Cosmology with compact binary mergers, HandsOn exercises with GW open data
Text/References:	1. A first course in General Relativity by B. F. Schutz , Cambridge University Press (1985) 2. Gravitational Wave Physics and Astronomy -- Jolien Creighton and Warren Anderson, Wiles, Series in Cosmology (2011) 3. Gravitational Waves Vol 1: Theory and Experiments by Michele Maggiore, Oxford University Press (2007)

Elective Courses (Even semester)- open to all

Course Code	**PH 500**
Title:	**Thin film Physics and Technology**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Vacuum technology, gas transport and pumping systems, pressure measurements, physical and chemical vapour deposition processes, sputtering and plasma CVD, deposition by electron beams, arc plasma and pulsed laser, Molecular beam epitaxy and metal organic CVD, Chemical solution based deposition processes, electrochemical deposition, Langmuir Blodgett and self-assembly processes, Physics of thin film deposition, adsorption, surface deposition, nucleation, growth and structure development, surface structure, role of surfaces, epitaxial growth, lattice mismatch, strain, growth modes, self-organization, self-aligned structures, heterostructures, multilayer superlattice structures, patterning techniques for IC, MEMS and other device fabrications, application of thin films.
Text/References:	K. L. Chopra, Thin films phenomena, Mc Graw Hill 1968 M. Ohring, Materials science of thin films, Academic press 1992 D. L. Smith, Thin films deposition: Principles and practices, Mc. Graw Hill 1995 J. E. Mahan, Physical vapour deposition, John Wiley 2000 K. W. Kolasinski, Surface science, John Wiley 2002 J. H. Fendler, Nanoparticles and nanostructured films, Springer 2000

Course Code:	**PH 540**
Title:	**Elementary Particle Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Phenomenology of strong and weak interactions. Conserved quantum numbers. Leptons, nucleons and mesons. Partial conservation of axial current. Non-abelian gauge theories. Spontaneous breaking of global and local symmetries. The Higgs mechanism. Weinberg Salam Theory. Quantum Chromodynamics. Accelerator experiments and detectors. Low energy and non-accelerator experiments. Questions beyond the Standard model. Unification proposals.
Text/References:	1. F. Halzen and A.D. Martin, Quarks and Leptons, John Wiley, 1984

	2. G. Kane, Modern Elementary Particle Physics, Addison Wesley, 1987 3. K. Huang, Quarks, Leptons and Gauge Fields, World Scientific,

Course Code:	**PH 544**
Title:	**General Theory of Relativity**
Type	T
Lecture	2
Tutorial	1
Practical	0
Pre-requisite:	This course is a basic introduction to the general theory of relativity and its applications to isolated macroscopic objects and cosmology. Prerequisite: Classical Mechanics, Special Theory of Relativity
Description:	1. Covariance of Physical Laws [1lecture]2. Special Relativity [2 lectures]3. The Equivalence Principle [2lectures]4. Space and Space-time Curvature [4 lectures]5. Tensors in Curved Space-time [4 lectures]6. The Geodesic equation [2 lectures]7. geodesic Deviation Equation [2 lectures]8. Curvature and Einstein Field equations [4 lectures]9. Geometry Outside of a Spherical Star [3lectures]10. Tests of General Relativity [3 lectures]11. Gravitational Radiation [3 lectures]12. Black Holes[2 lectures]13. Cosmology [4 lectures] .
Text/References:	1. Gravity- An introduction to Einstein's general relativity – James B. Hartle (Addison-Wesley, 2003) 2. Gravitation and Cosmology - S. Weinberg (Wiley, 1972) 3. Space-time and Geometry: An Introduction to General Relativity - Sean Carroll (Pearson, 2003). 4. Also see the Arxiv: gr-qc/97120194. 5. Introduction to General Relativity - J. V. Narlikar (Cambridge) 6. Classical Theory of Fields - L. D. Landau and E. M. Lifshitz (Butterworth-Heinemann)

Course Code:	PH 546
Title:	**Quantum Optics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Quantum theory of light: field quantization, lamb shift, quantum beats

	Quantum theory of coherence: photon detection and quantum coherence functions, first order coherence and Young's double source experiment, second order coherence, physics behind Hanburry-Brown and Twiss experiment, interference of two photons, photon antibunching, Poissonian and sub-Poissonian light, photon counting and photon statistics. Classical and non-classical light: Coherent, Fock and squeezed states of light, coherent state as an eigen state of annihilation operator and as a displaced harmonic oscillator state, properties of coherent state, physics of squeezed states, squeezed state and uncertainty relation, squeezed coherent state, quadrature variance, multimode squeezing, squeezing via nonlinear optical processes, applications of squeezed states for quantum noise reduction beyond standard short noise limit. EPR paradox, hidden variable, Bell's theorem and quantum cryptography, Quantum non-demolition (QND) measurement: conditions for QND, QND measurement of photon number by optical Kerr effect and by dispersive atom-field coupling, QND measurement in optical parametric processes Quantum optical tests of complimentarity: a micro maser with path detector, quantum eraser and quantum optical Ramsey fringes
Text/References:	1. Quantum Optics, M.O. Scully and M.S. Zubairy, Cambridge University Press (2001). 2. Elements of quantum optics, P. Meyster and M. Sargent, Springer Verlag 2001 3. Quantum Optics, D. F. Walls and G. J. Miburn, Springer Verlag 4. Quantum Optics: An Introduction, Mark Fox, Oxford Master Series in Physics (2006). 5. Introductory Quantum Optics, C.C. Gerry and P.L. Knight, Cambridge University Press (2005).

Course Code:	**PH 550**
Title:	**Soft Matter Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Basic phenomenology, Liquid crystals, polymers, membranes, surfactants, colloids, gels. Phase transitions, Landau theory, order parameter (conserved and non-conserved), nucleation and spinodal decomposition. Nematic liquid crystals, Mean field theory for isotropic-nematic transition, Landau-deGennes theory, Effect of spatial gradients, Onsager's theory for isotropicnematic transition.

	Polymers, random walk, gaussian chain, excluded volume, Flory theory, Deforming polymer chains, Temperature effects, Field theories and RG approach, solutions, melts, dynamics – Rouse and Zimm. Membranes and interfaces – Free energy and shape transitions. Flow and deformation of soft matter, mechanical properties and molecular models, colloids – rheology and dimensional analysis, viscoelasticity and response functions. Optional: • Elastic soft matter, Fundamentals, Kuhn theory of rubber elasticity, polymer gels. Physics of jamming, Supercooled liquids, and search for a transition, Jamming phase diagram for glasses, foams, and granular matter
Text/References:	1. M. Doi, Soft Matter Physics, Oxford University Press, 2. P.M. Chaikin& T.C. Lubensky, Principles of Condensed Matter Physics, CambridgeUniversity Press, 3. M. Rubinstein & R.H. Colby, Polymer Physics, Oxford University Press, P.G. de Gennes& J. Prost, 4. The Physics of Liquid Crystals, Oxford University Press, 5. M. Doi& S.F. Edwards, The Theory of Polymer Dynamics, Oxford University Press, 6. P.G. de Gennes, Scaling Concepts in Polymer Physics, Cornell University Press, 7. W.B. Russel, D.A. Saville, W.R. Schowalter, Colloidal Dispersions, Cambridge University Press, 1989

Course Code:	**PH 554**
Title:	**Computational Many Body Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Basic introduction of PHython, Scipy, Numpy, Mpi4Py, Exact Diagonalization, Tight Binding Models, Graphene, Chern Insulators, Quantum Hall effects, Lanczos and Krylov subspace methods. Kernel polynomial methods for thermodynamics quantities, Mean-field solutions, Interfacing Hamiltonian, Fock space representation, Density functional theory, Entanglement based methods. Density matrix renormalization group, Time evolving matrix product states, Introduction to Monte Carlo methods. Phase transition and Ising model, Optional: Introduction to Quantum Monte Carlo and Dynamical mean field theory.
Text/References:	1. Numerical Phython : A Practical Techniques Approach for Industry, Robert Johansson, Apress 2. Computational Physics J.M.Thijsen, Cambridge University Press (2007)

	3. Review on DMRG by Ulrich Schollwock. http://arxiv.org/abs/1008.3477 (2010) 4. The kernel polynomial method, WeiBe et.al., Rev.Mod. Phys.78.275 (2006) 5. Lecture Note by Anders W. Sandvik http://arxiv.org/abs/1101.3281v1 (2011)

Course Code:	**PH 556**
Title:	**Astrophysics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Introduction to stellarium, telescopes and multi-wavelength/multi-messenger astronomy, sizes and distances in astrophysics, astrometry, photometry The rest of the course may follow either a mix of the following topics orexplore a given topic in depth: Stellar physics: Stellar physics observables (spectra, flux), H-R diagrams and interpretation, stellar structure equations, nuclear physics and nuclear reactions in stars, lifecycle of stars, birth of stars – giant molecular clouds and Jeans criteria, main sequence stars, post-main sequence stars, white dwarfs and Chandrashekhar limit, neutron stars, black holes Galactic physics: Distance ladder in astronomy, observables in galaxies (surface brightness), galaxy classification and Hubble sequence, Faber-Jackson and Tully-Fisher relations, Dynamical mass, Dark matter in galaxies, potential theory and circular speeds, rotation curves, inferred properties of dark matter halos Cosmology: Hubble expansion, Introduction to general relativity and curved space-time, geodesics, FRW metric and Friedmann equations, solutions to Friedmann equations in different epochs, cosmological history of our universe, dark matter and dark energy, global cosmological observables and the expansion rate
Text/References:	General Astrophysics: --------------------------------------- An introduction to astronomy and astrophysics - Pankaj Jain An Introduction to Modern Astrophysics - Carroll and Ostlie Astrophysical concepts - Harwitt

	Additional References: Stellar physics: ----------------------- An introduction to stellar astrophysics - Francis LeBlanc Black holes, White dwarfs and neutron stars- Shapiro Galactic Physics: ------------------------ Galactic Astronomy - Binney and Tremaine Galactic Dynamics - Binney and Tremaine Cosmology: ---------------- Modern cosmology - Scott Dodelson The early universe- Kolb and Turner

Course Code:	**PH 562**
Title:	**Continuum Mechanics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	1) Tensors: co/contra variant tensors, contraction, Levi-civita symbols. 2) Fluid mechanics: Continuity and Euler equations, Navier-Stokes equation for viscous fluids, stokes solution in various geometries, drag, vorticity, stream lines. If times permits, surface (capillary) waves. 3) Elasticity: Stress, Strain, constitutive equation, shear, extension, torsion, bending, examples in various geometries and boundary conditions. 4) Free energy of continuum media: polymer, membrane, liquid-crystals and fluctuations (if time permits).
Text/References:	1. N.C. Rana and P.S. Jog: Classical Mechanics, Tata McGraw Hill, 1991. 2. 2. L.D. Landau and E.M. Lifshitz: Theory of Elasticity, Fluid Mechanics. 3. L.D. Landau and E.M. Lifshitz: Fluid Mechanics (both 2,3 from Pergamon Press) 4. P.M. Chaikin& T.C. Lubensky, Principles of Condensed Matter Physics: (Cambridge University Press),Paperback-1999. 5. David Rubin, Erhard Krempl, and W. Michael Lai, Introduction to Continuum Mechanics, Butterworth-Heinemann, 2009

Course Code:	**PH 564**

Title:	**Methods in Experimental Nuclear and Particle Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Passage of radiation through matter : Interaction of heavy charged particles, neutrons, gamma rays and relativistic particles. Radiation Detection: Detection mechanism, characteristics of detectors. Detectors in Nuclear Physics: gas detectors, scintillation counters, solid state detectors. Detectors in Particle Physics: Drift Chambers, spark chambers, bubble chambers, time projection chambers. Accelerators: Van de Graff, LINAC, Cyclotrons, Synchrotron, Colliders. Pulse Processing: Timing and Energy measurements, data acquisition and analysis. CAMAC and NIM Standards.
Text/References:	1. W. R. Leo, Techniques for Nuclear and Particle Physics Experiments, Springer Verlag, 1994. 2. M. S. Livingston and J.P. Blewett, Particle Accelerators, McGraw-Hill, New York, 1990. 3. Glenn F. Knoll, Radiation Detection and Measurements, John Wiley and Sons, 1989.

Course Code	**PH 566**
Title:	**Advanced Simulation Techniques in Physics**
Credits:	8
Type	T
Lecture	3
Tutorial	1
Practical	0
Description:	Basic Numerical Methods and Classical Simulations: Review of differentiation, integration (quadrature), and finding roots. Integration of ordinary differential equations. Monte Carlo simulations, applications to classical spin systems. Classical Molecular Dynamics. Quantum Simulations: Time-independent Schrodinger equation in one dimension (radial or linear equations). Scattering from a spherical potential; Born Approximation; Bound State solutions. Single particle time-dependent Schrodinger equations. Hartree-Fock Theory: restricted and unrestricted theory applied to atoms. Schrodinger equation in a basis: Matrix operations, variational properties; applications of basis functions for atomic, molecular, solid-state and nuclear calculations. Mini-projects on different fields of physics, e.g., Thermal simulations of matter using Car-Parrinello molecular dynamics; Many-Interacting-Particle Problems on Hubbard and Anderson model for electrons using Lanczos method (exact diagonalisation)

	for the lowest states; Quantum Monte Carlo methods; Computational methods for Lattice field theories; Microscopic mean-field theories (Hartree-Fock, Bogoliubov and relativistic mean-field); methods in nuclear many-body problems.
Text/References:	S. J. Chapman, Introduction to Fortran 90 and 95, Mc Graw Hill, Int. Ed.1998. S. E. Koonin and D. C. Meredith, Computational Physics, Addison-Wesley,1990. Tao Pang, An Introduction to Computational Physics, Cambridge Univ Press,1997. R. H. Landau and M. J. P. Mejia, Computational Physics, John Wiley, 1997. J. M. Thijssen, Computational Physics, Cambridge Univ Press, 1999. K. H. Hoffmann and M. Schreiber, Computational Physics, Springer, 1996.

Course Code:	**PH 572**
Title:	**Special Topics in Elementary Particle Physics**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Renormalisation in QED. Ward-Takahashi Identities. Functional methods, effective action, expansion in fields and derivatives. Renormalisation Group. Wilson interpretation of RG. Non-abelian gauge theories. Fadde'ev-Popov method of quantization. BRST symmetry and renormalisation. Chiral fermions and anomalies. Optional material: Poincare group and classification of space-time fields by mass and spin or helicity. Systematic renormalisation of phi4 theory.
Text/References:	1. P. Ramond, Field Theory: A Modern Primer 2nd Ed. 2. W. Greiner and J. Reinhardt, Field quantization. 3. W. Greiner and J. Reinhardt, Quantum Electrodynamics. 4. M. Peskin and D. V. Schroder, Quantum Field Theory 5. S. Weinberg, Quantum Theory of Fields vol.s I and II 6. V. Parameswaran Nair, Quantum Field Theory: A modern perspective, Springer 2005

Course Name	**Physics of Semiconductor Devices**
Course code	**PH 574**
Total Credits	6
Type	T
Lecture	2
Tutorial	1

Practical	0
Description	**Basics of Semiconductors:** Brief review of Band structure. Band diagram of few important semiconductors: Si, Ge, GaAs, GaN, constant energy surface, density of states, effective mass, different directions in the Brillouin zone and their common names. Direct and indirect gaps. **Doping**: Hydrogenic impurity model in detail (show how to construct impurity wave function using the band wave functions as the basis.) shallow and deep donors, Probability of Ionisation of a dopant (Saha ionization equation) Fermi level, Intrinsic, extrinsic and compensated semiconductors, carrier statistics, carrier density product $np = n_i^2$ [How does one experimentally measure donor level positions?] **Boltzmann transport equation,** Mobility, drift, diffusion, electrochemical potential and its difference with electrostatic potential. Discuss clearly the questions like what does a voltmeter actually measure. **Band-bending and band discontinuity at the interface:** Poisson-Boltzmann formulation: Metal-semiconductor junctions, Schottky and Ohmic contacts, p-n junction, derivation of forward and reverse bias I-V equation, tunnel diodes (NDR region and its use in oscillator circuits), Gunn effect, p-i-n structures. BJTs (with band diagrams under bias), Triac/SCR, Metal-insulator-semiconductor (MIS) structures. **Field effect devices:** JFET, MOSFET Band diagram, operation regimes, principle of operation of MOSFETs, Basic derivation of the inversion voltage (use Poisson-Boltzmann). current-voltage and capacitance-voltage characteristics of MOSFET, Source-Drain/Transfer characteristics of MOSFET, comparison with BJT's $I_C - V_{CE}$ curves. **Band engineering:** Poisson Schrodinger equation, the envelope function approximation, alloying, strain and polarization charges at interfaces, Modulation doping, Single heterojunction, Quantum wells. Explain why modulation doping gives higher mobility. HEMT devices (GaAs-AlGaAs, GaN-AlGaN) Formation of the 2DEG at the interface, compare with MOSFETs. **Optoelectronic devices:** Carrier statistics under illumination condition, Generation and Recombination of Carriers, Quasi-Fermi levels, photovoltaic Effect, working of Solar Cells, Current-Voltage characteristics. Shockley-Quessar limit. **Light emitting diodes** (LED), Internal Quantum Efficiency, External Quantum Efficiency, How to improve quantum efficiency of LEDs, Laser-diodes.

Text Reference	(i) Solid State Electronic Devices - B. G. Streetman and S. K. Banerjee, Boston : Pearson, 7th edition, 2015 (ii) Physics of Semiconductor Devices -S.M. Sze and K. K. Ng, Wiley- Interscience, 3rd edition, 2006. (iii) Semiconductor Physics: An Introduction -K. Seeger, Springer-Verlag, Berlin, 9th edition, 2004. (iv)Physics of semiconductor devices – M. Shur, Prentice/Hall International, 1990 (v) The Physics of Low-dimensional Semiconductors: An Introduction- J. M. Davies, Cambridge University Press, 1997

Course Code	**PH 576**
Title:	**Nanoscale Quantum Transport**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Type	T
Description:	**Preliminary concepts:** Fundamental length scales (De Broglie wavelength, Mean Free Path, Coherence Length, Thermal Diffusion Length) and classification of transport regimes, Resistance (in d-dimension) in the bulk and mesoscopic limits. Energy levels, wave functions, and DOS in quantum wells (both square and triangular), quantum wires, and quantum dots. (Optional: Coupling between quantum wells and superlattices); Revision of Bloch wavefunction and effective mass tensor. Band-structures of GaAs and Si, concept of valleys, longitudinal and transverse effective masses, the band-gap lattice parameter diagram, the concept of heterojunctions and different band alignments. Envelope function and effective mass approximation for heterostructures. **Quantum nano/heterostructures in the real world:** Quantization in (doped) heterojunction systems, the GaAs-AlGaAs heterojunction and the 2D electron gas (with comparison to fictitious quantum well discussed earlier). The double barrier structure and resonant tunneling diode. From 2DEG to quantum wires, quantum point contacts, quantum wires, and quantum dots in the real world (qualitative description of gated 2DEG based devices). **Semi-classical transport and scattering mechanisms:** Brief review of semi-classical transport (Boltzmann Transport Equation). Coulomb, Surface roughness, and Lattice scattering, Carrier mobilities in 2DEGs. **Ballistic Transport: Landauer and Landauer-Buettiker formalisms:** Current in resonant tunneling diodes (coherent and sequential tunneling), Landauer

	formula, introduction to the multi-channel case, generalized multi-channel case and Landauer-Buettiker formalism, specific examples (2-probe, 3-probe, and 4-probe cases). **Ballistic transport in quantum wires:** Conductance quantization in QPCs, Adiabatic transport model, Bias spectroscopy of QPCs. **Low dimensional Quantum heterostructures in magnetic field:** Quantum Hall effects, QPC in magnetic field, 0.7 feature in QPCs. **Quantum dots, Coulomb blockade, and Single Electron Transistors:** Solving for the (Fock-Darwin) eigenstates, Coulomb Blockade and fundamentals of single electron tunneling, Orthodox theory of single electron tunneling (Transfer Hamiltonian Formalism), Stability diagrams of double quantum dots (quantum dot molecules).
Text/References:	(i) Transport in Nanostructures - David K. Ferry, Stephen Goodnick, Jonathan Bird, Cambridge University Press 2009) (ii) Quantum Heterostructures: Microelectronics and Optoelectronics - Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Cambridge University Press 1999 (iii) Electronic Transport in Mesoscopic Systems - Supriyo Dutta, Cambridge University Press 1995 (iv) Quantum Transport - Introduction to Nanoscience, Y. V. Nazarov, Y. M. Blanter, Cambridge University Press 2009 (v) The Physics of Low-dimensional Semiconductors: An Introduction - John M. Davies, Cambridge University Press, 1997

Course Code	**PH 578**
Title:	**Nanodevices and Applications**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	1) Nano sensors, nano-pressure, nanopiezeo sensors, plasmonic nanosensors, nano for gas sensors & Nano actuators, with particular emphasis on biomaterial based devices, Field effect transistor based biosensors (bio-FETs) 2) Novel batteries: Li, Na, and other materials based batteries 3) Memory devices: DVD Roms, magnetic, solid state, memristors, and other modern proposals 4) Nano and Microfluidic devices: To learn the basic behaviour of liquid in

	micro or nanosystems. Emphasize on interaction of fundamental mechanism and desing of microfluidic devices. Application is Lab on a chip state of art, analyse it. Theory of micro and nanofluidics, equation of change, flow at microscale, diffusion and microscale mixing, circuit analysis, Stokes flow electrostatics and electrodynamics, electrical double layer, zeta potential, species and charge transport, electro-osmosis and electrophoresis, AC field in microsystem, hyrdodymanics, surfactant/suspension and separation, technological production of components, mixure, pumps, and fabrication of lab-on-chip 5) Quantum Computing Hardware: Quantum Information Processing - Q-bits: Charge bits and Spin bits - Quantum Computing devices, quantum communication devices. Josephson Junction based quantum computing: charge, flux, and phase qubits. Building large Quantum Computers, Fabrication, testing architectural challenges, Quantum dot cellular automata (QCA) – computing with QCA
Text/References:	**Books on Nanosensors:** (i) Introduction to Biosensors From Electric Circuits to immunosensors, Yoon, Jeong-Yeol (Springer 2016). (ii) (ii) Biosensors: A Practical Approach, A. E. G. Cass IRL Press at Oxford University Press, 1990. (iii) Molecular Sensors and Nanodevices; Principles; Designs and Applications in Biomedical Engineering; JXJ Zhang, K Hoshino, Elsevier; 2014. (iv) Nanofabrication Towards Biomedical Applications, Challa Kumar, Wiley-VCH, 2016 (v) MEMS and Nanotechnology-Based Sensors and Devices for Communications, A R Jha- Medical and Aerospace Applications 1st Edition CRC Press 2019, (vi) Nanotechnology and Biosensors, Dimitrios P Nikolelis, Georgia Paraskevi Nikoleli (Elsevier 2018) **Books on Batteries:** (i) Introduction To Nanotechnology, Poole and Owens – John Wiley and Sons 2003 Nanomaterials for Electrochemical Energy Storage Devices; Poulomi Roy, S. K. Srivastava- Wiley-Scrivener 2019 (ii) Modern Battery Engineering: A Comprehensive Introduction by Kai

	Peter Birke, World Scientific; Illustrated edition (2019) (iii) Modern Batteries, 2nd Edition, by C. Vincent and Bruno Scrosati- Paperback ISBN: 9780340662786 eBook ISBN: 9780080536699 Imprint: Butterworth-Heinemann 1997 **Books on Memory Devices:** (i) Nanomaterials-Based Charge Trapping Memory Devices By Ammar Nayfeh, Nazek El-Atab (Elsevier 2020) (ii) Phase Change Memory Device Physics, Reliability and Applications - Editors: Pigozzo, Andrea (Ed.), Springer 2018 (iii) Advances in Non-volatile Memory and Storage Technology, 1st Edition, Editor: Yoshio Nishi. Hardcover ISBN: 9780857098030, eBook ISBN: 9780857098092, Imprint: Woodhead Publishing 2014 (iv) Advances in Memristors, Memristive Devices and Systems, Vaidyanathan, Sundarapandian, Volos, Christos (Eds.), Springer 2017 **Books on MicroFluidics:** (i) Micro- and Nanoscale Fluid Mechanics for Engineers: Transport in Microfluidic Devices By Brian J. Kirby. 2009, http://kirbyresearch.com/textbook (ii) Probstein, R.F. Physicochemical Hydrodynamics, 2nd Ed., Wiley, 1994 (iii) Tabeling, P. Introduction to Microfluidics, Oxford, 2005. (iv) Bruss, H. Theoretical Microfluidics, Oxford, 2008. (v) Nguyen, N-T and Wereley, S "Fundamentals and Applications of Microfluidics", 2nd Edition, Artech House, ISBN: 1580539726 (vi) Berthier J. and Silberzan, P. Microfluidics for Biotechnology. Artech HousePublishers. ISBN: 1-58053-961-0. (2010) **Books on Quantum Computing:** (i) Quantum Computation and Quantum Information 10th Anniversary Edition Hardcover – 9 December 2010 by Michael A. Nielsen and Isaac L. Chuang. (ii) Quantum Computer Systems: Research for Noisy Intermediate-Scale Quantum Computers, Synthesis Lectures on Computer Architecture (2020) by Yongshan Ding and Fred Chong, published by Morgan Claypool, DOI: 10.2200/S01014ED1V01Y202005CAC051

Course Code	**PH 580**
Title:	**Magnetism and Superconductivity**
Credits:	6

Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Magnetism: Classification of magnetic materials; localized and itinerant magnetism; various types of exchange interactions- direct, super, RKKY and DM; magneto-crystalline anisotropy energy; shape anisotropy; domains, domain walls and magnetization process; magnetism in thin films and fine particles; basics of spin dependent scattering/spin-polarized transport; magneto-transport effects such as CMR, AMR, GMR, TMR; basics of magnetic recording, Hall effect, essentials of spintronics and spintronic devices; basic ideas of de Haas- van Alphen effect and quantum Hall effect. Superconductivity: Overview; types of superconductors; electrodynamics and thermodynamics of superconductors; Elements of Ginzburg-Landau theory and BCS theory; Fluxoid quantisation; Giaever tunnelling; Josephson tunnelling; principle of quantum interference; applications of superconductivity; SQUID, recent discoveries on high temperature superconductors.
Text/References:	1. Magnetism in Condensed Matter - Stephen Blundell, Oxford Master Series 2001 2. Magnetism and Magnetic Materials – J M D Coey, Cambridge University Press 2012 3. Physics of Ferromagnetism - S. Chikazumi, Oxford University Press 1997 4. Introduction to Spintronics - S. Bandyopadhya and M. Cahay, CRC press 2020 5. Introduction to Solid State Physics - C Kiitel, , 7th ed, John Wiley 2005 6. Superconductivity, Superfluids and Condensates - J F Annet, Oxford Master Series 2004 7. Superconductivity - C Poole, H Farach and R Creswick, R Prozorov , Elsevier 2014

Course Code	**PH 601 (needs PH 534 as the pre-requisite)**
Title:	**Advanced Quantum Information and Computation**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Module 1: Computational Complexity & Models of Quantum Computing (20% lectures) Classical and quantum complexity: P, NP, NP-Complete and PSPACE in

	comparison to BQP. Grover does not change complexity. Models such as measurement based QC, topological QC. Module 2: Communication and Cryptography (30% lectures) classical Shannon theory, noisy quantum states, channel and source coding, channel capacity, connection to error correction, BB-84 and Eckert, post quantum cryptography. Module 3: Error Correction (20% lectures) Error Correction: Classical error correction, bit and phase flip errors, Steane and shor code, stabilizers and graph states, Gottesman-Knill Theorem and implications. Module 4: Physical Systems and Simulations (30% lectures) One or few physical implementations (such as circuit-based QC, adiabatic QC, ion traps, linear optics, superconducting qubits.). Schmidt rank, MPS and classical simulation of quantum states, quantum simulations.
Text/References:	[1] Nielsen, Michael A., and Isaac L. Chuang. "Quantum Computation and Quantum Information (Cambridge University Press, Cambridge, 2000)."302240URL https://doi. org/10.1017/CBO9780511976667. [2] Nakahara, Mikio.302240Quantum computing: from linear algebra to physical realizations. CRC press, 2008. [3] Preskill, John. "Lecture notes for physics 229: Quantum information and computation."302240California Institute of Technology30224016, no. 1 (1998): 1-8. [4] Wilde, Mark M.302240Quantum information theory. Cambridge University Press, 2013. [5] Hayashi, Masahito, Satoshi Ishizaka, Akinori Kawachi, Gen Kimura, and Tomohiro Ogawa.302240Introduction to quantum information science. Springer, 2014. [6] Breuer, Heinz-Peter, and Francesco Petruccione.302240The theory of open quantum systems. Oxford University Press on Demand, 2002. [7] Bengtsson, Ingemar, and Karol Życzkowski.302240Geometry of quantum states: an introduction to quantum entanglement. Cambridge university press, 2017. [8] Wolf, Michael M. "Quantum channels & operations: Guided tour."302240Lecture notes available at http://www-m5. ma. tum. de/foswiki/pub M3022405 (2).

Course Name	**Relativistic Cosmology**
Course Code:	**PH 818**
Credits:	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description:	Expansion of the Universe, Friedman-Robertson-Walker-Lemaitre model, Geodesics and Distance, geodesic deviation, Standard candles, and Standard Rulers. Standard cosmological model: radiation dominated era, matter

	domination, dark energy, and accelerated expansion. Horizon problem, flatness problem. Inflationary paradigm. Thermal history of the universe, primordial nucleosynthesis, decoupling of neutrinos, weakly interacting massive particles, electron-positron annihilation, matter radiation decoupling, last scattering surface, cosmic microwave background radiation. Scalar fields in an expanding universe. Generation of perturbations in inflation, Tensor, and Scalar perturbations, Reheating Non-linear collapse, Press-Schechter formalism, Matter power spectra observations, galaxy correlation functions and bias, Lyman alpha, 21 cm observations, weak lensing, x-ray surveys, Baryon Acoustic oscillations Fluctuations in the cosmic microwave background radiation. Transfer Functions, Polarization power spectra, E-modes and B-modes. Sachs-Wolfe and Integrated Sachs Wolfe effect, Silk damping, The observed fluctuations in the cosmic microwave background radiation and its relation with Cosmological Parameters, Observational constraints. Perturbations in an expanding universe. Relativistic perturbation theory, growth of perturbations in different scenarios. Fluctuations in the cosmic microwave background radiation. Transfer Functions, Baryon Acoustic oscillations Late time perturbations and measurements of the Hubble parameter - Type Ia supernovae, Baryon acoustic oscillations, Strong lensing, Gravitational wave measurements. Geometric effects, redshift space distortions.
Text/References:	1.S. Weinberg, Cosmology, Oxford University Press, 2008 2. Ruth Durrer, The cosmic microwave background, Cambridge University Press, 2008. 3.T. Padmanabhan, Theoretical Astrophysics, Vol.III: Galaxies and Cosmology, Cambridge University Press, 2002. 4. Scott Dodelson, Modern Cosmolog, Reed Elsevier (2020).