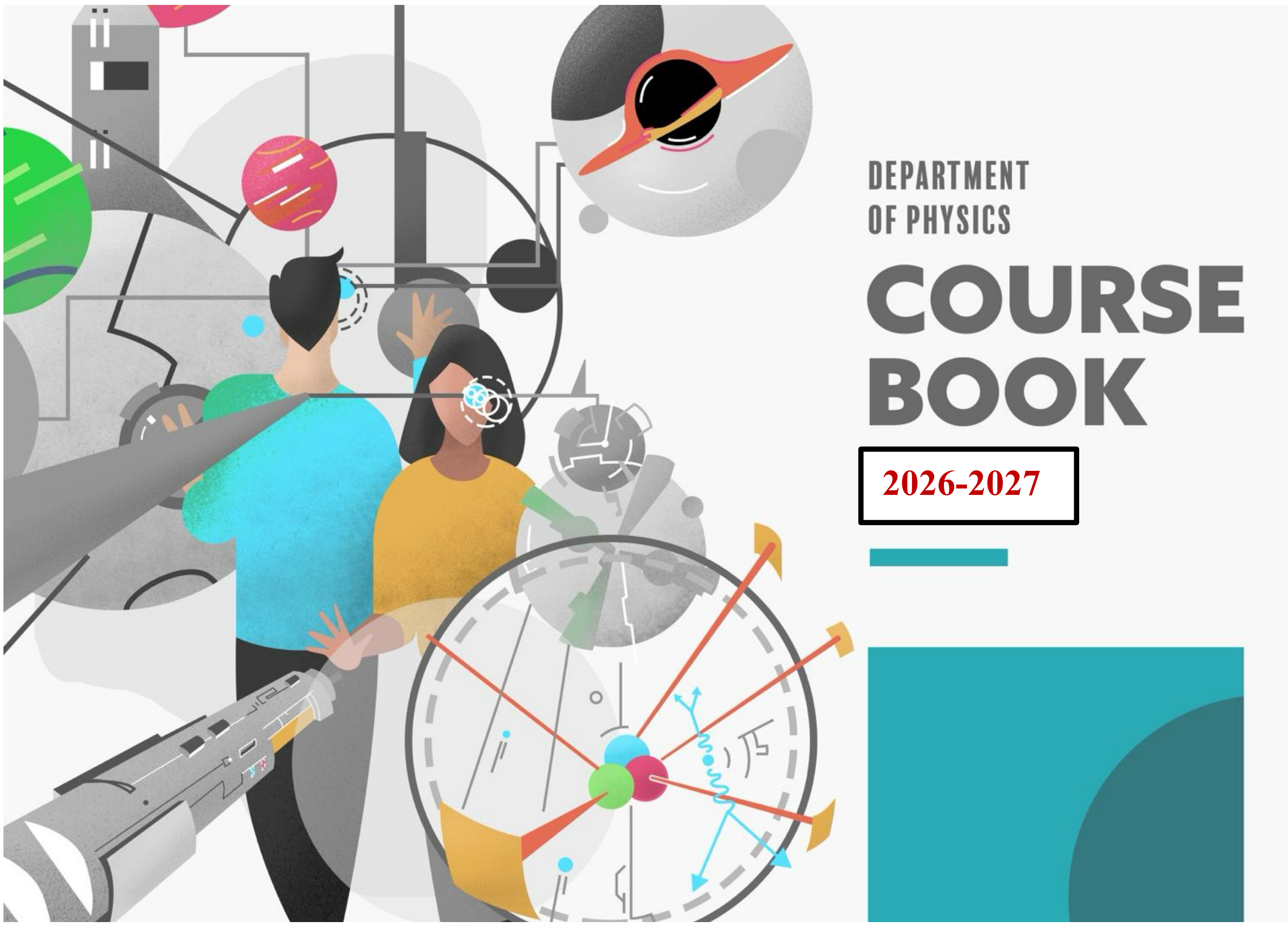
iit bombay
हीरक जयंती २०१८
Diamond Jubilee 2018
एक साथ प्रगति की ओर
Achieving Excellence Together



INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
भारतीय प्रौद्योगिकी संस्थान मुंबई
ज्ञानम् परमम् ध्येयम्

July 2026

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,

Subhabrata Dhar

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

List of Faculty Advisors			
B.Tech. (2022)	Siddhartha Santra	M. Sc. (2025)	Rahul Kashyap M. Maniraj
B.Tech. (2023)	Sumiran Pujari	M.Sc. (2026)	Subhaskar Mandal Debojit Sarkar
B.Tech. (2024)	Amitabha Nandi	Ph.D. (2026)	Raghunath Chelakkot
B.Tech. (2025)	Sayantika Bhowal Uditendu Mukhopadhyay		
B.Tech. (2026)	Prashant Kumar Manibrata Sen		

Minimum Credits required	
Degree	**Credits**
B. Tech. Engineering Physics	265
B. Tech. Engineering Physics (with Honours)	265 + 24 = 289 (4 years)
Minor - Engineering Physics	30
B. Tech.-M.Tech. Dual Degree*	265 + 126 = 391 (Nanoscience) 265 + 120 = 385 (Quantum technologies) (5 years)
B. Tech.-M.Sc. Dual Degree**	265 + 96 = 361 (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.) including PMRFs 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), GC 101 Gender in Work place (Pass/No Pass), TA 101 Teaching Assistant Skill Enhancement & Training (Pass/No Pass) and a 4 credit Seminar are compulsory for all. Seminar course can be taken in the first or second semester.

*subject to the interest by a B.Tech. student AND the approval of the Department (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 Department (minimum CPI required = 8.0 at the end of the third year)

***Subject to the interest by a B. Tech. student AND the approval of the Department (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 Department (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.
2. 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.
3. Support and Outreach:
    a) 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).
    b) We conduct help sessions for the students, based on feedback from the class and the instructor, especially before the major exams.
    c) 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)

2023 BATCH ONWARDS

CURRICULUM FOR B.TECH IN ENGINEERING PHYSICS				
Year/ Sem	**Course code**	**Course Title**	**Category**	**Credits**
Year I Sem I	BB 101	Biology	Basic Sciences and Mathematics	2-1-0-6
	MS 101	Makerspace	Engineering Sciences and Skills	8
	MA 105	Calculus	Basic Sciences and Mathematics	3-1-0-8
	PH 109	Fundamental Themes in Physics (DIC 1)	Department 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
Year I Sem II	CS 101	Computer programming	Engineering Sciences and skills	2-1-0-6
	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	0
				Total credits: 33
Year II Sem I	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 sem.)
	PH 114	Thermal Physics (DIC-2, Part-II)	Department Core	2-1-0-3 (half sem.)
	PH 217	Classical Mechanics	Department Core	2-1-0-6
	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	Course Title	Category	Credits
Year II Sem II	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 III Sem I	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
	PH 446	Solid State Physics + Nuclear Physics Lab	Department Lab (Core)	0-1-3-3
		HASMED Elective 1	HASMED Elective	2-1-0-6
		Honours/DDP course	Department Elective	2-1-0-6
				Total credits: 35 (excl. Honours)
Year III Sem II	PH 314	Molecular Spectroscopy and Optical Physics	Department Core	3-1-0-8
	PH 447	Optics + Spectroscopy Lab	Department Lab (Core)	0-0-3-3
		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 I or Equivalent Elective	BTP/ Department Elective	2-1-0-6
		Honours/DDP course	Department Elective	2-1-0-6
				Total credits: 35 (excl. Honours)

Year/ Sem	Course code	Course Title	Category	Credits
Year IV Sem I		BTP II or Equivalent Elective	BTP/Department/ STEM Elective	2-1-0-6
		Department Elective 2	Department 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
		Honours/DDP course	Department/DD Elective	2-1-0-6
				Total credits: 30 (excl. Honours)
Year IV Sem II		BTP III or Equivalent Elective	BTP/Department/ STEM 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
		Honours/DDP course	Department/DD Elective	2-1-0-6
				Total credits: 30 (excl. Honours)
ONLY FOR B.TECH - M.TECH DUAL DEGREE IN NANOSCIENCE (NS)				
Year V Sem I	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
Year V Sem II	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 B. Tech - M.Tech DD (NS) students need to take 4 Electives of their choice plus Supervised Learning Project (SLP) of 6 credits each for a total of (42+54+30) = 126 credits.

Total credits (minimum) for 4 Year B. Tech. = 265
Total credits (minimum) for 5 Year B. Tech-M.Tech. DDP (NS) = 265 + 126

ONLY FOR B.TECH - M.TECH DUAL DEGREE IN QUANTUM TECHNOLOGIES (QT)				
Year V Sem I	PH 534	Quantum Computation and Information-I	Core Subject for DD in QT	2-1-0-6
	PH XXX	Dual degree project I (DDP I)	Core for DD in QT	36
				Total credits: 42
Year V Sem II	EE 801 PH 576 EE 755	Introduction to Quantum Engineering, or Nanoscale Quantum Transport, or Quantum Transport in Nanoscale Devices.	Core Subject for DD in QT (any one)	2-1-0-6
	PH XXX	Dual degree project II (DDP II)	Core for DD in QT	36
				Total credits: 42

In addition, the B. Tech - M. Tech DD (QT) students need to take 6 Electives of their choice from the special basket of 6 credit courses for a total of (42+42+36) = 120 credits.

The pre-requisites needed for the B. Tech - M. Tech DD (QT) are the following courses:

a) Quantum Mechanics (PH204 or PH403)

b) One of the following courses: Electronic Devices and Circuits (EE207), Digital Electronics (EE221), Digital Systems (EE224), Signal Processing I (EE229), Design and Analysis of Algorithms (CS218), Data Structures and Algorithms (CS213), Discrete Structures (CS105), Introduction to Condensed Matter Physics (PH436), Electronic Devices and Characterization (PH207), Electronic properties of materials (MM318).

Total credits (minimum) for 5 Year B. Tech-M.Tech. DDP (QT) = 265 + 120

ONLY FOR B.TECH - M. Sc. DUAL DEGREE STUDENTS (effective from July 2026)				
Year V Sem I		Mandatory/Elective	Special Basket	2-1-0-6
	PH XXX	Dual degree MSc. project I	Department Core for DD	36
				Total credits: 42
Year V Sem II		Mandatory/Elective	Special Basket	2-1-0-6
	PH XXX	Dual degree MSc. project II	Department Core for DD	36
				Total credits: 42

In addition, the B. Tech – M.Sc. DD students need to take 2 Mandatory/Elective courses in Year IV of B.Tech. of 6 credits from the Special Basket for a total of (42+42+12) = 96 credits.

Total credits (minimum) for 5 Year B. Tech-M.Sc. DDP = 265 + 96

ONLY FOR 5-YEAR INTEGRATED M. Sc. STUDENTS				
Year V Sem I		Department Elective 1	Department Elective	2-1-0-6
		Department Elective 2	Department Elective	2-1-0-6
	PH 593	M.Sc. Project I	MSP	30
				Total credits: 42
Year V Sem II		Department Elective 3	Department Elective	2-1-0-6
		Department Elective 4	Department Elective	2-1-0-6
	PH 594	M.Sc. Project II	MSP	30
				Total credits: 42

In addition, the 5-Year Integrated M.Sc. students need to take 2 Elective courses in Year IV of B.Tech. of 6 credits for a total of (42+42+12) = 96 credits.

Total credits (minimum) for 5 Year Integrated M.Sc. = 265 + 96

Rules for clearing backlogs

1. Summer courses

A student can take up to a **maximum of 24 credits** of Mandatory Courses (Core + HSS + Department & Institute Electives) in which s/he has received FR/DX/DR/W grade. However, if a student accumulates two (or more) "FR" in Mandatory Courses and does not find enough courses (totalling up to 24 credits) in a summer term, s/he can take a maximum of two Mandatory Courses in which s/he has NEVER registered.

2. Self-study

Students can take up to **two courses** as self-study, **after the expiry** of the regular programme duration (4 years for B.Tech., 5 years for Dual Degree) after taking necessary approval. This option is only available for completing the mandatory credits.

3. NPTEL/SWAYAM courses

A student can take **maximum of 12 credits** of NPTEL/SWAYAM courses in lieu of departmental elective and Institute elective courses for the regular student (not under ARP), and, (b) a maximum of 24 credits of NPTEL/SWAYAM courses in lieu of any courses including core courses for the students, who are under ARP or in extension years after the approval from DUGC of the department towards the partial completion of mandatory academic curriculum. b) A student can take NPTEL/SWAYAM courses as 'Additional Learning' for UG students subject to not exceeding credit limit based on approval of DUGC.

12 Weeks NPTEL/SWAYAM courses would be typically considered equivalent to 6 credits at IIT Bombay. However, in some special cases, DUGC/DPGC/UGC/PGC may consider and approve 12 weeks NPTEL/SWAYAM course(s) equivalent to 8 credits at IIT Bombay. b) 8 Weeks NPTEL/SWAYAM courses would be considered equivalent to 4 or 3 credits at IIT Bombay, depending on approval of DUGC/DPGC.

Course(s) completed by student(s) outside IIT Bombay by means of NPTEL and / or SWAYAM and/ or Semester Exchange, following due approval of DUGC/ DPGC, will contribute only towards completion of credits. Grade(s) earned in such courses will not be considered for SPI/CPI calculation.

B.Tech./M.Tech./Int. M.Sc. Course Basket

Honours (6 credits)			
Course code	**Title**	**Course code**	**Title**
PH 303	Supervised Learning	PH 557	Theoretical Condensed matter physics
PH 523	Quantum Mechanics III	PH 544	General Theory of Relativity
PH 534	Quantum Information and Computing	PH 554	Computational Many Body Physics
PH 563	Group Theory Methods in physics	PH 564	Methods in Exp. Nuclear and Particle Physics
PH 565	Semiconductor Physics	PH 580	Magnetism and Superconductivity
PH 567	Nonlinear Dynamics	PH 587	B.Tech. Project I
PH 562	Continuum Mechanics	PH 588	B.Tech. Project II
PH 540	Elementary Particle Physics	PH 589	B.Tech. Project III

B. Tech. Electives for Odd/Autumn Semester (6 credits)			
Course code	**Title**	**Course code**	**Title**
PH 505	Introduction to Nuclear and Particle Physics	PH 563	Group Theory Methods in Physics
PH 515	Introduction to Atomic and Molecular Physics	PH 565	Semiconductor Physics
PH 517	Methods in Analytical Techniques	PH 567	Nonlinear Dynamics
PH 523	Quantum Mechanics III	PH 569	Applied Solid State Physics
PH 534	Quantum Information and Computing	PH 571	Experimental Techniques in Soft Matter Physics (5 credits)
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 556	Astrophysics	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 821	Gravitational Wave Physics and Astronomy

B. Tech. Electives for Even/Spring Semester (6 credits)			
Course code	**Title**	**Course code**	**Title**
PH 500	Thin film Physics and Technology	PH 564	Methods in Experimental Nuclear and Particle Physics
PH 530	Light Matter Interaction	PH 566	Advanced Simulation Techniques in Physics
PH 540	Elementary Particle Physics	PH 572	Special Topics in Elementary Particle Physics
PH 544	General Theory of Relativity	PH574	Physics of Semiconductor Devices
PH 546	Quantum Optics	PH 576	Nanoscale Quantum Transport
PH 550	Soft Matter Physics	PH 578	Nanodevices and Applications
PH 554	Computational Many Body Physics	PH 580	Magnetism and Superconductivity
PH 562	Continuum Mechanics	PH 582	Geometry and Topology in Quantum Matter
PH 819	Advanced Astrophysics	PH 601	Advanced Quantum Information and Computation
		PH 818	Relativistic Cosmology

B.Tech. - M.Sc. Dual Degree Special Basket			
Odd/Autumn Semester		**Even/Spring Semester**	
Course code	**Title**	**Course code**	**Title**
Mandatory			
PH 505	Introduction to Nuclear and Particle Physics	PH 510	Electromagnetic Theory II
Electives			
PH 523	Quantum Mechanics III	PH 544	General Theory of Relativity
PH 543	Advanced Statistical Mechanics	PH 554	Computational Many Body Physics
PH 534	Quantum Information and Computing	PH 563	Continuum mechanics
PH 817	Special Topics in QFT and Beyond the Standard Model	PH 815	Standard Model of Particle Physics
PH 561	Ultrafast Sciences	PH 582	Geometry and Topology in Quant Matter

B.Tech. - M. Tech Dual Degree in Quantum Technologies Special Basket			
Odd/Autumn Semester		**Even/Spring Semester**	
Course code	**Title**	**Course code**	**Title**
Mandatory			
PH 534	Quantum Information and Computing	**(Any one)**	
		EE 801	Introduction to Quantum Engineering
		PH 576	Nanoscale Quantum Transport
		EE 755	Quantum Transport in Nanoscale Devices
Electives			
PH 557	Theoretical Condensed Matter	PH 601	Quantum Computation and Information-II
EE 236	Electronic Devices Laboratory	PH 546	Quantum Optics
EE 751	Nano-magnetism and Spintronics	PH 530	Light Matter Interaction
EE 787	Topological electronics	PH 576	Nanoscale Quantum Transport*
		EE 784	2D Materials and Devices
		EE 755	Quantum Transport in Nanoscale Devices*
		EE 801	Introduction to Quantum Engineering*

* Provided the electives were not taken as mandatory

B.Tech. Engineering Physics – Minor (6 credits)			
Course code	**Title**	**Course code**	**Title**
PH 251	Classical Mechanics	PH 352	Introduction to Condensed Matter Physics*
PH 252	Introduction to Quantum Mechanics	PH 353	Light Matter Interaction*
PH 253	Thermal and Statistical Physics		

For the award of minor, a student should take 5 courses, completing 30 credits.

* These two courses can be replaced with courses from the Department elective. The other three (PH 251, PH 252 and PH 253) are mandatory.

List of pre-requisites for different courses for B.Tech. students			
Course Number	**Course Title**	**Prerequisite(s)**	**Class strength**
PH 225	Quantum Mechanics I	PH 110 (EP: Intro to Classical and Quantum Physics) A student will not be allowed to enrol for both PH 225 and PH 252 (QM Minor) over the course of their BTech programme	100
PH 216	Statistical Physics	PH 110 (EP: Intro to Classical and Quantum Physics) PH 114 (EP: DIC-II Thermal Physics) PH 217/ PH 251 (EP: Classical Mechanics/Classical Mechanics Minor) A student will not be allowed to enrol for both PH 216 and PH 253 (Therm. & Stat. Physics Minor) over the course of their BTech programme	--
PH 217	Classical Mechanics	PH 110 (EP: Intro to Classical and Quantum Physics	--
PH222	Digital Electronics and Microprocessors	--	70
PH221	Analog Electronics	--	70
PH 418	Intro. to Condensed Matter Physics	PH 225/PH 403 (EP/MSc: Quantum Mechanics I)	--
PH 436	Intro. to Condensed Matter Physics	PH 225/PH 403 (EP/MSc: Quantum Mechanics I)	--
PH 435	Electronics Lab (MSc Physics)	--	70
PH 554	Computational Many Body Physics	PH 225/PH 403 (EP/MSc: Quantum Mechanics I) PH 418/PH 436 (EP/MSc: Intro. CM Physics) PH 216/PH 410 (EP/MSc: Statistical Physics)	--
PH 578	Nanodevices and applications	Previous exposure to Condensed Matter Physics and Quantum Mechanics (PH 110) is recommended.	--
PH 575	Nanoscience – Fund. to fabrication	Previous exposure to Condensed Matter Physics and Quantum Mechanics (PH 110) is recommended.	--
PH 574	Phys. of Semiconductor Devices	PH 225/PH 403 (EP/MSc: Quantum Mechanics I) PH 418/PH 436 (EP/MSc: Intro. CM Physics)	--
PH 309	Quantum Mechanics II	PH 225/PH 403 (EP/MSc: Quantum Mechanics I)	80
PH 544	General Theory of Relativity	PH 110 (EP: Intro to Classical and Quantum Physics	50
PH 312	Electromagnetic Theory	--	80
All courses can be approved by the instructor by relaxing the pre-requisites or if suitable alternatives are determined.			

M. Sc.

(PHYSICS)

CURRICULUM FOR M.Sc. IN PHYSICS			
Year/ Sem	**Course code**	**Course Title**	**Credits**
Year I Sem I	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 I Sem II	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 II Sem I	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 or	0-0-3-6
		Departmental Elective	2-1-0-6
		Departmental Elective I	2-1-0-6
		Departmental Elective II	2-1-0-6
			Total credits: 36
Year/ Sem	**Course code**	**Course Title**	**Credits**
Year II Sem II	PH 510	Electromagnetic Theory II	2-1-0-6
	PH 530	Light Matter Interaction	2-1-0-6
	PH 527	Physics Lab (Solid State and Nuclear Physics)	0-0-3-6
	PH 596	M.Sc. Project stage II or	0-0-3-6
		Departmental Elective	2-1-0-6
		Departmental Elective III	2-1-0-6
		Departmental Elective IV	2-1-0-6
			Total credits: 36

Total credits (minimum) for 2 Year M. Sc. = 145

ONLY FOR M. Sc.- Ph.D. STUDENTS			
Year III Sem I	PH 555	M.Sc. Project stage III	24
		Extra elective 1	2-1-0-6
		Extra elective 2	2-1-0-6
			Total credits: 36
Year III Sem II	PH 899	Communications skills	P/NP

MSc students can take only one institute elective in STEM over the entire duration. No projects, supervised learning or non-STEM courses from other Departments are allowed.

Total credits (minimum) for M. Sc.- Ph.D. = 145 + 36

Rules for clearing backlogs

1. Masters students may be allowed to register for courses in the summer semester only as "Additional Learning". Such courses cannot be re-tagged as "Elective", even later on.

2. Students from the graduating batch are allowed to register for summer courses ONLY to complete any courses from their mandatory curriculum in which they have an active backlog.

3. Self-study option is not there for M.Sc. students.

4. A student can take maximum of 12 credits of NPTEL/SWAYAM courses in lieu of Departmental/Institute Elective courses. Students who are on ARP or academic probation can take these in lieu of core courses. Regular students (who are not in ARP) can also take NPTEL/SWAYAM courses as "Additional Learning". Both cases above are allowed only on approval from DPGC.

   Course(s) completed by student(s) outside IIT Bombay by means of NPTEL and/or SWAYAM and/or Semester Exchange, following due approval of DPGC, will contribute only towards completion of credits. Grade(s) earned in such courses will not be considered for SPI/CPI calculation. These students shall be eligible for the award of Medals and Prizes.

   12 Weeks NPTEL/SWAYAM courses would be typically considered equivalent to 6 credits at IIT Bombay. However, in some special cases, DPGC may consider and approve 12 weeks NPTEL/SWAYAM course(s) equivalent to 8 credits at IIT Bombay. 8 Weeks NPTEL/SWAYAM courses would be considered equivalent to 4 or 3 credits at IIT Bombay, depending on approval of DPGC.

M.Sc. Course Basket

Electives for Odd/Autumn Semester (6 credits)			
Course code	**Title**	**Course code**	**Title**
PH 517	Methods in Analytical Techniques	PH 565	Semiconductor Physics
PH 523	Quantum Mechanics III	PH 567	Nonlinear Dynamics
PH 534	Quantum Information and Computing	PH 569	Applied Solid State Physics
PH 543	Advanced Statistical Mechanics	PH 571	Experimental Techniques in Soft Matter Physics (5 credits)
PH 549	Physics of Biological Systems	PH 575	Nanoscience: Fundamentals to Fabrication
PH 556	Astrophysics	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 821	Gravitational Wave Physics and Astronomy

Electives for Even/Spring Semester (6 credits)			
Course code	**Title**	**Course code**	**Title**
PH 500	Thin film Physics and Technology	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 582	Geometry and Topology in Quantum Matter
PH 562	Continuum Mechanics	PH 601	Advanced Quantum Information and Computation
PH 819	Advanced Astrophysics	PH 818	Relativistic Cosmology
PH 564	Methods in Experimental Nuclear and Particle Physics		

Ph. D.

(PHYSICS)

2026 BATCH ONWARDS

CURRICULUM FOR Ph.D. IN PHYSICS			
Odd/Autumn Semester		**Even/Spring Semester**	
Course code	**Title**	**Course code**	**Title**
Institute Mandatory (in any one semester)			
GC 101	Gender sensitization course	GC 101	Gender sensitization course
TA 101	Teaching Assistant Skill Enhancement & Training	TA 101	Teaching Assistant Skill Enhancement & Training
Department Mandatory			
PHS 801	Seminar	PHS 802	Seminar (if not taken in odd sem.)
		PH 899	Communication skills

Seminar (PHS 801/802) (4 credits) is mandatory.

Other mandatory institute and department courses (PH 899, GC 101 and TA 101) are uncredited (only pass/no pass grade).

Post M.Sc. students: Additional 5 courses must be taken, with at least 4 from the group baskets. 1 elective course can be from outside the Department.
Total credit = 4 + 30 = 34.

Post M.Tech./M.E.: Additional 2 courses from group basket must be taken.
Total credit = 4 + 12 = 16.

Post B.Tech./B.E./B.S.: Additional 6 courses must be taken, with at least 5 from the group baskets. 1 elective course can be from outside the Department. **Total credit = 4 + 36 = 40.**

The credits requirements for PMRFs are the same as those of other students.

Course Basket

These courses are recommendatory in nature (unless mentioned otherwise) and students can choose alternative courses in consultation with their group or supervisors.

High Energy Physics Theory			
Odd/Autumn Semester		**Even/Spring Semester**	
Course code	**Title**	**Course code**	**Title**
Electives			
PH 563	Group Theoretical Methods in Physics	PH 408	Mathematical Physics II
PH 523	Quantum Mechanics III	PH 540	Elementary Particle Physics
PH 813	Advanced Topics in Astro-particle Physics	PH 544	General Theory of Relativity
PH 815	Standard Model of Particle Physics		
PH 817	Special Topics in QFT and Beyond the Standard Model		
High Energy Physics Experiment			
Electives			
PH 219	Data Analysis & Interpretation	PH 540	Elementary Particle Physics
PH 505	Introduction to Nuclear and Particle Physics	PH 564	Methods in Experimental Nuclear and Particle Physics
PH 523	Quantum Mechanics III		
PH 309	Quantum Mechanics II	PH 422	Quantum Mechanics II (only if PH 309 is not taken)
PH 434	Programming Lab. (5 credit)	PH 566	Advanced Simulation Techniques in Physics (8 credit) (only if PH 434 is not taken)

Soft Matter (Theory/Experiment)			
Odd/Autumn Semester		Even/Spring Semester	
Course code	Title	Course code	Title
Recommended			
PH 543	Advanced Statistical Mechanics	PH 550	Soft Matter Physics
PH 549	Physics of Biological Systems	PH 562	Continuum Mechanics
PH 567	Nonlinear dynamics		
Electives			
PH 407	Mathematical Physics I (8 credit)	PH 408	Mathematical Physics II (8 credit)
		PH 410	Statistical Physics
PH 434	Programming Lab. (5 credit)	PH 566	Advanced Simulation Techniques in Physics (8 credit) (only if PH 434 is not taken)
Optics and Photonics			
Recommended			
PH 403	Quantum Mechanics I	PH 422	Quantum Mechanics II
PH 515	Intro.to Atomic and Molecular Physics	PH 424	Electromagnetic Theory I
PH 517	Methods in Analytical Techniques	PH 500	Thin Film Physics
PH 561	Ultrafast Sciences	PH 510	Electromagnetic Theory II
PH 575	Nanoscience: Fundamentals to Fabrication	PH 530	Light matter Interaction
PH 565	Semiconductor Physics	PH 546	Quantum Optics
PH 569	Applied Solid State Physics	PH 574	Phys. of Semiconductor Devices
		PH 576	Nanoscale Quantum Transport
		PH 578	Nano Devices and Applications
		PH 601	Advanced Quantum Information and Computation
		PH 804	Laboratory Techniques (8 credit)
Electives			
PH 436	Introduction to Condensed Matter Physics	PH 418	Introduction to Condensed Matter Physics (if PH 436 is not taken)
PH 434	Programming Lab. (5 credit)	PH 566	Advanced Simulation Techniques in Physics (8 credit) (only if PH 434 is not taken)

Astronomy, Cosmology and Gravity (Theory/Experiment)			
Odd/Autumn Semester		**Even/Spring Semester**	
Course code	**Title**	**Course code**	**Title**
Electives			
PH 307	Introduction to Numerical Analysis	PH 544	General Relativity
PH 556	Astrophysics	PH 818	Relativistic Cosmology
PH 821	Gravitational Wave Astronomy	PH 819	Advanced Astrophysics
Condensed Matter Physics Theory			
Electives			
PH 407	Mathematical Physics I (8 credit)	PH 408	Mathematical Physics- II (8 credit)
PH 523	Quantum Mechanics III	PH 410	Statistical Physics
PH 557	Theor. Cond. Matter Physics	PH 554	Comp. Many Body Physics
PH 543	Advanced Statistical Mechanics	PH 582	Geometry and Topology in Quantum Matter
PH 569	Applied Solid State Physics	PH 530	Light matter Interaction
PH 561	Ultrafast Sciences	PH 576	Nanoscale Quantum Transport
PH 563	Group Theor. Methods Physics	PH 580	Magnetism and Superconductivity
PH 817	Specialized Topics in QFT and Beyond Standard Model Physics	PH 408	Mathematical Physics- II (8 credit)
PH 534	Quantum Information and Computing	PH 410	Statistical Physics
PH 436	Introduction to Condensed Matter Physics	PH 418	Introduction to Condensed Matter Physics (if PH 436 is not taken)
PH 434	Programming Lab. (5 credit)	PH 566	Advanced Simulation Techniques in Physics (8 credit) (only if PH 434 is not taken)
PH 309	Quantum Mechanics II	PH 422	Quantum Mechanics II (only if PH 309 is not taken)

Quantum Information Theory			
Odd/Autumn Semester		**Even/Spring Semester**	
Course code	**Title**	**Course code**	**Title**
Mandatory			
PH 534	Quantum Information and Computing		
Electives			
PH 567	Nonlinear dynamics	PH 601	Advanced Quantum Information and Computation
PH 557	Theoretical Condensed Matter Physics	PH 554	Computational Many Body Physics
PH 515	Introduction to Atomic and Molecular Physics	PH 536	Physics of Quantum Devices
PH 563	Group Theoretical Methods in Physics	PH 422	Quantum Mechanics II
PH 543	Advanced Statistical Mechanics	PH 546	Quantum Optics
PH 567	Nonlinear dynamics	PH 530	Light Matter Interaction
Condensed Matter Physics Experiment			
Recommended			
PH 517	Methods in Analytical Techniques	PH 500	Thin film Physics and Technology
PH 534	Quantum Information and Computing	PH 530	Light Matter Interaction
PH 543	Advanced Statistical Mechanics	PH 574	Physics of Semiconductor Devices
PH 561	Ultrafast Sciences	PH 580	Magnetism and Superconductivity
PH 563	Group Theoretical Methods in Physics	PH 804	Laboratory Techniques (8 credit)
PH 565	Semiconductor Physics		
PH 569	Applied Solid State Physics		
Electives (Any two)			
PH 557	Theor. Condensed Matter Physics	PH 554	Computational Many Body Physics
		PH 582	Geometry and Topology in Quantum Matter
Electives (Any two)			
PH 575	Nanoscience: Fundamentals to Fabrication	PH 576	Nanoscale Quantum Transport
		PH 578	Nanodevices and Applications
Electives (Any one)			
PH 434	Programming Lab. (5 credit)	PH 566	Advanced Simulation Techniques in Physics (8 credit)

Department rules for projects

- The main supervisor for any BTP/SLP/MSP project must be from the Physics Department, and will need to approve the project at the start of the semester (within the final course adjustment deadline). A form will be floated in the first two weeks of the semester collecting project details and supervisor approval. The supervisor will ensure coordination with external co-supervisors (if any), due progress, timely submission of reports and final presentation.

- A student can register for only one BTP (either BTP-1, BTP-2 or BTP-3) in 3rd or 4th year only. However, to register for BTP-2, BTP-1 will be a prerequisite. Similarly, to register BTP-3, BTP-1 and BTP-2 will be prerequisites.

- SLP can be taken only once (but can be counted as a department elective), but only in 2nd or 3rd year of the B.Tech. program. SLP in the 4th year is allowed only for students who convert to DD or IDDDP programs.

- The equivalent course elective for BTP shall be as follows: BTP-1 or Department elective; BTP-2 or Department or STEM elective and BTP-3 or Department or STEM elective.

- With regards to the award of Undergraduate Research Awards (see below), students having done a year-long project (BTP-1 and BTP-2 or BTP-2 and BTP-3) under the same supervisor, can only be recommended for URA02. All other criteria related to the award of URA02 under institute rules must also be satisfied.

Undergraduate Research Awards (URA)

Some students may have an inclination towards research. The Undergraduate Research Awards (URA) is designed for such students. URA will be available at three levels, all of them independent of each other. They will carry codes similar to course codes so that they can be listed in grade reports.

- **URA01**: for preliminary research/ developmental experience
- **URA02**: for B. Tech. Level Research Project
- **URA03**: for Dual Degree Level Research Project

URA01 — This is a recognition of a small research/ developmental effort, successfully completed by a student in the first, second or third year of an undergraduate programme – that is, a B.Tech., or a Dual Degree Programme. A faculty member must agree to supervise the student for the URA01project. The student works with this faculty member, with the approval of the DUGC, for four-to-six month duration – including the summer or winter vacations. No formal registration is required with the academic office at this stage. If the faculty member is satisfied with the quantum and quality of work done, at any stage, s/he may recommend the award of URA01 to the student, which will then be listed in the transcript of the student in the semester immediately following the semester in which this award was recommended. No credits are assigned to URA01. URA01 can be awarded only once to a student. The grade for URA01 will be “PP”.

URA02 – This is to be treated as recognition of truly exceptional work, both in quality and in extent, done in the B.Tech. Project. If the committee evaluating the B.Tech. Project of a B.Tech. student believes that the student has carried out truly exceptional work in the B.Tech. Project and the quantum of work is substantially higher than what is expected, it may recommend that two more faculty members, other than those who already participated in the committee for evaluation, duly chosen by the DUGC, examine the work done and evaluate whether a URA02 can be awarded to the student in addition to the AA grade already given. A joint recommendation must then be made by all: the original committee of evaluation and these two other faculty members that this student be awarded URA02, duly routed through the Convener, DUGC to the Convener, UGAPEC. This award, on approval by the UGAPEC, will be mentioned on the grade report of the student as URA02 carrying six credits and the grade AA. No formal registration is required with the academic office. The advantage to the student would be that his / her CPI would improve, given that these credits are with an AA grade. URA 2 is not available for DD students. Students should have earned minimum of 12 credits in BTP, in order to apply for URA 02

URA03 – These are to be treated as recognition of truly exceptional work, both in quality and in extent, in the Dual Degree Project. If the committee evaluating the Final Stage of the Dual Degree Project of a given Dual Degree student believes that the student has carried out truly exceptional work and the quantum of work is substantially higher than what is expected, it may recommend that two more faculty members, other than those who already participated in the committee for evaluation, duly chosen by the DUGC, examine the work done and evaluate whether a URA03 can be awarded to the student in addition to the AA grade already given. A joint recommendation must then be made by all: the original committee of evaluation and these two other faculty members that this student be awarded URA03, duly routed through the Convener, DUGC to the Convener, UGAPEC. This award, on approval by the UGAPEC, will be mentioned on the grade report of the student as URA03 carrying six credits and the grade AA. No formal registration is required with the academic office. The advantage to the student would be that his / her CPI would improve, given that these credits are with an AA grade.

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, Archimedes 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 Zn^{2+} / Zn couple. b) To determine the concentration of Fe^{2+} 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. <u>Hours:</u> 2 lectures (55 minutes each), 2 hours of laboratory time which will include practice on computers. <u>Description:</u> 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 consumers' 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 balance 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' 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 edition) Roger 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 Electronics, H. 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 method. 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. Lalö 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(TI) 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 314**
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	**Optics** 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 elective courses.

Minor in Engineering Physics Course Content

Course Name	Classical Mechanics (compulsory course). Or higher level of this
Course Code	**PH 251**
Total Credits	6
Prerequisite	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 1st order and 2nd 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 edition, John Wiley, 1985 3. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill, 1965.

Course Name	**Introduction to Condensed Matter Physics**
Course Code	**PH 352**
Total Credits	6
Prerequisite	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 Reference	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 Name	**Light matter Interactions**
Course Code	**PH 353**
Total Credits	6
Prerequisite	
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 Reference	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. Course Contents

First Year, First Semester

Course Code	**PH 401**
Course Name	**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 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.
Text/References	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 11. Percival & Richards, Introduction to Dynamics, Cambridge

Course Code	**PH 403**
Course Name	**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. Schrodinger's equation, Schrodinger's equation for Unitaries, Schrodinger, 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. Laloe for reference material. 5. L. D. Landau and E. M. Lifshitz, Pergamon Press 1965

Course Code	**PH 405**
Course Name	**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**
Course Name	**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**
Course Name	**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**
Course Name	**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
Course Name	**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 hypergeometric 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**
Course Name	**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**
Course Name	**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**
Course Name	**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**
Course Name	**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 EM Fields 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**
Course Name	**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**
Course Name	**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**
Course Name	**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**
Course Name	**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**
Course Name	**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, Bremstrahlung, 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**
Course Name	**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**
Course Name	**Optics and Spectroscopy Lab**
Credits	6
Type	L
Lecture	0
Tutorial	0
Practical	6
Description	**Optics** Spatial Filtering Spatial Coherence Mach-Zehnder Interferometer Nonlinear Optics / Z Scan CdsNanoparticals (Theory) **Spectroscopy** Spin Orbit Coupling of Cu Absorption Spectrum of Iodine Rotation Spectrum of CN
Text/References	Lab manuals

Elective Course Contents
(Odd semester)

Course Code	**PH 517**
Course Name	**Methods in Analytical Techniques**
Total Credits	6
Type	T
Lecture	2
Tutorial	0
Practical	2
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**
Course Name	**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 543**
Course Name	**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**
Course Name	**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 in-vivo 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**
Course Name	**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**
Course Name	**Ultrafast Sciences**
Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description	Ultrafast science: Introduction, Spatio-temporal properties of ultrashort pulsesGeneration of ultra-short pulses, Material dispersion and compensationNonlinear optics, Ultrashort pulse characterizationPulse propagation through various media, Pulse-shaping and coherent controlApplications 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**
Course Name	**Group Theoretical Methods in Physics**
Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description	**Discrete groups and applications**: 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**
Course Name	**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-field effects 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**
Course Name	**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 Code	**PH 569**
Course Name	**Applied Solid State Physics**
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 Code	**PH 571**
Course Name	**Experimental Techniques in Soft Matter Physics**
Credits	**5**
Type	T
Lecture	1

Tutorial	1
Practical	3
Description	This course, "Experimental Techniques in Soft Matter Physics," is designed for Ph.D. and M.Sc. (Physics) students seeking a rigorous foundation in characterizing soft condensed matter systems. The curriculum focuses on the essential techniques used to probe structure and dynamics across multiple length and time scales. We will provide in-depth coverage of Light Microscopy Techniques (including Confocal) for imaging structure and dynamic processes: Scattering Techniques (Dynamic Light Scattering, Static Light Scattering, and principles of SAXS/SANS) for determining size and structure; comprehensive Rheology for quantifying flow, deformation, and viscoelasticity; and methods for measuring Surface Tension and Interfacial Forces. The primary objective is to provide fundamental theory between experimental methods and equip them with practical ability to select appropriate experimental tools, design effective experiments, and critically analyze the resulting data, making this course essential for any student pursuing research in soft matter, materials science, or biophysics.
Text/References	1. Soft Condensed Matter by R.A.L. Jones: 2002; Published by Oxford University Press. 2. Soft Matter Physics by M. Doi; 2013; Published by Oxford University Press. 3. Fundamentals of Soft Matter Science by Linda S. Hirst; 2013; CRC Press (part of Taylor & Francis Group). 4. Soft Matter Physics: An Introduction by M. Kleman and O. D. Laventrovich; Springer 2003. 5. Intermolecular and Surface Forces by Jacob N. Israelachvili; 199; Academic Press.

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

	Nano Fabrication 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 Code	**PH 813**
Course Name	**Advanced Topics in Astro-particle Physics**
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 Code	**PH 815**
Course Name	**Standard Model of Particle Physics**
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 Code	**PH 817**
Course Name	**Specialized Topics in QFT and Beyond Standard Model Physics**
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 on Non-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 Code	**PH 819**
Course Name	**Advanced Astrophysics**
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 collision-less-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 Code	**PH 821**
Course Name	**Gravitational Wave Physics and Astronomy**
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 Course Contents
(Even semester)

Course Code	**PH 500**
Course Name	**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 534**
Course Name	**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 540**
Course Name	**Elementary Particle Physics**
Credits	6
Type	
Lecture	T
Tutorial	2
Practical	1
Description	0
Text/References	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.
	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**
Course Name	**General Theory of Relativity**
Credits	
Type	T
Lecture	2
Tutorial	1
Practical	0

Description	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
Text/References	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] .
	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
Course Name	**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**
Course Name	**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 isotropic nematic 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, Cambridge University 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**
Course Name	**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 Python : 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**
Course Name	**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**
Course Name	**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**
Course Name	**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**
Course Name	**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**
Course Name	**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. I and II 6. V. Parameswaran Nair, Quantum Field Theory: A modern perspective, Springer 2005

Course Code	**Physics of Semiconductor Devices**
Course Name	**PH 574**
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/References	(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**
Course Name	**Nanoscale Quantum Transport**
Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
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**
Course Name	**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, mixture, 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**
Course Name	**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 582**
Course Name	**Geometry and Topology in Quantum Matter**
Credits	6
Type	T
Lecture	2
Tutorial	1
Practical	0
Description	The Berry phase, a fundamental geometric phase acquired by the wave function of a quantum system during adiabatic evolution, plays a crucial role in understanding a wide range of quantum phenomena. In quantum materials, it underpins the modern theory of polarization, anomalous Hall effects, and the topological classification of materials. By establishing a connection between the geometry of the wave function in momentum space and observable physical properties, the Berry phase provides deep insights into electronic polarization, anomalous Hall transport, and orbital magnetism. A key derivative of the Berry phase, the Berry curvature, acts as a fictitious magnetic field that governs the dynamics of quasi-particles, further enriching our understanding of quantum transport properties. Given its foundational significance, this course aims to equip students with a comprehensive understanding of Berry phase theory and its applications in topological systems, ferroelectrics, quantum Hall effects, and related transport phenomena with increasing national and global emphasis on next-generation quantum materials, this course is particularly timely. By introducing students to these advanced concepts, it aims to motivate

	and prepare them for research in the evolving field of quantum materials.1) Introduction- Scope and objective, historical background2) Concept of Berry phase - Adiabatic theorem- Geometric phase- Berry Connection- Berry Curvature- Quantum metric3) Application of Berry phase to condensed matter systems(a) Topology - Topological invariant, Symmetry. - Quantum Hall effect, anomalous Hall effect. - Topological semi metals.(a) Topology - Topological invariant, Symmetry. - Quantum Hall effect, anomalous Hall effect. - Topological semi metals.(b) Electric polarization and orbital magnetization- Modern theory of polarization and orbital magnetization- Magneto electric effect and Axion coupling- Surface Anomalous Hall effect.4) Special topics in topology and geometry - Topology with disorder - Anderson insulators. - Manifestation of topology in Transport. - Interaction effects - Fractional quantum Hall, spin liquids- Topology in spin system - Magnon topology, Skyrmions.- Classification of topological insulators, superconductors.
Text/References	1. Berry Phases in Electronic Structure Theory: Electric Polarization, Orbital Magnetization, and Topological Insulators - David Vanderbilt, Cambridge University Press (2018). DOI: 10.1017/9781316662205. 2. Topological Insulators and Topological Superconductors - B. Andrei Bernevig and Taylor L. Hughes, Princeton University Press (2013). PDF. 3. A Short Course on Topological Insulators: Band-structure Topology and Edge States in One and Two Dimensions - Janos K. Asboth, Laszlo Oroszlany, and Andras Palyi, Springer (2). Springer Link. E-References: 4. Geometry and Topology in Electronic Structure Theory 302226 Raffaele Resta (2022). Draft. 5. Lecture Notes on Quantum Hall Effect 302226 David Tong (2016). Link. 6. Berry Phase Effects on Electronic Properties 302226 Di Xiao, Ming-Che Chang, and Qian Niu, Rev. Mod. Phys. 82, 1959 (2010).DOI: 10.1103/RevModPhys.82.1959.

Course Code	**PH 601 (needs PH 534 as the pre-requisite)**
Course Name	**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 Code	**PH 818**
Course Name	**Relativistic Cosmology**
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).