

UNIVERSITY OF DELHI

MASTER OF SCIENCE in PHYSICS

(Two Years Programme (2nd year) and One Year Programme-NEP)

(Coursework only)

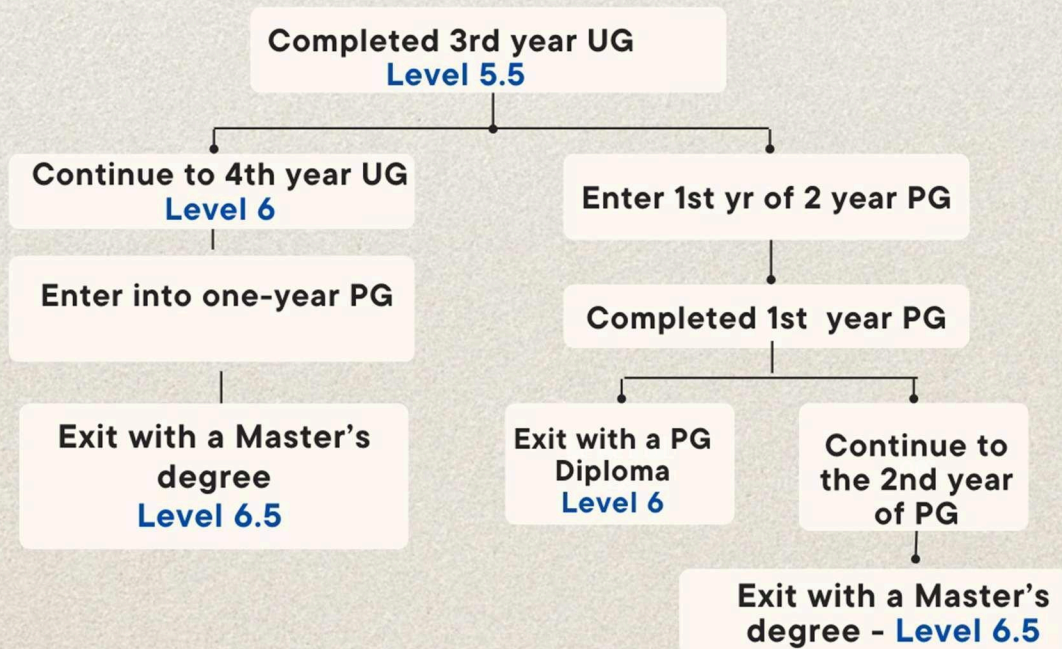
(Effective from Academic Year 2025-26)

Proposed Postgraduate Curricular Framework 2025
(based on NEP 2020)

LEVELS 6 AND 6.5



Progression from UG to PG



Programme Specific Outcomes (PSOs)

- ❖ Understanding the basic concepts of physics particularly concepts in classical mechanics, quantum mechanics, statistical mechanics and electricity and magnetism to appreciate how diverse phenomena observed in nature follow from a small set of fundamental laws through logical and mathematical reasoning.
- ❖ Learn to carry out experiments in basic as well as certain advanced areas of physics such as nuclear physics, condensed matter physics, nanoscience, lasers, and electronics.
- ❖ Understand the basic concepts of certain sub fields such as nuclear and high energy physics, atomic and molecular physics, solid state physics, and plasma physics, and astrophysics, general theory of relativity, nonlinear dynamics and complex systems.
- ❖ Gain hands-on experience to work in applied fields.
- ❖ Enhancing skills in experimental techniques and computation
- ❖ Gain a thorough grounding in the subject to be able to teach it at college and school levels.
- ❖ Viewing physics as a training ground for the mind to develop a critical attitude and a faculty of logical reasoning that can be applied to diverse fields.

Programme Structure

The M. Sc. programme is a two-year course divided into four semesters. A student is required to complete 88 credits (LEVEL 6 AND 6.5) for the completion of the course and the award of degree. The student who exits after one year at level 6 (44 credits) and acquires required credits shall be awarded with a PG diploma. The M.Sc. Physics Programme would make the students competent in natural science, viz., Physics, and help them understand its role in modern day technology. Overall, the course would enable the students to understand the fundamental concepts and experimental methods of physics which would help them to innovate/apply/generate new devices/applications/insights/knowledge. Knowledge gained through the open electives would be an asset in branching out in fields other than physics.

		Semester	Semester
Part – I	First Year	Semester I	Semester II
Part – II	Second Year	Semester III	Semester IV

**PG curricular structure for 2nd year of PG Programmes (3+2)
& 1 year PG Programme (4+1)
(Only Coursework)**

Course Credit Scheme for M.Sc. Physics

Semester	Core Courses			Elective Course			SBC			Total Credits
	No. of papers	Credits (L+T+P)	Total Credits	No. of papers	Credits (L+T+P)	Total Credits	No. of papers	Credits (L+T+P)	Total Credits	
I										
II										
III	02 DSC7 DSC8	3+1+0	08	DSE5 DSE6 DSE7/GEC3 3DSEs or 2DSEs + 1 GEC	4	12	01	As per the course	02	22
IV	02 DSC9 DSC10	3+1+0	08	DSE8 DSE9 DSE10/GEC4 3DSEs or 2DSEs+1GEC	4	12	01	As per the course	02	22
Total Credits for the Course										44

The mode(s) of internal assessment will vary from course to course. The internal assessment marks will be based on performance in tests / quizzes / assignments / project work / presentations / attendance, etc. All laboratory courses will be evaluated based on continuous evaluation and end-of semester examination as per the university's rules.

2 Year M.Sc. Programme (Semester Wise)

Semester III					
Number of core courses: 2	Page	Credits in each core course			
CORE COURSE:		Lecture	Tutorial	Practical	Credits
PH-DSC 5101: Nuclear and Particle Physics	21	3	1	0	4
PH-DSC5102 : Statistical Physics	24	3	1	0	4
Total credits in Core courses					8
Number of Elective/General Elective courses		Credits in each elective course			
ELECTIVE COURSES: (Select 3 DSE courses or 2 DSE courses and 1 GE)		Lecture	Tutorial	Practical	Credits
EXPERIMENTAL COURSES					
Module A-I:					
PH-DSE5111:Physics at the Nanoscale – I (Theory)	26	3	1	0	4
PH-DSE5112:Nanomaterials Lab – I (Lab)	28	0	0	4	4
Module B-I:					
PH-DSE5113: Advanced Electronics - I (Theory)	31	3	1	0	4
PH-DSE5114:Advanced Electronics - I (Lab)	33	0	0	4	4
Module C-I:					
PH-DSE5115:Advanced Nuclear Physics – I (Theory)	37	3	1	0	4
PH-DSE5116:Advanced Nuclear Physics - I (Lab)	40	0	0	4	4

ELECTIVE COURSES:		Lecture	Tutorial	Practical	Credits
Module D-I:					
PH-DSE5117: Fundamentals of Spectroscopy (Theory)	43	3	1	0	4
PH-DSE5118: Lasers and Spectroscopy (Lab)	45	0	0	4	4
Module E-I:					
PH-DSE5119: Advanced Solid State Physics –I (Theory)	47	3	1	0	4
PH-DSE5120: Advanced Solid State Physics – I (Lab)	49	0	0	4	4
THEORY COURSES					
PH-DSE5131: General Theory of Relativity and Cosmology I	51	3	1	0	4
PH-DSE5132: Condensed Matter Physics I	54	3	1	0	4
PH-DSE5133: Plasma Physics I	56	3	1	0	4
PH-DSE5134: Particle Physics I	58	3	1	0	4
PH-DSE5135: Quantum Field Theory I	60	3	1	0	4
PH-DSE5136: Basics of Astronomy and Observational Techniques	62	3	1	0	4
PH-DSE5137: Radio Astronomy and Instrumentation	64	2	0	2	4
PH-DSE5138: Fluid Dynamics	67	3	1	0	4
PH-DSE5139: Nonlinear Dynamics	69	3	1	0	4
PH-DSE5140: Applied Physics	71	3	1	0	4
PH-DSE5141: Quantum Information and Computation	73	3	1	0	4
PH-DSE5142: Computational Material Science	76	3	0	1	4
PH-DSE5143: Quantum Optics	78	3	1	0	4

ELECTIVE COURSES:		Lecture	Tutorial	Practical	Credits
PH-DSE5144: Atmospheric Physics	80	3	1	0	4
PH-DSE5145: X-ray Spectroscopic Techniques	82	3	1	0	4
PH-DSE5146: Complex Systems	84	3	1	0	4
PH-DSE5147: Accelerator Physics	86	3	1	0	4
PH-DSE5148: Research Methodology in Physics	88	3	0	1	4
Total credits in Electives/General Electives					12
SKILL BASED COURSES <i>(Only 1 course can be opted and a particular SBC can be taken only once in the programme)</i>		Lecture	Tutorial	Practical	Credits
PH-SBC5171: Workshop Skills	103	0	0	2	2
PH-SBC5172: Strategies for Scientific Dialogue in Research	104	1	0	1	2
PH-SBC5173: Advanced Computational Physics	106	0	0	2	2
PH-SBC5174: Introductory Innovation Lab	108	0	0	2	2
PH-SBC5175: Introductory Observational Astronomy Laboratory	110	0	0	2	2
PH-SBC5176: Integrated Analytical Techniques in Electronic, Experimental and Condensed Matter Physics	112	0	0	2	2
PH-SBC5177: Integrated Analytical Techniques in Electromagnetic and Quantum Physics	114	0	0	2	2
PH-SBC5178: Integrated Analytical Techniques in Mathematical and Classical Physics	116	0	0	2	2
PH-SBC5179: Radiation Safety	118	1	0	1	2
PH-SBC5180: Order of Magnitude Physics	121	1	0	1	2
PH-SBC5181: Electronic Circuit and Simulation	123	0	0	2	2
PH-SBC5182: Thin Film Fabrication	125	0	0	2	2

SKILL BASED COURSES		Lecture	Tutorial	Practical	Credits
PH-SBC5183: Material synthesis and characterization	127	0	0	2	2
PH-SBC5184: Introductory Plasma Physics Lab	129	0	0	2	2
PH-SBC5185: Lasers and their applications	131	0	0	2	2
Total credits in Skill Based Courses					2
Total credits in Semester III					22
GENERAL ELECTIVE (GE)	Courses to be offered to other departments				
PH-GEC5101: Radiation Safety	133	3	1	0	4
PH-GEC5102: Complex System & Networks	136	3	1	0	4
PH-GEC5103: Introductory Astronomy	138	3	1	0	4
PH-GEC5104: Physics for Biological Systems	141	3	1	0	4
PH-GEC5105: Physics Education	143	3	1	0	4

Semester IV					
Number of core courses: 2		Credits in each core course			
CORE COURSE:		Lecture	Tutorial	Practical	Credits
PH-DSC5201: Atomic & Molecular Physics	146	3	1	0	4
PH-DSC5202: Advanced Classical Dynamics, Fields & Matter	149	3	1	0	4
Total credits in Core courses					8
Number of Elective/General Elective courses: 4		Credits in each elective course			

ELECTIVE COURSES: (Select 3 DSE courses or 2 DSE courses and 1 GE)		Theory	Practical	Tutorial	Credits
EXPERIMENTAL COURSES					
Module A-II:					
PH-DSE5211: Physics at the Nanoscale – II (Theory)	152	3	1	0	4
PH-DSE5212: Nanomaterials – II (Lab)	154	0	0	4	4
Module B-II:					
PH-DSE5213: Advanced Electronics - II (Theory)	157	3	1	0	4
PH-DSE5214: Advanced Electronics- II (Lab)	159	0	0	4	4
Module C-II:					
PH-DSE5215: Advanced Nuclear Physics – II (Theory)	161	3	1	0	4
PH-DSE5216: Advanced Nuclear Physics - II (Lab)	164	0	0	4	4
Module D-II:					
PH-DSE5217: Advanced Laser Physics (Theory)	167	3	1	0	4
PH-DSE5218: Advanced Laser Physics (Lab)	169	0	0	4	4
Module E-II:					
PH-DSE5219: Advanced Solid State Physics–II (Theory)	171	3	1	0	4
PH-DSE5220: Advanced Solid State Physics – II (Lab)	174	0	0	4	4
Special Lab courses:					
PH-DSE5221: Advanced Numerical Techniques	176	0	0	4	4
PH-DSE5222: Advanced Observational Astrophysics Lab	178	0	0	4	4
PH-DSE5223: Machine Learning for Physicists	181	2	0	2	4

ELECTIVE COURSES:		Theory	Practical	Tutorial	Credits
THEORY COURSES					
PH-DSE5231: General Theory of Relativity and Cosmology II	183	3	1	0	4
PH-DSE5232: Condensed Matter Physics II	185	3	1	0	4
PH-DSE5233: Plasma Physics II	187	3	1	0	4
PH-DSE5234: Particle Physics II	189	3	1	0	4
PH-DSE5235: Quantum Field Theory II	191	3	1	0	4
PH-DSE5236: Nuclear Astrophysics	193	3	1	0	4
PH-DSE5237: Supersymmetric Quantum Mechanics	195	3	1	0	4
PH-DSE5238: Spintronics Fundamentals and Applications	197	3	1	0	4
PH-DSE5239: Molecular Electronics	199	3	1	0	4
PH-DSE5240: Astrophysics	201	3	1	0	4
PH-DSE5241: Soft Matter Physics	203	3	1	0	4
PH-DSE5242: Advanced Course on Quantum Computing	205	2	0	2	4
PH-DSE5243: String Theory	208	3	1	0	4
PH-DSE5244: Superconductivity, Superfluidity & Critical Phenomena	210	3	1	0	4
PH-DSE5245: Accelerator Applications	212	3	1	0	4
PH-DSE5246: Metamaterials, Plasmonics and Photonics	214	3	1	0	4
PH-DSE5247: Nuclear Safety & Security	216	3	1	0	4
PH-DSE5248: Advanced Statistical Physics	219	3	1	0	4
PH-DSE5249: Biophysics	221	3	1	0	4
Total credits in Electives/General Electives					12
Notes: • More than one experimental paper as DSE is not allowed. • Experimental paper from Module A to E is allowed only with its prerequisite and corequisite.					

SKILL BASED COURSES Only 1 course can be opted and a particular SBC can be taken only once in the programme		Theory	Practical	Tutorial	Credits
PH-SBC5271: Workshop skills	235	0	0	2	2
PH-SBC5272: Strategies for Scientific Dialogue in Research	236	1	0	1	2
PH-SBC5273: Detector Design and Simulation	238	0	0	2	2
PH-SBC5274: Interdisciplinary Innovation Lab	241	0	0	2	2
PH-SBC5275: Physics-Informed Machine Learning	243	1	0	1	2
PH-SBC5276: Integrated Analytical Techniques in Electronic, Experimental and Condensed Matter Physics	245	0	0	2	2
PH-SBC5277: Integrated Analytical Techniques in Electromagnetic and Quantum Physics	247	0	0	2	2
PH-SBC5278: Integrated Analytical Techniques in Mathematical and Classical Physics	249	0	0	2	2
PH-SBC5279: Integrated Analytical Techniques in Statistical and Nuclear Physics	251	0	0	2	2
PH-SBC5280: Radiation Safety	253	1	0	1	2
PH-SBC5281: Order of Magnitude Physics	256	1	0	1	2
PH-SBC5282: Electronic Circuit and Simulation	258	0	0	2	2
PH-SBC5283: Thin Film Fabrication	260	0	0	2	2
PH-SBC5284: Material synthesis and characterization	262	0	0	2	2

SKILL BASED COURSES		Lecture	Tutorial	Practical	Credits
PH-SBC5285: Introductory Plasma Physics Lab	264	0	0	2	2
PH-SBC5286: Lasers and their applications	266	0	0	2	2
Total credits in Skill Based Courses					2
Total credits in Semester IV					22
Notes: • More than one experimental paper as DSE is not allowed. • Experimental paper from A-I to E-I is allowed only with its core requirement.					
GENERAL ELECTIVE (GE)	Courses to be offered to other departments				
PH-GEC5201: Radiation Safety	268	3	1	0	4
PH-GEC5202: Complex System & Networks	271	3	1	0	4
PH-GEC5203: Introductory Astronomy	273	3	1	0	4
PH-GEC5204: Physics for Biological Systems	276	3	1	0	4
PH-GEC5205: Physics Education	278	3	1	0	4

1 Year M.Sc. Programme (Semester Wise)

Semester I					
Number of core courses: 2		Credits in each core course			
CORE COURSE:		Lecture	Tutorial	Practical	Credits
PH-DSC 5101: Nuclear and Particle Physics	21	3	1	0	4
PH-DSC5102 : Statistical Physics	24	3	1	0	4
Total credits in Core courses					8
Number of Elective/General Elective courses		Credits in each elective course			
ELECTIVE COURSES: (Select 3 DSE courses or 2 DSE courses and 1 GE)		Lecture	Tutorial	Practical	Credits
EXPERIMENTAL COURSES					
Module A-I:					
PH-DSE5111:Physics at the Nanoscale – I (Theory)	26	3	1	0	4
PH-DSE5112:Nanomaterials Lab – I (Lab)	28	0	0	4	4
Module B-I:					
PH-DSE5113: Advanced Electronics - I (Theory)	31	3	1	0	4
PH-DSE5114:Advanced Electronics - I (Lab)	33	0	0	4	4
Module C-I:					
PH-DSE5115:Advanced Nuclear Physics – I (Theory)	37	3	1	0	4
PH-DSE5116:Advanced Nuclear Physics - I (Lab)	40	0	0	4	4
Module D-I:					
PH-DSE5117:Fundamentals of Spectroscopy (Theory)	43	3	1	0	4

ELECTIVE COURSES:		Lecture	Tutorial	Practical	Credits
PH-DSE5118:Lasers and Spectroscopy (Lab)	45	0	0	4	4
Module E-I:					
PH-DSE5119:Advanced Solid State Physics –I (Theory)	47	3	1	0	4
PH-DSE5120:Advanced Solid State Physics – I (Lab)	49	0	0	4	4
THEORY COURSES					
PH-DSE5131:General Theory of Relativity and Cosmology I	51	3	1	0	4
PH-DSE5132: Condensed Matter Physics I	54	3	1	0	4
PH-DSE5133: Plasma Physics I	56	3	1	0	4
PH-DSE5134: Particle Physics I	58	3	1	0	4
PH-DSE5135: Quantum Field Theory I	60	3	1	0	4
PH-DSE5136: Basics of Astronomy and Observational Techniques	62	3	1	0	4
PH-DSE5137: Radio Astronomy and Instrumentation	64	2	0	2	4
PH-DSE5138: Fluid Dynamics	67	3	1	0	4
PH-DSE5139: Nonlinear Dynamics	69	3	1	0	4
PH-DSE5140: Applied Physics	71	3	1	0	4
PH-DSE5141: Quantum Information and Computation	73	3	1	0	4
PH-DSE5142: Computational Material Science	76	3	0	1	4
PH-DSE5143: Quantum Optics	78	3	1	0	4
PH-DSE5144: Atmospheric Physics	80	3	1	0	4
PH-DSE5145: X-ray Spectroscopic Techniques	82	3	1	0	4
PH-DSE5146: Complex Systems	84	3	1	0	4
PH-DSE5147: Accelerator Physics	86	3	1	0	4
PH-DSE5161: Quantum Mechanics I	91	3	1	0	4

ELECTIVE COURSES		Lecture	Tutorial	Practical	Credits
PH-DSE5162: Electronics	94	3	1	0	4
PH-DSE5163: Foundational Laboratory in Experimental Physics	97	0	0	4	4
PH-DSE5164: Experimental Laboratory in Material and Optical Physics	100	0	0	4	4
PH-DSE5148: Research Methodology in Physics		3	0	1	4
Total credits in Electives/General Electives					12
SKILL BASED COURSES	Only 1 course can be opted and a particular SBC can be taken only once in the programme				
PH-SBC5171: Workshop Skills	103	0	0	2	2
PH-SBC5172: Strategies for Scientific Dialogue in Research	104	1	0	1	2
PH-SBC5173: Advanced Computational Physics	106	0	0	2	2
PH-SBC5174: Introductory Innovation Lab	108	0	0	2	2
PH-SBC5175: Introductory Observational Astronomy Laboratory	110	0	0	2	2
PH-SBC5176: Integrated Analytical Techniques in Electronic, Experimental and Condensed Matter Physics	112	0	0	2	2
PH-SBC5177: Integrated Analytical Techniques in Electromagnetic and Quantum Physics	114	0	0	2	2
PH-SBC5178: Integrated Analytical Techniques in Mathematical and Classical Physics	116	0	0	2	2
PH-SBC5179: Radiation Safety	118	1	0	1	2
PH-SBC5180: Order of Magnitude Physics	121	1	0	1	2
PH-SBC5181: Electronic Circuit and Simulation	123	0	0	2	2
PH-SBC5182: Thin Film Fabrication	125	0	0	2	2

SKILL BASED COURSES		Lecture	Tutorial	Practical	Credits
PH-SBC5183: Material synthesis and characterization	127	0	0	2	2
PH-SBC5184: Introductory Plasma Physics Lab	129	0	0	2	2
PH-SBC5185: Lasers and their applications	131	0	0	2	2
Total credits in Skill Based Courses					2
Total credits in Semester I					22
Notes: ● One experimental paper from the DSE pool is compulsory. ● More than one experimental paper as DSE is not allowed. ● Experimental paper from A-I to E-I is allowed only with its corequisite. ● Core and Elective Courses from 1st-year M.Sc. can be taken as electives only if they were not studied during the UG degree					

Semester II					
Number of core courses: 2		Credits in each core course			
CORE COURSE:		Lecture	Tutorial	Practical	Credits
PH-DSC5201: Atomic & Molecular Physics	146	3	1	0	4
PH-DSC5202: Advanced Classical Dynamics, Fields & Matter	149	3	1	0	4
Total credits in Core courses					8
Number of Elective/General Elective courses: 4		Credits in each elective course			
ELECTIVE COURSES: (Select 3 DSE courses or 2 DSE courses and 1 GE)		Theory	Practical	Tutorial	Credits
EXPERIMENTAL COURSES					
Module A-II:					
PH-DSE5211: Physics at the Nanoscale – II (Theory)	152	3	1	0	4
PH-DSE5212: Nanomaterials – II (Lab)	154	0	0	4	4

ELECTIVE COURSES		Theory	Practical	Tutorial	Credits
Module B-II:					
PH-DSE5213: Advanced Electronics - II (Theory)	157	3	1	0	4
PH-DSE5214: Advanced Electronics- II (Lab)	159	0	0	4	4
Module C-II:					
PH-DSE5215:Advanced Nuclear Physics – II (Theory)	161	3	1	0	4
PH-DSE5216: Advanced Nuclear Physics - II (Lab)	164	0	0	4	4
Module D-II:					
PH-DSE5217: Advanced Laser Physics (Theory)	167	3	1	0	4
PH-DSE5218: Advanced Laser Physics (Lab)	169	0	0	4	4
Module E-II:					
PH-DSE5219: Advanced Solid State Physics–II (Theory)	171	3	1	0	4
PH-DSE5220: Advanced Solid State Physics – II (Lab)	174	0	0	4	4
Special Lab courses:					
PH-DSE5221:Advanced Numerical Techniques	176	0	0	4	4
PH-DSE5222:Advanced Observational Astrophysics Lab	178	0	0	4	4
PH-DSE5223:Machine Learning for Physicists	181	2	0	2	4
THEORY COURSES					
PH-DSE5231: General Theory of Relativity and Cosmology II	183	3	1	0	4
PH-DSE5232: Condensed Matter Physics II	185	3	1	0	4
PH-DSE5233: Plasma Physics II	187	3	1	0	4

ELECTIVE COURSES		Theory	Practical	Tutorial	Credits
PH-DSE5234: Particle Physics II	189	3	1	0	4
PH-DSE5235: Quantum Field Theory II	191	3	1	0	4
PH-DSE5236: Nuclear Astrophysics	193	3	1	0	4
PH-DSE5237: Supersymmetric Quantum Mechanics	195	3	1	0	4
PH-DSE5238: Spintronics Fundamentals and Applications	197	3	1	0	4
PH-DSE5239: Molecular Electronics	199	3	1	0	4
PH-DSE5240: Astrophysics	201	3	1	0	4
PH-DSE5241: Soft Matter Physics	203	3	1	0	4
PH-DSE5242: Advanced Course on Quantum Computing	205	2	0	2	4
PH-DSE5243: String Theory	208	3	1	0	4
PH-DSE5244: Superconductivity, Superfluidity & Critical Phenomena	210	3	1	0	4
PH-DSE5245: Accelerator Applications	212	3	1	0	4
PH-DSE5246: Metamaterials, Plasmonics and Photonics	214	3	1	0	4
PH-DSE5247: Nuclear Safety & Security	216	3	1	0	4
PH-DSE5248: Advanced Statistical Physics	219	3	1	0	4
PH-DSE5249: Biophysics	221	3	1	0	4
PH-DSE5261: Quantum Mechanics II	223	3	1	0	4
PH-DSE5262: Solid State Physics	226	3	1	0	4

ELECTIVE COURSES		Theory	Practical	Tutorial	Credits
PH-DSE5266: Foundational Laboratory in Experimental Physics	229	0	0	4	4
PH-DSE5267: Experimental Laboratory in Material and Optical Physics	232	0	0	4	4
Total credits in Electives/General Electives					12
Notes: • More than one experimental paper as DSE is not allowed. • Experimental paper from Module A to E is allowed only with its prerequisite and corequisite.					
SKILL BASED COURSES (Only 1 course can be opted and a particular SBC can be taken only once in the programme)		Lecture	Tutorial	Practical	Credits
PH-SBC5271: Workshop skills	235	0	0	2	2
PH-SBC5272: Strategies for Scientific Dialogue in Research	236	1	0	1	2
PH-SBC5273: Detector Design and Simulation	238	0	0	2	2
PH-SBC5274: Interdisciplinary Innovation Lab	241	0	0	2	2
PH-SBC5275: Physics-Informed Machine Learning	243	1	0	1	2
PH-SBC5276: Integrated Analytical Techniques in Electronic, Experimental and Condensed Matter Physics	245	0	0	2	2
PH-SBC5277: Integrated Analytical Techniques in Electromagnetic and Quantum Physics	247	0	0	2	2
PH-SBC5278: Integrated Analytical Techniques in Mathematical and Classical Physics	249	0	0	2	2
PH-SBC5279: Integrated Analytical Techniques in Statistical and Nuclear Physics	251	0	0	2	2
PH-SBC5280: Radiation Safety	253	1	0	1	2
PH-SBC5281: Order of Magnitude Physics	256	1	0	1	2
PH-SBC5282: Electronic Circuit and Simulation	258	0	0	2	2

SKILL BASED COURSES		Lecture	Tutorial	Practical	Credits
PH-SBC5283: Thin Film Fabrication	260	0	0	2	2
PH-SBC5284: Material synthesis and characterization	262	0	0	2	2
PH-SBC5285: Introductory Plasma Physics Lab	264	0	0	2	2
PH-SBC5286: Lasers and their applications	266	0	0	2	2
Total credits in Skill Based Courses					2
Total credits in Semester II					22
Notes: - One experimental paper from the DSE pool may be compulsory as decided by the departmental course coordination committee. - More than one experimental paper as DSE is not allowed. - Experimental paper from A-II to E-II is allowed only with its corequisite and prerequisite. - Core and Elective Courses from 1st-year M.Sc. can be taken as electives only if they were not studied during the UG degree.					

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSC5101
Course Name: Nuclear & Particle Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nuclear and Particle Physics DSC	4	3	1	0	Quantum Mechanics -I & II, Electrodynamics, Mathematical Physics

Duration: 60 Hours(45L+15T)

Course Objectives

This course introduces the fundamental concepts of nuclear and particle physics, including nuclear structure, properties, and interactions. It aims to develop an understanding of nuclear forces, models, and decay processes. The course also provides a foundation in relativistic kinematics and the classification of elementary particles. Additionally, it familiarizes students with symmetry principles and the basic framework of the Standard Model.

Unit I: General properties of the nucleus

(8 Hours)

Nuclear landscape, nuclear mass determination and binding energy, nucleon separation energy, angular momentum, spin, parity, iso-spin and moments of nuclei (Electric and Magnetic); nuclear size determination, Rutherford scattering and Mott scattering, nuclear form-factors.

Unit II: Nuclear Force

(14 Hours)

Two-nucleon bound system: deuteron, properties of deuteron, dipole moment of the deuteron; quadrupole moment of the deuteron (qualitative idea only), central and tensor potential.

Low-energy nucleon-nucleon scattering: neutron-proton scattering, scattering length, effective range theory (qualitative idea only), spin dependence (ortho and para-hydrogen), charge symmetry and charge independence, low-energy proton-proton scattering (qualitative idea only). High energy nucleon-nucleon scattering: evidence for saturation property, exchange character, evidence for hardcore potential, spin-orbit potential, exchange model: meson theory.

Unit III: Nuclear Models & Decays

(12 Hours)

Nuclear Models: Concept of Liquid drop model, magic nuclei, extreme single particle shell model, nuclear spin-orbit coupling, spin and magnetic moments of the nuclei, Collective or Unified Model (qualitative idea only).

Electromagnetic decays: selection rules, Fermi theory of beta decay, Kurie plot, Fermi and Gamow-Teller transitions, $\ln(ft)$ value, Parity violation in beta-decay, Gamma decay, selection rules, Concept of Nuclear Reactions (Direct and Compound Nuclear Reaction).

Unit IV: Elementary Particle Physics

(11 Hours)

Relativistic kinematics, Various Interactions, Parity, Charge Conjugation and Time Reversal, Classification: spin and parity determination of pions and strange particles, Gell-Mann Nishijima scheme, Properties of quarks and their classification, Elementary ideas of SU(2) and SU(3) symmetry groups and hadron classification, Introduction to the standard model (qualitative idea only), Electroweak interaction-W & Z Bosons (qualitative idea only)

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcomes

Upon completion of the course, students will be able to explain nuclear properties and analyze nuclear forces and models governing nuclear structure and stability. They will interpret various nuclear decay processes using appropriate theoretical frameworks. Students will also classify elementary particles and understand fundamental interactions and symmetry principles. Furthermore, they will acquire a qualitative understanding of the Standard Model and electroweak interactions.

Suggested Readings

1. Introducing Nuclear Physics, K. S. Krane (Wiley India, 2008)

2. Nuclear Physics – Theory & Experiments, R.R. Roy & B.P. Nigam (New Age International, 2005)
3. Nuclear Physics in A Nutshell, C. A. Bertulani (1st Ed., Princeton University Press, 2007)
4. Concept of Nuclear Physics, B. L. Cohen (McGraw – Hill, 2003)
5. Nuclear Physics, S. N. Ghoshal (First edition, S. Chand Publication)
6. Nuclear & Particle Physics: An Introduction, B. Martin (Wiley, 2006)
7. Introduction to Elementary Particles, D. Griffiths (Academic Press, 2nd Ed. 2008)
8. Nuclear Physics, A. Kamal (Springer, 2014)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSC5102
Course Name: Statistical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Statistical Physics DSC	4	3	1	0	

Duration: 60 Hours(45L+15T)

Course Objective:

This course introduces students to statistical mechanics, which is part of the foundation of several branches of physics and has many applications beyond physics. The course demonstrates the profound consequences of an economical set of assumptions about nature known as the postulates of statistical mechanics. In particular, it shows how the postulates explain the general laws of thermodynamics as well as properties of classical and quantum gases, other condensed matter systems in equilibrium, and phase transitions.

Contents:

Unit I (5 Hours)

Review of thermodynamics and topics in probability theory: Quasistatic and nonquasistatic processes, laws of thermodynamics, entropy of a probability distribution, random walks.

Unit II (20 Hours)

Classical ensemble theory: Phase space, microstates and macrostates; Liouville's equation, Postulates of statistical mechanics, Microcanonical ensemble, Boltzmann relation for entropy, Definition of temperature, derivation of the laws of thermodynamics for macroscopic systems, Sackur-Tetrode equation, Canonical ensemble; partition function; Helmholtz free energy, Grand- canonical ensemble, Equivalence of the various ensembles, Application to various classical systems.

Unit III (12 Hours)

Quantum statistical mechanics: Indistinguishable particles in quantum mechanics. Bosons and Fermions. Bose-Einstein statistics, ideal Bose gas, photons, Bose-Einstein condensation. Fermi-Dirac statistics, Fermi energy, ideal Fermi gas. Density operator, Quantum Liouville equation. Pure and mixed states.

Unit IV

(8 Hours)

Interacting systems and phase transitions: Interacting spin systems. The Ising model. Exact solution of Ising model in 1-dimension, mean-field solution in higher dimensions. Paramagnetic and ferromagnetic phases. Critical exponents. Order parameter, Landau theory, Universality.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcomes

Upon successful completion of this course, students will be able to explain how the probabilistic behavior of microscopic constituents leads to the emergence of deterministic macroscopic laws governing thermodynamic systems. Relate the concepts of entropy and temperature as defined in statistical mechanics to their more familiar versions in thermodynamics. Solve for the thermal properties of classical and quantum gases and other condensed systems from a knowledge of their microscopic Hamiltonians. Appreciate that interactions between particles can explain the various phases of matter observed in nature, as well as the universality of critical exponents characterizing phase transitions.

Suggested Readings

1. Statistical Physics of Particles, Mehran Kardar (Cambridge University Press, 2007).
2. Statistical Mechanics, Kerson Huang (2 nd Edition, Wiley-India, 2008).
3. Statistical Mechanics, R.K. Pathria (Butterworth-Heinemann, 1996).
4. Statistical Mechanics: An Advanced course with problems and solutions, Ryogo Kubo (North- Holland, 1965).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5111
Course Name: Physics at the Nanoscale – I (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics at the Nanoscale- I (Theory) DSE	4	3	1	0	Quantum mechanics (DSC), Solid State Physics (DSC)

Duration: 60 Hours(45L+15T)

Course Objectives:

To introduce knowledge on basics of nanoscience and the fundamental concepts behind size reduction in various physical properties. More specifically, the student will be able to understand the different properties of materials in reduced scales.

Contents:

Unit I (12 Hours)

Quantum confined systems: Quantum confinement and its consequences, quantum wells, quantum wires, quantum dots and artificial atoms. Electronic structure from bulk to quantum dot. Review of density of states. Electron states in direct and indirect gap semiconductors-nanocrystals. Confinement in disordered and amorphous systems.

Unit II (10 Hours)

Dielectric properties: Coulomb interaction in nanostructures. Concept of dielectric constant for nanostructures and charging of nanostructures. Quasi-particles and excitons: Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasiparticles and excitons. Charging effects.

Unit III (11 Hours)

Optical properties: Optical properties and radiative processes: General formulation of absorption, emission and luminescence; Optical properties of heterostructures and nanostructures. Carrier transport in nanostructures: Coulomb blockade effect, scattering and tunneling of particle; applications of tunneling, single electron transistors. Surface defects.

Unit IV (12 Hours)

Basics of Characterization techniques: X-ray diffraction, Direct imaging by scanning electron microscope, transmission electron microscope, and scanning probe techniques.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The learner will be able to comprehend the significance of nanoscience and nanotechnology and its applications in various fields. The students will have in-depth knowledge of the behavior of various classes of materials in reduced dimensions.

Suggested Readings

1. Nanostructures-Theory & Modelling, C. Delerue and M. Lannoo (Springer, 2004)
2. Nanostructure, V. A. Shchukin, N. N. Ledentsov and D. Bimberg (Springer, 2004)
3. Characterization of Nanophase Materials, Z. L. Wang (Ed.) (Wiley-VCH, 2000)
4. Semiconductor Nanocrystal Quantum Dots, A. L. Rogach (Ed.) (Springer Wien NY, 2008)
5. Introduction to Nanotechnology, C. P. Poole Jr. & F. J. Owens (Wiley-Interscience, 2003)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5112
Course Name: Nanomaterials – I (Lab)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nanomaterials I (Lab.) DSE	4	0	0	4	Solid State Physics (Core lab), Electronics (Core lab)

Duration: 120 Hours(8 Hours/Week)

Course Objectives

The main goal of this course is to synthesis of different class of materials by various synthesis methods. The synthesis methods are designed based the fundamental learning from the corresponding theory course. As synthesised nano materials will be characterized by different analytical techniques and analysed with respect to size reduction in the respective physical properties. Based on the synthesis and characterization, the student would able to design nanomaterial for desired applications.

Contents:

LIST OF EXPERIMENTS

The student has to choose one experiment from each Unit.

Unit I: This unit includes the synthesis of nanomaterials by various methods (Any one technique will be given). (40-50 Hours)

1. Growth of nanoparticles by chemical routes.
2. Growth of nanophase by sputtering.
3. Growth of quantum dots by thermal evaporation.
4. Growth of nanoparticles by mechanical milling/attrition.
5. Growth of nanomaterials by nanopores-template method.
6. Growth of semiconductor quantum dots in matrices (glass/polymer etc).

Unit II: This unit consists of different characterization techniques – structure and morphology. (32-35 Hours)

1. Structural characterization of nanomaterials by XRD- determination of average grain size, lattice parameters, strains etc.

2. Structural characterization of nanomaterials by TEM - determination of grain size and its distribution.
3. Surface morphological characterization of nanomaterials by AFM.
4. Surface morphological characterization of nanomaterials by SEM.
5. Surface morphological characterization of nanomaterials by TEM.
6. Determination of pores size of nanomaterials by BET.

Unit III: This unit consist of different characterization techniques – vibrational spectroscopy and magnetic properties. (18-20 Hours)

1. Measurement and analyses of UV/VIS Absorption spectrum of nanomaterials.
2. Measurement and analysis of Photoluminescence spectrum of nanomaterials.
3. Measurement and analysis of Raman spectrum of nanomaterials.
4. Measurement and analysis of photoluminescence of nanomaterials at low temperatures.
5. Magnetization characterisation of magnetic nanoparticle by VSM.

Unit IV: This unit includes the various characterization techniques – Electronic structure, ferroelectric and thermal properties. (12-15 Hours)

1. Measurement of sensor property of nanomaterials.
2. Determination of stoichiometry of nanomaterials by XPS/EDAX/ESCA.
3. Measurement and analysis of ferroelectric properties of nanomaterials.
4. Thermal characterization of polymers by DSC technique.

Course Learning Outcomes

The students will get a better understanding of the concepts studied by them in the theory course and correlate with experimental observations. In addition, the students are exposed with thermal, microscopic, electrical and spectroscopic methods of characterization of nanomaterials.

Note: **The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment*

Suggested Readings

1. Nanotechnology, G. Timp (AIP press, Springer-Verlag, New York, 1999)
2. Nanostructured materials and nanotechnology, Hari Singh Nalwa. (Academic Press, USA, 2002)
3. Hand book of Nanostructured Materials and Technology, Hari Singh Nalwa. (Vol.1-5, Academic Press, USA, 2000)
4. Handbook of Nanoscience, Engineering and Technology, W. Gaddand, D. Brenner,
5. S. Lysherski and G. J. Infrate. (Electrical Engineering Handbook, CRC Press, 2012)

6. Sol-Gel Science, C.J. Brinker and G.W. Scherrer (Academic Press, Boston, 1994)
7. Nanoscale Characterization of Surfaces & Interfaces, N John Dinardo (Weinheim Cambridge: Wiley-VCH, 2000)
8. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Ray F. Egerton (Springer, 2005)
9. Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology), Roland Wiesendanger (Springer, 1998)
10. Chemistry of nanomaterials: Synthesis, properties and applications, CNR Rao et.al. (WileyVCH, 2004)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5113
Course Name: Advanced Electronics – I (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Electronics-I (Theory) DSE	4	3	1	0	Solid State Physics (DSC), Electronics (DSC)

Duration: 60 Hours(45L+15T)

Course Objectives

To enhance the understanding of basic design principles and constructional details of specialized semiconductor devices used for high frequency applications in modern communication networks and systems. To understand the use of semiconducting devices for diverse applications acting as signal/light sources, detection of signals and transduction of analog signals used in day to day electronics.

Contents:

Unit I (12 Hours)

Microwave Devices: Vacuum tube devices: Reflex klystron and magnetron. Transfer electron devices: Tunnel and Gunn diode, Avalanche Transit time devices (Read, IMPATT diodes, parametric devices).

Unit II (13 Hours)

Photonic Devices: Radiative transition and optical absorption, LED, semiconductor lasers, heterostructure and quantum well devices, charge coupled devices, photodetector, Schottky barrier and p-i-n photodiode, avalanche photodiode, photomultiplier tubes, Solar cells.

Unit III (13 Hours)

Memory Devices: MOSFET (n-MOS, p-MOS) and CMOS. Static and dynamic RAM, nonvolatile memories. Optical and magnetic memories.

Some other important devices: Piezoelectric sensors and actuators, Transducers (temperature, pressure, vacuum, magnetic field, vibration, particle detector). OLED, solid state battery and LCD.

Unit IV (7 Hours)

IC fabrication technology: MOSFET fabrication process. Substrate, dielectric, conducting and resistive layers. Lithography. Diffusion of impurities and deposition techniques.

Tutorial Component**(15 Hours)**

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

A student of this course is expected to have enhanced awareness of the constant evolution in the physics of semiconductor devices and materials, the basic device design along-with the standard technological procedures adapted in the semiconductor industry for IC manufacturing and mass production of semiconductor devices.

Suggested Readings

1. Physics of Semiconductor Devices, S. M. Sze and K. K. Ng (3rd Ed., Wiley, 2008)
2. Semiconductor devices Physics and Technology, S. M. Sze (2nd Ed., Wiley, 2008)
3. Microwave Devices and Circuits, S. Y. Liao (3rd Ed., Pearson, 2003)
4. Electronic Instrumentation and Measurement Techniques, W. D. Cooper and A. D. Helfrick (2nd Ed., Phi Learning, 2008)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: DSE5114
Course Name: Advanced Electronics – I (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Electronics- I (Lab.) DSE	4	0	0	4	Solid State Physics(DSC), Electronics (DSC), Electronics Lab (DSE)

Duration: 120 Hours(8 Hours/Week)

Course Objectives

The major objective of this course is to strengthen the designing techniques of electronic circuits through a standard set of experiments. It would help the students to suitably correlate them with the corresponding theory. Also to enable the student to find appropriate for circuit elements for given set of parameters and design the circuit on a bread board and find if there is trouble shooting and finally to demonstrate the working of the circuit for the given set of parameters.

Contents:

Group A : **Circuit Design and Analysis**

(40-45 Hours)

Unit I

Design of Analog Circuits(based on Transistors)

- 1. Amplifiers** (Circuit design of Low gain, Mid gain High Gain with the specified parameters of gain and collector current and V_{CC})
 Amplifier using Transistors:-
 Design Low Gain Amplifier
 Design Mid Gain Amplifier
 Design High Gain Amplifier
 Design Power Amplifier
 Design Tuned Amplifier/ Double Tuned Amplifier

or

2. **Oscillators**

Design RC Phase Shift Oscillator for given frequency values (Using Transistor & OP amp).

Design Wien Bridge Oscillator Using OP amp., Crystal Oscillators

Design Colpitts Oscillator (using transistors)

Design Relaxation Oscillator (using transistors)

Design Hartley Oscillator (using transistors)

Unit II: Operational Amplifier based experiments

(20-25 Hours)

This Unit Includes Design of operational circuits (linear and digital) using discrete and I.C. components. Phase sensitive detector, filters, multistage amplifiers, oscillators, wave shaping circuits.

1. OpAmp Circuits

Design Experiment/Ckt. -Offset Null, Non Inverted Input

Design Inverting amplifier for Various Voltage Gain & response

Design Summing Amplifier for Three Input Inverting Operational Amplifier

Design Summing Amplifier in differential configuration One and Two input

Design Voltage follower, Average Amplifier, Differentiator etc.

Design Experiment/Ckt. - Inverted Input Operational Amplifier

Design OP Amp Basic Integrator, Zero Crossing Detector, Peak Detector, Instrumentation Amplifier

Or

1. Design of Active Filters Using OP amp. In the given ranges of frequency Low Pass, High Pass, Band Pass

And Analysis using Bode Plots

Design of Passive Filters Using OP amp. In the given ranges of frequency Low Pass, High Pass, Band

And Analysis using Bode Plots

Unit III

(25-30 Hours)

Designing of Multivibrators (based on transistors and ICs)

Design Multivibrator Using Transistor- Astable, Monostable, Bistable for given time period and High /Low time; Pulse generator for given pulse width

Multivibrator Using Ic 555 Multivibrator Using Transistor- Astable, Monostable, Bistable for given time period and High /Low time

Multivibrator Using OP amp.- Astable, Monostable, Bistable for given time period and High /Low time

Or

Designing of Sweep Generators:-

A Sweep Generator using RC circuit

Constant Current Sweep Generator using UJT

Sawtooth Sweep Generator using UJT

Sawtooth Sweep Generator using Zener Diode

Bootstrap Sweep Generator

Sawtooth Sweep Generator using Triangular Wave

Phase Locked Loop:-

Design Various frequency lock range Circuit

Unit IV

(25-30 Hours)

Microcontrollers

Using standard self-wave and interfacing circuits for physics experiments. (I.V. characteristics, temperature controller, traffic light signals etc.)

or

learning Pspice

learning circuit designing on the software (using simple pn junction diode, RC circuits, filters using opamp) software

and to verify the outcome of the experiments performed in the previous units

or

Digital electronics experiments (for those students who have not performed any digital circuit experiments in B.Sc. nor in M.Sc.ist year, such students will be allocated following group of experiments in the beginning of the session)

Design of Combinational Logic circuits using Digital ICs :

Karnaugh Mapping

HALF- ADDER

FULL- ADDER

HALF- SUBTRACTOR

FULL- SUBTRACTOR

DEMULTIPLEXERS

ENCODERS, DECODERS

Design of Sequential Logic Circuits Using Digital ICs

FLIP FLOPS- RS, D, JK, MASTER SLAVE JK

REGISTERS- SERIAL, PARALLEL

COUNTERS- ASYNCHRONOUS, SYNCHRONOUS

Course Learning Outcomes

The student will gain practical knowledge of designing, assembling, and testing electronic circuits as well as understanding troubleshooting.

The skill will be helpful life long in the field where ever circuit design and applications are required

Note : The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment

Suggested Readings

1. Electronic Instrumentation and Measurement Techniques, W. D. Cooper and A. D. Helfrick (2nd Ed., Phi Learning, 2008)
2. Electronic Devices and Circuits, J. Millman and C. C. Halkias and S. Jit (4th Ed., McGrawHill, 2015)
3. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M. Sayer and A. Mansingh (Prentice Hall India, 2010)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/Semester I of 1 year MSc
Course Code: PH-DSE5115
Course Name: Advanced Nuclear Physics-I (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Nuclear Physics-I (Theory) DSE	4	3	1	0	Quantum Mechanics -I & II, Electrodynamics, Mathematical Physics Co-Requisite Nuclear & Particle Physics, Statistical Mechanics

Duration: 60 Hours(45L+15T)

Course Objectives

The course is designed to provide fundamental knowledge of nuclear experimental techniques, radiation detectors, nuclear electronics, signal processing, and reaction kinematics used in accelerator-based nuclear and particle physics experiments. It also aims to introduce modern detector technologies and the applications of nuclear techniques in various scientific and societal fields.

Contents:

Unit I: Interaction of radiation with matters & Radiation Detectors (13 Hours)

Radiation Detectors: Interaction of radiation with matters, Types of detectors: Gas detectors: Ionization chambers, Proportional counter, Multi-Wire proportional Counters (MWPC), Scintillation Detectors: Inorganic (NaI(Tl), CsI(Tl), BGO, BaF₂, La₂Br₃) and Organic (Anthracene & Plastic) Scintillators, Solid states Detectors: Si(Li), HPGe Clover and segmented HPGe Detectors, Surface Barrier Detectors, Passivated Detectors, Neutron Detectors, Basic principle and working of a neutron detectors (Liquid and solid based detectors)

Unit II: Nuclear electronics and Signal processing (11 Hours)

Nuclear electronics and Signal processing: Front-end linear (preamplifiers, Amplifiers, Single channel Analyser, MCA) and logical units for slow and fast signal processing. Coincidence technique (slow and fast), Data acquisition systems - CAMMAC and VME, Digital pulse processing (introduction only), NIM, ECL and TTL standard, types of noise, Nuclear Techniques & their Application: Methods for charge and mass identification, energy loss, Time of Flight (TOF), mass spectrometer, Neutron: TOF and Pulse shape discrimination.

Unit III: Experimental Techniques and Detector Arrays (11 Hours)

Detector array (Gamma-rays, neutrons, charge particles), Multiplicity, Charge particle, neutron and gamma-ray spectroscopy, Angular distribution and correlation, Brief ideas of multipolarity and transition probabilities, Weisskopf-estimate, Internal conversion coefficient and their ratios, Polarization and its measurement, Doppler shift and Doppler broadening, Methods for life time measurements: Delay coincidence, pulse beam (slope and centroid shift), recoil distance and Doppler shift attenuation method, measurement of magnetic and quadrupole moment (g -factor, Hyperfine interaction). Application of nuclear techniques in other areas (Medical, Archaeology, Material research, Agriculture etc).

Unit IV: Reaction Kinematics (10 Hours)

Nuclear Reactions: Classification and nomenclature of nuclear reaction, Conservation Laws, Kinematics of nuclear reaction, Cross sections in center of mass and laboratory frames, Potentials involved in nuclear reaction, Introduction to partial wave approach to nuclear reactions, Cross section using classical scattering, Rutherford cross section using classical approach, Orbiting, rainbow and glory scattering, Cross section in scattering of identical particles, Reciprocity theorem.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Upon successful completion of the course, students will develop a strong understanding of nuclear experimental techniques, radiation detectors, nuclear electronics, and signal processing methods used in accelerator-based experiments. They will acquire the theoretical and practical knowledge required to perform nuclear and particle physics experiments, analyze reaction kinematics and scattering processes, and understand the application of nuclear techniques in scientific research and societal applications.

Suggested Readings

1. Radiation Detection and Measurement, G. F. Knoll (3rdEd., John Wiley & Sons, Inc.,2000)
2. Physics & Engineering of Radiation Detection, S. N. Ahmed (Academic Press 2007)
3. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer Verlag 1987)
4. Nuclear Physics: Principles and Applications, J.S. Lilly (John Wiley & Sons, Inc.

5. Heavy ion reactions, Vol. I & II, R. A. Broglia & Aage Winther (Benjamin/Cummings, 1981)
6. Introducing Nuclear Physics, K. S. Krane (Wiley India, 2008)
7. Introduction to Nuclear Reactions, G.R. Satchler (2nd Edition, Palgrave Macmillan UK / Macmillan / Oxford University Press, 1990)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5116
Course Name: Advanced Nuclear Physics-I (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Nuclear Physics-I (Lab.) DSE	4	0	0	4	Nuclear and Particle Physics (DSC) Co-Requisite Advanced Nuclear Physics -1 (Theory)

Duration: 120 Hours(8 Hours/Week)

Course Objectives

The course introduces students to fundamental experimental techniques in nuclear physics, radiation interaction, detector response, and basic nuclear electronics. Students will gain hands-on experience with scintillation detectors, radiation measurements, spectroscopy, and detector calibration techniques.

Contents:

Unit I: Radioactivity and Radiation Interaction Studies

Experiments

1. Study of radioactive isotopes by thermal neutron activation analysis (neutron flux, growth of activity and half-life measurements)
2. Determination of the absolute disintegration rate of natural ^{40}K source using UX_2 source as a standard and deduction of the partial beta-decay half-life of ^{40}K
3. Absorption of gamma-rays in material media at different energies
4. Beta end point energy measurement using G-M detector set-up

Each student/group shall perform one experiment from this unit.

Unit II NaI(Tl) Scintillation Spectroscopy and Detector Characterization

Experiments

1. Investigation of energy response and calibration of a NaI(Tl) scintillation spectrometer based on gamma-ray spectroscopy
2. Determination of detection efficiency of a NaI(Tl) scintillation spectrometer
3. Detection of gamma rays using different scintillation detectors and their comparison (Energy response and energy resolution)

Each student/group shall perform one experiment from this unit.

Unit III Radiation Spectroscopy and Scattering Experiments

Experiments

1. Beta-ray spectroscopy using an anthracene scintillation spectrometer (Energy calibration and end-point energy measurement using Kurie plot)
2. Study of angular distribution of Compton scattered gamma rays using a scintillation spectrometer and deduction of total scattering cross-section
3. Alpha spectroscopy using a Si surface-barrier detector: Measurement of stopping power of alpha particles
4. Proportional counter: energy response and low-energy X-ray measurements

Each student/group shall perform one experiment from this unit.

Unit IV Experimental Techniques and Nuclear Electronics

Experiments

1. Pulse processing using a digital shaping unit: single and coincidence measurements
2. Energy and timing responses studies of fast scintillators, plastic detectors, BaF₂ CeBr₃ and LaBr₃ etc.
3. Determination of gas pressure in a vacuum chamber using different pumps and vacuum pressure gauges

Each student/group shall perform one experiment from this unit.

Course Learning Outcomes

After completion of the course, students will be able to: Understand the principles of radiation detection and measurement, Calibrate scintillation detectors and analyze detector response, Perform gamma-ray and beta-ray spectroscopy, Study radiation interaction with matter, Use nuclear electronics and pulse processing systems, Acquire practical skills in vacuum technology and detector instrumentation.

Suggested Readings

1. Radiation Detection and Measurement, G. F. Knoll (John Wiley & Sons, Inc. 3rd Ed., 2000)
2. Physics & Engineering of Radiation Detection, S. N. Ahmed (Academic Press 2007)
3. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer-Verlag 1987)
4. Nuclear Physics: Principles and Applications, J.S. Lilly (John Wiley & Sons, Inc. 2002)
5. Radiation Detection for Nuclear Physics: Methods and Industrial Applications, David Jenkins (IOP Publishing, 2020)
6. Practical Gamma-ray Spectrometry, Gordon R. Gilmore (John Wiley & Sons, Ltd 2nd Ed., 2008)

7. Measurement and Detection of Radiation, Nicholas Tsoulfanidis (Taylor & Francis, 5th Ed., 2021)

General Note: The list of experiments is tentative and may be modified depending upon: 1) Availability of instruments, 2) Maintenance schedules, 3) Radiation safety considerations, 4) Availability of radioactive sources, 5) Batch strength and laboratory infrastructure. 6) Interested students may also undertake minor project work related to detector development, data acquisition, spectroscopy, or radiation measurements.

A visit to an Indian accelerator facility may be organized, and students may be required to submit a report on the visit. The report will be evaluated as a part of the continuous evaluation process.

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5117
Course Name: Fundamentals of Spectroscopy (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Fundamentals of Spectroscopy (Theory) DSE	4	3	1	0	Quantum Mechanics-I & II (DSC)

Duration: 60 Hours(45L+15T)

Course Objectives

To teach the students the nature of molecular spectra (rotational, vibrational, electronic and Raman) of polyatomic molecules (including diatomic) classified on the basis of their topological symmetry using group theoretical approach.

Contents:

Unit I (15 Hours)

Molecular symmetry and group theory: Symmetry operations and point groups for molecules, the representation of a point group, matrices and basis sets, reducible and irreducible representations, application to vibrational spectroscopy.

Unit II (12 Hours)

Theory: Microwave, Infrared, Raman, far infrared and UV-VIS spectra of diatomic and polyatomic molecules, far infrared and UV-VIS spectra of gases, liquids and solids, determination of force constants and force field from isotropic molecules and spectroscopic data, spectroscopic instrumentation, diffuse reflectance spectroscopy, fluorescence spectroscopy, confocal microscopy, near-field scanning optical microscopy.

Unit III (8 Hours)

Raman Scattering: Raman and Rayleigh Scattering, Polarizability, Quantum theory of Raman effect, Rotational, Vibrational and Rotation-vibration Raman spectra of diatomic and polyatomic molecules, correlation of infrared and Raman spectra.

Unit IV (10 Hours)

Nuclear Magnetic Resonance Spectroscopy: General theory of high-resolution NMR spectroscopy, experimental technique, analyses of NMR spectra, spin-spin coupling, chemical

shift. Electron Spin Resonance Spectroscopy: Experimental methods, derivative spectra, hyperfine structure, anisotropic systems

X-ray Photo-electron Spectroscopy: Instrumentation, XPS spectra and its interpretations, chemical shift, oxidation state analysis

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Learning Outcomes:

Students learn to assign the point groups to polyatomic molecules (including diatomic) and to predict the nature of their vibrational spectra depending on their symmetry using group theoretical treatment. The complete picture of rotational, vibrational and electronic spectra of polyatomic molecules will be comprehended. This kind of specialization is expected to provide a larger scope for research in the various related and interdisciplinary areas. At the end the student should be able to apply the correct formalism for analysing the different spectroscopic phenomena (and their corresponding data in their spectral range).

Suggested Readings

1. Molecular Symmetry, D. J. Willock (John Wiley & Sons, 2009)
2. Molecular Spectra and Molecular Structure, G. Herzberg (Van Nostrand, 1950)
3. Group Theory and Physics, S. Sternberg (Cambridge Univ. Press, 1995)
4. Modern Spectroscopy, J. M. Hollas (4th Ed., John Wiley, 2004)
5. Molecular Quantum Mechanics, P Atkins & R. Friedman (Oxford Univ. Press, 2005)
6. Molecular Physics, W. Demtroder (Wiley-VCH, 2005)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5118
Course Name: Lasers and Spectroscopy (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Lasers and Spectroscopy (Lab.) DSE	4	0	0	4	Electronics (DSE Lab.), Wave & Optics (DSE Lab.), Solid State Physics (DSE lab.)

Duration: 120 Hours(8 Hours/Week)

Course Objectives

Provide an exposure to instrumentation such as light sources, spectrometers, optical detectors, optical and opto-mechanical components, gain experience in spectroscopic techniques for measurement, analyses of various kinds of spectra

Contents:

Unit I (30 Hours)

1. Measurement and analyses of electronic spectra of molecules and liquids.
2. Measurement and analyses of vibrational spectra of molecules and liquids.
3. Measurement and analyses of rotational spectra of molecules and liquids.

Unit II (30 Hours)

1. Measurement and analyses of absorption/transmission spectra of solids.
2. Measurement and analyses of reflection spectra of solids.
3. Determination of optical constants of thin films by ellipsometry.

Unit III (30 Hours)

1. Measurement and analyses of Raman spectra of liquids/solids.
2. Measurement and analyses of fluorescence spectra of liquids/solids.
3. Measurement of absorption/transmission/reflection spectra at low temperatures.

Unit IV (30 Hours)

1. Measurement and analyses of photoluminescence spectra of nanomaterials.
2. Measurement and analyses of XPS of nanomaterials/thin films/bulk samples.

NOTE *This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work.*

The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment

Course Learning Outcomes

The student would be equipped with an in-depth knowledge of laser-based metrologies; spectroscopic techniques that can be applied in wide-ranging fields spanning semiconductors, pharmaceutical, chemical, food-processing industries, to name a few.

Suggested Readings

1. Lasers: Fundamental and Applications, Graduate Text in Physics, K. Thyagarajan, Ajoy Ghatak (2nd edition, Springer, 2002)
2. Polarization of light, Ajoy Ghatak and Arun Kumar (Mc GrawHill Education, 2012)
3. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000)
4. Teaching laser physics by experiments, (Am. J. Phys., 2011, <http://doi.org/1-3488984>)
5. Infrared Spectroscopy, Fundamentals and Applications, Barbara Stuart, (Wiley & Sons, 2004)
6. Modern Raman Spectroscopy-a practical approach, E. Smith and G. Dent (John Wiley & Sons, 2004)
7. Spectroscopic Ellipsometry: Principles and Applications, H. Fujiwara (Wiley& Sons, 2007)
12. Introduction to Holography, Vincent Toal, (CRC Press, 2012)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5119
Course Name: Advanced Solid State Physics-I (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Solid State Physics-I (Theory) DSE	4	3	1	0	Quantum Mechanics-1 & II (DSC), Solid State Physics (DSC)

Duration: 60 Hours(45L+15T)

Course Objectives

This course intends to provide knowledge of conceptual advanced level solid-state physics. In addition, this course aims to provide a general introduction to theoretical and experimental topics in solid state physics by covering electrical transport, dielectric, optical, and magnetic properties of solids.

Contents:

Unit I (9 Hours)

Transport Properties of Solids: Boltzmann transport equation, resistivity of metals and semiconductors, Fermi surfaces – determination, Landau levels, de Hass van Alphen effect, Quantum Hall effect- Integral quantum Hall effect and. Magnetoresistance.

Unit II (18 Hours)

Dielectric and Optical Properties of Solids: Dielectrics and ferroelectrics, macroscopic electric field, local field at an atom, dielectric constant and polarizability, ferroelectricity, antiferroelectricity, piezoelectric crystals, ferroelasticity, electrostriction. Optical constants and their physical significance, Reflectivity in metals, plasmonic properties of metals, determination of band gap in semiconductors: direct and indirect band gap, defect mediated optical transitions, excitons, photoluminescence, Electroluminescence

Unit III (10 Hours)

Magnetism: Types of magnetic materials, Quantum theory of paramagnetism, Hund's rule, Ferromagnetism, antiferromagnetism: molecular field, Curie temperature. Domain theory, Magnetic Anisotropy, Magnetic interactions, Heitler-London method, exchange and

superexchange, magnetic moments and crystal-field effects, spin-wave excitations and thermodynamics, antiferromagnetism, Magnetostriction.

Unit IV

(8 Hours)

Superconductivity: Phenomenological theories of superconductivity, BCS theory, two fluid and Pippard's theory, London equations Flux quantization, BCS ground state and energy gap, Cooper pairs, coherence, vortex states Ginzburg-Landau theory, Josephson effect, SQUID, introduction to high-temperature superconductors.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The students should be able to elucidate the important features of advanced topics in solid state physics by covering dielectric and optical properties, magnetism, and superconductivity.

Suggested Readings

1. Solid State Physics, N. W. Ashcroft and N.D. Mermin (1st Ed., Cengage Learning, 2003)
2. Elementary Excitations in Solids, D. Pines (CRC press, 1999)
3. The Wave Mechanics of Electrons in Metals, S. Raimes (North-Holland, 1970)
4. Lecture Notes on Electron Correlation & Magnetism, P. Fazekas (World Scientific, 1999)
5. Introduction to Superconductivity, M. Tinkham (Dover Publications Inc., 2004)
6. Condensed Matter Physics, M. Marder (2nd Ed., John Wiley & Sons, 2010)
7. Principles of Condensed Matter Physics, P.M. Chaikin and T.C. Lubensky (Cambridge University Press, 1995)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5120
Course Name: Advanced Solid State Physics– I (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Solid State Physics-I (Lab.) DSE	4	0	0	4	Solid State Physics (DSE Lab), Electronics (DSE Lab.)

Duration: 120 Hours(8 Hours/Week)

Course Objectives

To carry out advanced level experiments to determine the optical, dielectric and magnetic properties of the materials. Also, to expose the students to various materials characterisation techniques.

Contents:

List of Experiments

UNIT-I: Electronic Conductivity of Metal/Semiconductor Materials: (32 Hours)

1. Determine the value of the Hall coefficient for the given sample and calculate the value of the mobility of the carriers and the carrier concentration. (Transverse magnetoresistance coefficient is given)
2. Determine the transverse magneto-resistance coefficient and the resistivity for the given sample and calculate the value of the mobility of the carriers and the carrier concentration. (R_H is given).
3. Measure Hall coefficient, dc conductivity and mobility of a semiconductor at different temperatures (77 K to room temperature).
4. Resistivity measurements using four probe technique
5. Resistivity of semiconducting materials using Van-der Pauw method

UNIT-II: Semiconducting Devices (28 Hours)

1. Estimating the band gap, ideality factor of semiconducting materials used in a PN junction from the temperature dependent current-voltage measurements.
2. Transfer characteristics and gain of a FET
3. Photocurrent measurements of semiconducting materials

UNIT-III: Ferroelectric, ferromagnetic, and dielectric properties of materials (32 Hours)

1. B-H curve of iron, steel, and nickel

2. Determine the relaxation time for a given sample and find the value of 'g' using electron spin resonance.
3. Determine the Curie temperature of a given ferroelectric material by measuring the temperature dependent capacitance.

UNIT-IV: Morphological, structural, optical, and magnetic properties of materials

(28Hours)

1. A research level project (individual or Group of students) based on the experiments given in the above units.

NOTE

This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work. The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment

Course Learning Outcomes

The students will get a better understanding of the concepts studied by them and correlate both theory and experiments. The students will learn about the various materials characterization techniques and analysis.

Suggested Readings

1. Optical Properties of Photonic Crystals, K. Sakoda (Springer, 2001)
2. The Rietveld method, R.A.Young (IUCR-Oxford University Press, 1995)
3. Fundamentals of Crystallography, C.Giacovazzo (IUCR-Oxford University Press, 2002)
4. Characterization of nanophase materials, Zhon Ling Wang (Wiley-VCH Verlag GmbH, 2000)
5. Physical Properties of Semiconductors, C. M. Wolfe, J.R.N.Holonyak and G.E.Stillman (Prentice Hall International Inc., London, 1989).
6. Handbook on Semiconductors, Vol. 1-4., T.S. Moss, Ed., by S.P.Keller (NorthHolland, Amsterdam, 1980)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5131
Course Name: General Theory of Relativity and Cosmology-I

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
General Theory of Relativity and Cosmology - I DSE	4	3	1	0	Classical Mechanics, Electrodynamics

Duration: 60 Hours(45L+15T)

Course Objectives:

The primary objective is to teach the physical and mathematical basis of Einstein's relativistic theory of gravitation, as well as concepts pertaining to the certain intriguing features and phenomena that culminate from such a theory, and the experimental detection of the same.

Contents:

Unit I (13 Hours)

Basic concepts, Tensors, Geodesics and Curvature:

Equality of inertial and gravitational masses. Eötvös torsion balance. Equivalence principle in strong and weak forms. Principle of general covariance. General Relativity versus Mach's principle. Definition and categorization of tensors. Metric tensor. Symmetric and antisymmetric tensors. Tensor densities. Levi-Civita tensor density. Dual tensors. Tensor calculus. Local flatness. Affine connection. Geodesic equation and particle dynamics. Congruence of curves. Parallel transport along a curve. Covariant differentiation. Affine geodesics. Curvature tensor, its properties and contractions. Einstein tensor. Bianchi identities. Irreducible curvature modes: Weyl tensor.

Unit II (10 Hours)

Gravitational Field equations, Lagrangian formulation and Coupled systems:

Weak and static field limit of the geodesic equation. Derivation of Einstein's field equations considering the limiting Newton's gravity, uniqueness of the curvature tensor, and the conservation of the Energy-momentum tensor. Einstein's field equations from action principle – the Einstein-Hilbert Lagrangian. Minimal gravitational coupling to scalar and vector fields.

Unit III

(10 Hours)

Spherically symmetric metric, Singularities, and Black hole:

Einstein's equations for isolated massive objects in spherically symmetric space-times. Schwarzschild exterior solution. Coordinate and curvature singularities. Radial motion towards singularities. Analytic extension of the Schwarzschild solution in lightcone coordinates and Eddington-Finkelstein coordinates. Event horizon. Black hole. Maximal analytic extension in Kruskal-Szekres coordinates. Kruskal diagram.

Unit IV

(12 Hours)

Particle trajectories, frequency shifts, Experimental tests of General Relativity:

Geodesics in Schwarzschild space-time. Effective potential and the constants of motion. Circular orbits and their stability. Motion in the equatorial plane. Bending of light rays. Precession of planetary perihelia. Gravitational frequency shift. Pound-Rebka experiment. Rader echo delay. Parametrized post-Newtonian formalism.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes: Those taking this course are expected to have a clear understanding of the geometrical aspects of Einstein's theory of gravity, and be able to make a rigorous usage of mathematical tools, such as tensors, as well as determine the evolution profiles of gravitating systems by solving the Einstein's field equations which are a set of coupled partial differential equations. Furthermore, they would have a rigorous training on the mathematical treatment of black holes, as well as on the experimental detection of related phenomena.

Suggested Reading

1. *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*, Steven Weinberg (John Wiley & Sons, 1972).
2. *Introducing Einstein's Relativity*, Ray d'Inverno (Clarendon Press, Oxford, 1992).
3. *The Classical Theory of Fields: Volume 2 (Course of Theoretical Physics Series)*, L.D. Landau and E.M. Lifshitz (Butterworth-Heinemann, Elsevier).

4. *Classical Fields: General Relativity and Gauge Theory*, Moshe Carmeli (World Scientific, 2001).
5. *A First Course in General Relativity (Second Edition)*, Bernard F. Schutz (Cambridge University Press, 2009).
6. *An Introduction to Relativity*, Jayant V. Narlikar (Cambridge University Press, 2010).
7. *Spacetime and Geometry: An Introduction to General Relativity*, Sean M. Carroll (Pearson Education, publishing as Addison-Wesley, 2004).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5132
Course Name: Condensed Matter Physics-I

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Condensed Matter Physics I DSE	4	3	1	0	Solid stated Physics

Duration: 60 Hours(45L+15T)

Course Objectives

Utilizing the basic concepts of solid state physics, the quantum theory of lattice dynamics and thermal neutron scattering would be extensively discussed in this course. The detailed theory of Mossbauer Effect would also be discussed.

Contents:

Unit I (12 Hours)

Lattice dynamics in 3-dimensions. Relations among atomic force constants under various general operations. Acoustic and optical modes. Normal modes. Quantization of lattice vibrations. Phonons, zero-point energy, quantum crystals. Stefan-Boltzmann law. Van Hove singularities. Lindemann melting criterion.

Unit II (12 Hours)

Theory of Thermal Neutron Scattering : Double differential scattering cross-section. Space-time dependent correlation functions and their properties. Dynamical structure factor of (i) a harmonic crystal, zero phonon and one phonon processes, (ii) non-interacting gas and (iii) a simple liquid.

Unit III (10 Hours)

Mossbauer Effect: Lamb-Mossbauer recoilless fraction. Atomic motions, Isomer shift. Quadrupole splitting. Magnetic splitting. Second order Doppler shift.

Unit IV (11 Hours)

Free electron Green's function, its Fourier transform and their relationships to the density of states. Green function of a system subject to small perturbation. Rigid band model and other applications to alloys etc.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

A student of this course is expected to thoroughly understand the concepts of lattice dynamics and neutron scattering theory along with their application in Mossbauer spectroscopy. In addition, the students would be able to perform various analytical as well as numerical calculations needed for understanding the quantum theory of solids.

Suggested Readings

1. Solid State Physics, Neil W. Ashcroft & N. David Mermin (Harcourt Publishers, 1976)
2. Solid State Physics, Gerald Burns (Academic Press, 1985)
3. Solid State Physics, Walter A. Harrison (Dover Publications, 1980)
4. Solid State Physics: An introduction to Principles of Materials Science, Harald Ibach and Hans Luth (Springer, 2003)
5. Solid State Physics, Advances in research and applications, Supplement 3, F. Seitz and D. Turnbull (Eds.) Theory of lattice dynamics in harmonic approximation, A.A. Maraduddin, E.W. Montroll and G.H. Weiss (Academic Press, 1963)
6. Theory of thermal neutron scattering, W. Marshall & S.W. Lovesey (Oxford Univ. Press, 1971)
7. Quantum Theory of Solids Part A & B, Callaway (Academic Press, 1974)
8. Mossbauer Effect : Principles and Applications, G. K. Wertheim (Academic Press, 1964)
9. The Mossbauer Effect, Hans Fraunfelder (W.A. Benjamin, 1963)
10. Quasielastic neutron scattering for the investigation of diffusive motions in solids and liquids Springer tracts in modern physics Vol. 64, Tasso Springer (Springer-Verlag, 1972)
11. Superconductivity, V.L. Ginzburg and E.A. Andryushin (World Scientific, 1994)
12. Introduction to Superconductivity and high-T_c materials, Michel Cyrot and Davor Pavuna, (World Scientific, 1992)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5133
Course Name: Plasma Physics -I

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Plasma Physics-I DSE	4	3	1	0	Solid state Physics, Quantum mechanics I & II

Duration: 60 Hours(45L+15T)

Course Objectives

Plasma physics is an important subject for a large number of research areas, including space plasma physics, solar physics, astrophysics, controlled fusion research, high-power laser physics, plasma processing, and many areas of experimental physics. The primary learning outcome for this course is for the students to learn the basic principles and main equations of plasma physics, at an introductory level, with emphasis on topics of broad applicability.

Contents:

Unit I (12 Hours)

Plasmas in nature, Saha equation, Comparison between real gaseous and plasmas, plasma examples. Criteria of plasmas, Microscopic description: Debye shielding, plasma frequency, plasma parameters, Coulomb collisions, Collisions in fully ionised plasma, Diffusion and resistivity., Plasma conductivity, Basics of Plasma production in the laboratory.

Unit II (12 Hours)

Particle Orbit theory: Motion of a charged particle in electric and magnetic fields curvature, gradient and external force drifts. Magnetic mirrors and their applications, Earth magnetic mirror, The loss cone, The effect of time-dependent electric and magnetic fields, polarisation drift and current, Heating by adiabatic compression, Ohmic Heating, RF Heating.

Unit III (14 Hours)

Electron plasma wave, ion-acoustic wave, electromagnetic wave in unmagnetized plasmas, Controlled thermonuclear: magnetically confined open and closed systems (linear pinch, mirror machine and Tokamak). Laser-plasmas: inertially confined system.

Kinetic theory of Plasma: Vlasov equation, Solution of linearised Vlasov equation, Langmuir waves, Ion-sound waves, Wave-particle interaction and Landau damping. Two-stream instability (linear and quasi-linear theory)..

Unit IV

(7 Hours)

Statistical description of plasmas, B.B.G.K.Y. hierarchy of equations, Boltzmann-Vlasov equation, Particle-In-Cell simulation method, demonstration of wave behaviour using PIC code.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

On completion of the course the student shall be able to: Define, using fundamental plasma parameters, under what conditions an ionised gas consisting of charged particles (electrons and ions) can be treated as a plasma. Distinguish the single particle approach, fluid approach and kinetic statistical approach to describe different plasma phenomena. Classify the electrostatic and electromagnetic waves that can propagate in magnetised and nonmagnetised plasmas, and describe the physical mechanisms generating these waves. Define and determine the basic transport phenomena such as plasma resistivity, diffusion (classical and anomalous) and mobility as a function of collision frequency and of the fundamental parameters for both magnetised and non-magnetised plasmas. Formulate the conditions for a plasma to be in a state of thermodynamic equilibrium, or non-equilibrium, and analyse the stability of this equilibrium and account for the most important plasma instabilities. Explain the physical mechanism behind Landau damping and make calculations in this area using kinetic theory

Suggested Readings

1. Introduction to Plasma Physics, F. F. Chen (Plenum Press, 1984)
2. Principles of Plasma Physics, N. A. Krall and Trivelpiece (San Francisco Press, 1986)
3. Introduction to Plasma Physics, R.J. Goldston and P.H. Rutherford (IOP, 1995) 1.
4. Introduction to Plasma Theory, D.R. Nicholson (Wiley, USA, 1983)
5. Fundamentals of Plasma Physics, J. A. Bittencourt (Springer, New York, 2004).
6. Fundamentals of Plasma Physics, P.M. Bellan (Cambridge, UK, 2006).
7. Cap, F. F, Handbook on Plasma Instabilities (Academic Press, New York, 1976).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5134
Course Name: Particle Physics I

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Particle Physics I DSE	4	3	1	0	Classical Mechanics, Quantum Mechanics I & II, Electromagnetic Theory Co-requisite: Quantum Field Theory I

Duration: 60 Hours(45L+15T)

Course Objectives

This course is designed to provide a balanced introduction to elementary particle physics, covering the theoretical concepts and with the range of observable phenomena related to particle physics. Further, the students will be able to gain knowledge on important topics in particle physics including Kinematics of Decays and Cross-section, Space-time Symmetries, and Processes in QED.

Contents:

Unit I (5 Hours)

Fundamental Building Blocks and the nature of Interactions, Conservation Laws: Energy, Angular Momentum, electromagnetic Charge, Lepton flavor and Baryon Numbers. Natural Units system. Order of Magnitude estimation a) Bohr's atomic radius, b) Compton wavelength of electron, c) cross-section in relativistic and non-relativistic limit $e\gamma \rightarrow e\gamma$, $e e \rightarrow \gamma^* \rightarrow \mu\mu$. Estimation of the radius associated with the lightest hadron, Estimation of Decay width of a particle from decay time.

Unit II (10 Hours)

Space-time Symmetries: Angular momentum; Parity Transformation of Fields and particle states, Charge Conjugation of Fields and Particle States Determination of spin, intrinsic parity and charge conjugation of π , $\pi^\pm$, neutrino, Multi-Photon States. CP Symmetry, Time-Reversal and CPT Symmetries, CPT Theorem, Signature of Parity Violation. Kinematics of Decays and Cross-section: Relativistic Kinematics: Momentum and Energy Covariance, Mandelstam variables s, t, u for $2 \rightarrow 2$, Kinematics for decay/scattering to n (> 2) particles. Dalitz plots, Boost invariant quantities and their importance, pseudo-rapidity η , and azimuthal angle ϕ .

Unit III (18 Hours)

Isospin and Charge Independence of Nuclear Force, Isospin-SU(2); SU(2) quadratic Casimir and importance of I , SU(2) multiplets, Iso-spin of pions and anti nucleons, Isospin addition

rule, Isospin states for Nucleon -Nucleon system and Pion Nucleon system, Isospin amplitudes of Nucleon Nucleon scattering and Pion Nucleon scattering, Qualitative Discussion of Baryon and Meson Resonances. Strangeness and Hypercharge Quantum Number, Gell-Mann-Nishijima Relation, $SU(2) \times Y$ as symmetry group for hadrons with $\mathbf{I}_k$ and $\mathbf{Y}$ as generators. Motivation for Higher symmetry: Clustering of multiple states with same spin-parity, Appearance of light hadronic states with multiplicity 8. $SU(3)$ symmetry, Gell-Mann matrices and properties of structure constants, Representations of $SU(3)$: Conjugate and adjoint. Wavefunctions of mesons and baryons in terms of quarks and antiquarks. Necessity of color. Number of colors, R-ratio, pion-decay.

Unit IV (12 Hours)

Flux of initial particles in scattering and measured integrated Luminosity. Decay width of particle decaying into 2 and 3 particles. Two and Three body Phase space Integrals, Multiparticle production as cascading decays, Fermi's Golden rule and Definition of scattering cross-section. Matrix element, cross-sections and helicity structures in $e + e \rightarrow \mu + \mu$ Bhabha scattering, Compton scattering. Phenomenological lagrangians and their use to describe meson decays

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Relativistic dynamics, esp. in the context of multiparticle interactions. The role of symmetries, both discrete and continuous in understanding particle interactions and their classification. $SU(3)$ and quark model. Based on observables, drawing up a theory of particle interactions. Fermi theory of beta decay.

Suggested Readings

1. An Introductory Course of Particle Physics, Palash B. Pal (CRC Press, 2015)
2. Introduction to Elementary Particles, D. Griffiths (2nd Ed., Wiley-VCH, 2008)
3. Introduction to High Energy Physics, D. H. Perkins (Cambridge University Press)
4. Quarks & Leptons, F. Halzen and A. D. Martin (John Wiley, 1984)
5. Elementary Particle Physics, S. Gasiorowicz (John Wiley, 1966)
6. Elementary Particles and the Laws of Physics, R. P. Feynman and S. Weinberg (CambridgeUniversity Press, 1999)
7. Introduction to Elementary Particle Physics, A. Bettini (Cambridge University Press, 2008)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5135
Course Name: Quantum Field theory I

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Field Theory I, PH-DSE	4	3	1	0	Classical Mechanics, Quantum Mechanics I & II, Electromagnetic Theory

Duration: 60 Hours(45L+15T)

Course Objectives

Quantum Field theory is one of the foundational fields in Theoretical Physics. It bridges together Quantum Mechanics and Special Relativity using new mathematical tools. The aim of part one of this course is to introduce these mathematical formalisms to the students and to teach them their applications.

Contents:

Unit I (7 Hours)

Quantum mechanics of many particle systems. The need for QFT (relativity, many-body and interactions). Review of Lagrangian of continuous systems. Canonical fields as generalized coordinates. Euler-Lagrange equations. Noether's theorem: examples in nonrelativistic and relativistic field theories; translation, rotation, Lorentz boost/Galilean transformation and internal symmetry transformations. Canonical quantization of the free scalar field Commutation relations, Energy momentum tensor,

Unit II (12 Hours)

Normal ordering. Propagators. Causality. n-point Green's function of elementary and composite operators. Interacting scalar fields. Perturbation Expansion of correlation functions. Time-ordering and Wick's theorem. S-matrix and Cross-sections. Feynman diagrams (Scalar QED) and calculation of cross sections. Crossing symmetry.

Unit III (11 Hours)

Symmetry of a complex scalar field Lagrangian and Maxwell field. Need for gauge-fixing Quantizing the Maxwell-field in a covariant gauge; physical state condition; spectrum. Irreducible representations of the Lorentz group, connection to quantum fields. The Dirac

field as a representation of $SO(3,1)$ (notion of $SL(2,C)$). Weyl, Majorana and Dirac fermions. Quantization of the Dirac field

Unit IV (15 Hours)

Quantum Electrodynamics; Feynman rules, S-matrices and tree-level cross-sections for simple processes, Gaussian integrals and power series expansion; Path integrals in Quantum Mechanics and Field Theory; Functional differentiation and integration (free scalar, vector and spinor)

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The students will learn about the role played by symmetries in studying classical and Quantum Field theories. Two different formalisms, namely covariant quantization and path integral quantization, will be taught. They will learn how to apply these in computing treelevel scattering amplitudes and cross-sections in various quantum Field theories, including Quantum Electrodynamics.

Suggested Readings

1. The Quantum Theory of Fields, Volume 1: Foundations, Steven Weinberg (Oxford University Press, 2005)
2. An Introduction to Quantum Field Theory, M. E. Peskin & D.V. Schroeder (Westview Press, 1995)
3. Lectures on Quantum Field Theory, Ashok Das (World Scientific, 2008)
4. Relativistic Quantum Mechanics, J.D. Bjorken and S. Drell (McGraw-Hill, 1964)
5. Relativistic Quantum Fields, J.D. Bjorken and S. Drell (McGraw-Hill, 1964)
6. Quantum Field Theory, C. Itzykson and J-B Zuber (McGraw-Hill, 1980)
7. Introduction to Relativistic Quantum Field Theory, S. Schweber (Row, Peterson, 1961)
8. Quantum Field Theory, L. H. Ryder (Cambridge University Press, 1996)
9. Introduction to Quantum Field Theory, P. Roman (John Wiley, 1969)
10. The Quantum Theory of Fields, Vol.2: Modern Applications, S. Weinberg (Oxford Univ. Press, 2005)
11. Introduction to the Theory of Quantized Fields, N.N. Bogoliubov & D.V. Shirkov (Nauka, Moscow, 1984)
12. An Introduction to Quantum Field Theory, M. E. Peskin & D.V. Schroeder (Westview Press, 1995)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5136
Course Name: Basics of Astronomy and Observational Techniques

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Basics of Astronomy and Observational Techniques DSE	4	3	1	0	

Duration: 60 Hours(45L+15T)

Course Objectives

This course covers a survey of modern astronomy basics from an observer's perspective, how data from distant sources is obtained through modern telescopes and detectors and is then interpreted.

Contents:

(18 Hours)

Unit I

Observational Data: Astronomical Coordinates- Celestial Sphere, Horizon, Equatorial, Ecliptic and Galactic Systems of Coordinates, Conversion from one system of coordinates to another, Magnitude Scale- Apparent and absolute magnitude, distance modulus. Determination of mass, luminosity, radius, temperature and distance of a star, Colour Index, Stellar classification – Henry-Draper and modern M-K Classification schemes, H-R Diagram, H-R Diagram of Clusters, Empirical Mass- luminosity relation.

Unit II

(12 Hours)

Telescopes & Instrumentation: Different optical configurations for Astronomical telescopes, Mountings, plate scale and diffraction limits, telescopes for gamma ray, X-ray, UV, IR, mm and radio astronomy, Stellar Photometry - solid state, Photo-multiplier tube and CCD based photometers, Spectroscopy and Polarimetry using CCD detectors.

Unit III

(8 Hours)

Sun: Physical Characteristics of sun- basic data, solar rotation, solar magnetic fields, Photosphere - granulation, sunspots, Babcock model of sunspot formation, solar atmosphere – chromosphere and Corona, Solar activity- flares, prominences, solar wind, activity cycle, Helioseismology.

Unit IV

(7 Hours)

Variable Stars & Asteroseismology: Photometry of variable stars, differential photometry, extinction coefficients, Classes of variable stars, Period-Mean density relationship, Classical Cepheids as distance indicators, pulsation Mechanisms.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will demonstrate a basic understanding of various aspects of observational astronomy and how data is acquired and interpreted to obtain physical properties of a variety of astronomical objects.

Suggested Readings

1. Astronomy, The Evolving Universe, M. Zeilik (Cambridge University Press, 2002)
2. Introduction to Astronomy & Cosmology, I. Morrison (Wiley, 2008)
3. Telescopes and Techniques, C. R. Kitchin (Springer, 1995)
4. Astronomical Photometry, A. A. Henden & R. H. Kaitchuk (Willmann-Bell, 1990)
5. An Introduction to Astronomical Photometry, E. Budding (Cambridge University Press, 1993)
6. Universe, R. A. Freedman & W. J. Kaufmann (W. H. Freeman & Co., 2008)
7. Fundamental Astronomy, H. Karttunen et al. (Springer, 2003)
8. Solar Astrophysics, P. V. Foukal (Wiley-VCH, 2004)
9. Fundamentals of Solar Astronomy, A. Bhatnagar & W.C. Livingston (World Scientific, 2005)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5137
Course Name: Radio Astronomy and Instrumentation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Radio Astronomy and Instrumentation DSE	4	2	0	2	

Duration: (30L+ 60P) 90 Hours

Course Objectives

The objective of this course is to introduce the basic principles of radio astronomy and the instrumentation used to detect radio-frequency electromagnetic radiation from astrophysical sources. Emphasis is placed on solar radio emission, antenna systems, signal detection, and interpretation of time-dependent signals.

Laboratory work will emphasise assembly, safe operation, controlled pointing, receiver settings, observational logs, signal-strength measurements, simple scans, plotting, and cautious interpretation. The course will remain within the scope of small, manually operable systems using a dish antenna and multiple horn antennas, with introductory exposure to dynamic spectra as a future extension.

Contents:

Unit I

(15 Hours)

Basic Radio Astronomy and Solar Radio Emission: Radio frequency region of electromagnetic spectrum; atmospheric transparency in radio band; advantages of radio astronomy; basic concepts of radio astronomy; radio emission mechanisms including thermal radiation, synchrotron radiation, bremsstrahlung, and plasma oscillations; solar radio emission including origin in solar corona, solar flares, and radio bursts; propagation through ionosphere including reflection, refraction, absorption, and electron density effects; measurable quantities including frequency, wavelength, power, intensity, and flux density; antenna fundamentals including size–wavelength relation, directional sensitivity, and gain; time variation of signals and noise including transient signals, thermal noise, atmospheric effects, and terrestrial interference.

Unit II

(15 Hours)

Antenna Systems and Receiver Fundamentals: Familiarisation with horn antennas and dish-based systems; structure of a small radio telescope using a dish antenna and four horn antennas; antenna fundamentals in practice, including directional response, gain, and beamwidth (qualitative); comparison between dish and horn antennas; basic antenna alignment and pointing using Alt-Az

coordinates. Introduction to receiver systems, including LNB for dish-based setup, low noise amplifier (LNA), and software defined radio (SDR) (conceptual level); signal transport through coaxial cables and F-type connectors; cable preparation and connection safety; use of satellite finder or equivalent as signal-strength indicator. Measurement concepts: background radio noise, reference level setting, and signal detection; identification of environmental radio interference and noise sources; observational precautions, instrumental limitations, and repeatability; introduction to time-dependent signal measurement and recording.

Unit III: Laboratory Activities

(30 Hours)

Antenna Measurement, Assembly, and Solar Signal Detection: Identification and assembly of components: dish antenna, LNB, satellite finder, set-top box/receiver chain, four horn antennas, LNA (where applicable), SDR (introductory), coaxial cables, connectors, and basic tools; preparation of cables and secure connections; construction of system block diagrams. Antenna alignment and setup: dish pointing and horn antenna orientation; measurement of directional response using horn antennas; measurement of background radio noise using antenna–receiver systems; calibration using reference/background readings. Detection experiments: observation of solar radio signal using dish and horn antennas; recording radio signal intensity as a function of time; observation of temporal variation in signal strength; detection of artificial sources and environmental interference; comparison of signals from multiple horn antennas and dish systems. Basic signal processing: averaging, smoothing, and peak identification (qualitative); preparation of observational records, including setup, measurement conditions, time variation, and interpretation.

Unit IV: Laboratory Activities

(30 Hours)

Signal Analysis, Dynamic Spectra, and Advanced Observations: Advanced observational exercises using dish and horn antenna systems; systematic recording of signal intensity as a function of time and orientation; simple altitude and azimuth scans across the Sun; identification of peak response and estimation of beam characteristics (qualitative). Receiver configuration (introductory): gain control, signal stability, and repeatability; data recording and handling; plotting of time-series data and interpretation of signal variations; identification of noise, baseline, and transient features. Introduction to e-CALLISTO spectrometer: concept, installation overview, antenna setup, receiver configuration, and data acquisition (demonstration or sample data); analysis of solar radio dynamic spectra for identification of radio bursts; interpretation of frequency–time structures (qualitative). Comparative studies: dish vs horn antenna response; multi-horn directional sensitivity; identification of interference and uncertainty; cautious interpretation of observational data; preparation of complete observational report, including experimental setup, data, plots, and limitations.

Course Learning Outcomes

Students will understand the basic principles of radio astronomy and solar radio emission, and the functioning of antenna and receiver systems used for radio detection. They will be able to assemble and operate small radio telescope setups using a dish antenna and multiple horn

antennas, perform antenna alignment and signal detection, measure and analyse time-dependent radio signals, identify noise and interference, and interpret simple observational data. Students will gain introductory exposure to dynamic spectra and solar radio bursts and will be able to prepare structured, cautious radio astronomy laboratory reports. In the event that larger dish antennas become available, students will be able to extend the skills acquired in this course to operate such systems, including improved pointing, enhanced sensitivity measurements, and more refined observational techniques consistent with larger-aperture radio observations.

Suggested Readings

1. J. D. Kraus, Radio Astronomy — selected introductory sections
2. J. D. Kraus and R. J. Marhefka, Antennas — selected introductory sections
3. IUCAA-NCRA, Affordable Solar Radio Telescope: Assembly / Instruction Manual
4. NCRA-TIFR / IUCAA, Affordable Small Radio Telescope Manual
5. SUNPIT(SUNdish Pipeline Tool): <https://sites.google.com/inaf.it/sundish/scientific-summary-of-the-project/observations-and-data-analysis/sundish-solar-pipeline>
6. e-CALLISTO Network Documentation — future extension only.

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5138
Course Name: Fluid Dynamics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Fluid Dynamics, DSE	4	3	1	0	Classical Mechanics, Mathematical Physics

Duration: 60 Hours(45L+15T)

Course Objectives

The primary objective is to teach the students the Physics of studying fluid motion. This is a useful course for those who would like to go for higher studies/research Astrophysics, Plasma Physics as well as those who might like to do M.Tech in Engineering courses.

Contents:

Unit I: (15 Hours)

Fluid packets and fields: Concept of an ideal fluid. Continuity Equation, Euler Equation. Lagrange derivative and Eulerian derivative, Hydrostatic equilibrium. Convection condition. Application of convection to dry and moist air. Brunt Vaaisaala frequency for Convective stability. Energy Flux and momentum flux. Concept of stress tensor,

Unit 2 (10 Hours)

Kelvin's theorem, Potential flow, incompressible flow. Two-dimensional flow, Stream function and the complex plane formalism of two-dimensional flow. Perturbation evolution in Fluids, waves, instabilities, Application to the ocean waves and atmospheric waves.

Unit 3 (10 Hours)

Shocks, planar shocks, RH conditions. Angular shock front, sonic boom. Blast waves. Evolution of shock front using scaling arguments.

Unit 4 (10 Hours)

Most general expression for Stress tensor for viscous fluids, Bulk and Shear Viscosity. Energy dissipation, Flow throw pipes, parallel sheets and fluid between rotating concentric cylinders. Law of similarity: Reynolds number, Froude Number and Strouhal number.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present

assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will be equipped for higher studies in Astrophysics and Plasma Physics. This will be value addition for those who plan to join DRDO, ISRO, BARC et al

Suggested Readings

1. Elementary Fluid Mechanics, Tsutomu Kambe (World Scientific, 2007)
2. Principles of Astrophysical Fluid Dynamics, Cathie Clarke, Bob Carswell (Cambridge University Press, 2007)
3. Fluid Mechanics, Landau and Lifshitz (Pergamon Press, 2013)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5139
Course Name: Nonlinear Dynamics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nonlinear Dynamics, DSE	4	3	1	0	

Duration: 60 Hours(45L+15T)

Course Objectives

The course will introduce the students to the basic concepts of nonlinear systems, dynamical theory, chaos, and soliton. These concepts will be demonstrated using simple models based on ordinary & partial differential equations and discrete maps. Properties of coupled systems also will be explored.

Contents:

Unit I (9 Hours)

Introduction to ordinary differential equations: linear and nonlinear, systems of ODEs, existence and uniqueness theorems, conservative versus dissipative systems, invariant curves and quasiperiodicity, review of KAM theorem, integrable and non-integrable systems.

Unit II (12 Hours)

Phase space analysis & Bifurcations: Phase portrait, linear stability, fixed points, periodic orbits, limit cycles, Poincaré-Bendixson theorem, Lyapunov functions, gradient systems; Bifurcations: Saddle-node, transcritical, pitchfork, Hopf, period doubling, intermittency, local and global; center manifold and normal form, structural stability.

Unit III (12 Hours)

Discrete systems, Strange attractors & Coupled systems: Poincaré cross sections, linear stability and cobweb analysis; universality; logistic, tent, and Henon maps. Unstable periodic orbits, chaotic motions; Characterization: fractal dimension and Lyapunov exponents; Cantor set and Koch curve. Stochastic versus deterministic systems. Introduction to synchronization.

Unit IV (12 Hours)

Partial different equations & Solitons linear and nonlinear, diffusive and dispersive; boundary value problems; methods of separation of variables, characteristics; inverse scattering; symbolic computation; similarity and Backlund transformations. Soliton theory: periodic, cnoidal and solitary wave solutions of Korteweg-de Vries, Nonlinear Schroedinger and sine-Gordon equations; conserved densities.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes:

The knowledge and familiarity about concepts and methods of dynamical system theory that acquired during this course will be useful and applicable in almost all branches of science: from systems of Nano to astrophysical scales. Students will be able to learn the different analytical techniques and the geometrical intuition of local & global behaviour to understand the evolution of complex nonlinear systems.

Suggested Readings:

1. Elementary Differential Equations and Boundary Value Problems, W. E. Boyce and R. C. DiPrima (Wiley, 2003).
2. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology Chemistry, and Engineering, S. H. Strogatz (Westview Press, 2001)
3. CHAOS: An Introduction to Dynamical Systems, K. Alligood, T. Sauer, and J. A. Yorke (Springer 1996)
4. Advanced Methods of Mathematical Physics R.S. Kaushal and D. Parashar (Narossa, 2000)
5. Nonlinear dynamics: integrability, chaos and patterns M. Lakshmanan and S. Rajasekar, (Springer-Verlag, 2003)
6. Solitons: An Introduction P. G. Drazin & R. S. Johnson (Cambridge University Press, 1989)
7. Nonlinear Science: Emergence and Dynamics of Coherent Structures, A. Scott (Oxford Univ. Press, 1999).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5140
Course Name: Applied Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Applied Physics DSE	4	3	1	0	Electronics, Solid State Physics

Duration: 60 Hours(45L+15T)

Course Objectives

This course intends to impart knowledge of conceptual physics and its applications relevant to various streams of engineering and technology. More specifically, the student will be able to understand the properties of materials being used in various applications including transducers, sensors and detectors, cryogenics and energy harvesting, energy storage and conversion devices.

Contents:

Unit I (10 Hours)

Transducers: Fundamentals of transducers, classifications and general characteristics; displacement transducers, strain gauges (Bound and unbound resistance type), transducers for biomedical applications. Microelectromechanical systems (MEMS); microfabrication and micromachining, advanced lithography techniques, diffusion & ion implantation, and high aspect ratio processes.

Unit II (12 Hours)

Sensors: Resistive, capacitive, inductive, electromagnetic, thermoelectric, piezoelectric, piezoresistive, photosensitive and electrochemical sensors; Toxic gas monitoring; thermal conductivity analyzers, colorimetric determination, sorption type dosimeters; infrared and ultraviolet sensors; flame ionisation detectors; semiconductor sensors. Lasers for optical communication system – Applications of optical fibre - Fibre optic communications.

Unit III (10 Hours)

Cryogenics: Cryogenics: Production of vacuum and measurements. Measurement of low pressure, calibration of vacuum gauges, general principle of mass flow measurement and control. Basic cryogenics science, cryostat design properties of material at low temperature. Measurement system for low temperatures; Applications of cryogenics – PPMS and MPMS; principle and working.

Unit IV

(13 Hours)

Alternate Energy Storage and Harvesting: Electrochemical energy storage devices - EMF, reversible and irreversible cells, free energy, thermodynamic calculation of the capacity of a battery, calculations of energy and power density of cells. Faradaic and non-faradaic processes and electrochemical performance techniques (CV, GCD, and EIS). Types of batteries, factors affecting battery capacity, voltage and current level; types of discharge: Supercapacitors (Electric double layer SCs) Basics of solar energy.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Learners will be able to comprehend basic physics principles used in emerging technological devices. The students will have the enriched knowledge on physics of materials and that will be used by them in different engineering and technological applications.

Suggested Readings

1. Handbook of Transducers, H. N. Norton (Prentice Hall, 1989)
2. An introduction to Microelectromechanical Systems Engineering, N. Maluf (Artech House Publishers, 2000)
3. Microsensors: Principles and Applications, J. W. Gardner (John Wiley, 1994)
4. Sensor Technology and Devices, L. R. Ristic (Artech House publishers, 1994)
5. Vacuum Technology by Roth (Elsevier, 1990)
6. Experimental Techniques in Low Temperature Physics, G. K. White (4th Ed., Oxford University Press, 2002)
7. The Physics of Solar Cells, Nelson (Imperial College Press, 2003)
8. Electrochemical Power Sources, V.S. Bagotsky, A. M. Skundin and Y.M. Volfkovich (Wiley, 2015)
9. Solid State Electronic Device, G. Streetman and S. Banerjee (6th Ed., Prentice Hall, 2006).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5141
Course Name: Quantum Information and Computation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Information and computation DSE	4	3	1	0	Basic linear algebra, basic coding in Python , Quantum Mechanics

Duration: 60 Hours(45L+15T)

Course Objectives:

This course introduces the fundamental principles of quantum information science, including quantum states, quantum channels, entanglement theory, quantum communication, cryptography, and quantum computation. The course serves as a foundation for advanced studies in quantum computing and quantum technologies.

Contents:

Unit I (15 Hours)

Quantum formalism: pure and mixed states, density matrices, quantum evolution, projective measurements, and positive operator-valued measures (POVMs); classical and quantum probabilities, composite quantum systems, tensor-product structure, bipartite and multipartite systems, reduced density matrices, partial trace, quantum channels, completely positive trace-preserving (CPTP) maps, Kraus representation, depolarizing, dephasing, and amplitude-damping channels, Markovian quantum dynamics, quantum dynamical semigroups, and the Lindblad master equation, the spin-boson model as an illustrative model of system-environment interaction and decoherence.

Unit-II (12 Hours)

Entanglement in bipartite and multipartite systems: Schmidt decomposition, separable and entangled states, positive partial transpose (PPT) criterion for entanglement detection, Bell inequalities, entanglement entropy, concurrence, logarithmic negativity, no-cloning theorem, quantum teleportation, quantum dense coding. Shannon entropy and its basic properties; von Neumann entropy and its applications in quantum information theory.

Unit-III (9 Hours)

Essential concepts of classical cryptography; quantum key distribution (QKD); BB84, B92, and Ekert protocols; quantum secret sharing; security principles of quantum cryptography; advantages and limitations of quantum cryptographic protocols.

Unit-IV:**(9 Hours)**

Quantum circuits and quantum gates, universal gate sets, introduction to quantum computation, computational complexity, quantum algorithms: Deutsch–Jozsa algorithm, Grover's search algorithm, and the Quantum Fourier Transform (introductory treatment), overview of Shor's algorithm and its significance.

Tutorial Component**(15 Hours)**

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

After completing this course, students will be able to describe the mathematical framework of quantum information theory, analyze quantum states, measurements, and noisy quantum channels, and understand and quantify quantum entanglement. They will also learn the fundamentals of quantum computation and quantum circuits. They will also learn simulation in the lab. This course will help students with the foundation necessary for advanced courses in quantum computing and quantum technologies.

Suggested Readings

1. Quantum Computation and Quantum Information (10th Anniversary Edition), Michael A. Nielsen and Isaac L. Chuang, (*Cambridge University Press*, 2010; ISBN: 9781107002173).
2. Quantum Computer Science: An Introduction, N. David Mermin, (*Cambridge University Press*, 2007; ISBN: 9780521876582).
3. Quantum Information Theory (2nd Edition), Mark M. Wilde, (*Cambridge University Press*, 2017; ISBN: 9781107176164).
4. Introduction to Classical and Quantum Computing, Thomas G. Wong, (*Rooted Grove*, 2022; ISBN: 9781733356473).
5. An Introduction to Quantum Computing, Phillip Kaye, Raymond Laflamme, and Michele Mosca, (*Oxford University Press*, 2007; ISBN: 9780198570004).
6. Quantum Computing: A Gentle Introduction, Eleanor G. Rieffel and Wolfgang H. Polak, (*MIT Press*, 2011; ISBN: 9780262015066).
7. Quantum Error Correction, Daniel A. Lidar and Todd A. Brun (Eds.), (*Cambridge University Press*, 2013; ISBN: 9780521897877).
8. The Theory of Open Quantum Systems, Heinz-Peter Breuer and Francesco Petruccione, (*Oxford University Press*, 2007; ISBN: 9780199213900).

9. Lecture Notes on Quantum Computation, John Preskill, (*California Institute of Technology, online resource, continuously updated*).
10. Lecture Notes on Quantum Error Correction, John Preskill, (*California Institute of Technology, online resource, continuously updated*).
11. IBM Quantum Learning Platform and Qiskit Documentation, (*IBM Quantum, online resource, continuously updated*).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/Semester I of 1 year MSc
Course Code: PH-DSE5142
Course Name: Computational Material Science

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Computational Material Science Course, DSE	4	3	0	1	Solid state physics, Quantum Mechanics I

Duration: (45L+ 30P) 75 Hours

Course Objective:

The objective of this course is to equip students with the theoretical knowledge and computational skills to model, simulate and predict the structure and properties of materials using first-principles calculations. The course aims to: Introduce the fundamental concepts of materials modelling and simulation. First-principles calculations. Develop proficiency in computational tools and software widely used in materials research. Enable students to apply simulations to study structural, mechanical, thermal, and electronic properties of materials.. Encourage critical thinking and problem-solving in the context of materials design and discovery.

Contents:

UNIT I: Methods in Computational Materials Science (11 Hours)

Basic idea behind materials modeling and simulation. Many-electron systems, first-principles methods, Thomas-Fermi, Hartree, Hartree-Fock, exchange and correlation, and introduction to beyond Hartree-Fock methods. Basis sets: local (eg. LCAO, Slater type, Gaussian etc.) and non-local (eg. Plane waves)

UNIT II: Density Functional Theory (DFT) (10 Hours)

Electron density, functional, Hohenberg-Kohn theorems, Kohn-Sham equations, Exchange-correlation functionals: local density approximation (LDA), generalized gradient approximation (GGA) and hybrid functionals. Self-consistent field (SCF) methods.

UNIT III: Implementation of DFT (24 Hours)

Pseudopotentials: Ultrasoft, Norm-conserving, plane wave (PW) & projector augmented waves (PAWs), Feynman-Hellmann Force, Geometry optimization algorithms, local and global minima, frequency calculations, irreducible Brillouin zone, k-points sampling, periodic boundary conditions; Some practical topics: energy cutoff and smearing, crystal structure prediction, Phase transformations, Surface relaxation.

Properties using DFT: Band structures, band gap, density of states (DOS), projected density of states (PDOS), orbital analysis, charge density analysis, quantum capacitance, electron transport.

UNIT IV: Laboratory Activities

(30 Hours)

The lab instructors are advised to plan the computational lab and choose the systems and properties depending on the availability of computational resources. It is also advised to use freely available DFT codes (eg. Quantum Espresso) and visualization codes (eg. ASE, VESTA etc) for the computational lab.

Transaction Mode: Lecture, problem solving, group discussion, self-study and computational laboratory.

Course Learning Outcomes:

On completion of this course, students will be able to: Understand many electrons systems and advanced methods to tackle such systems. Apply the laws of quantum physics for practical implementation of density functional theory. Apply the concepts of solid-state physics to the practical implementation of density functional theory. Explain the details of the density functional theory for electronic structure problems.

Suggested Readings:

1. Gunn Lee June.(2011).Computational Materials Science: An Introduction. CRC Press.
2. Kaxiras Efthimious.(2007). Atomic and Electronic Structure of Solids. Cambridge University Press.
3. M Martin Richard.(2008). Electronic Structure: Basic Theory and Practical Methods . Cambridge University Press.
4. S. Sholl David and A. Steckel Janice.(2009). Density Functional Theory: A Practical Introduction. John Wiley and Sons.
5. Feliciano Giustino.(2009).Materials Modelling Using Density Functional Theory: Properties and Predictions.Wiley.
6. Rajendra Prasad.(2013). Electronic Structure of Materials, Taylor and Francis.
7. M. Dreizler Reiner, K. U. Gross Eberhard. Density Functional Theory, An Approach to the Quantum Many-Body Problem. Springer, 2013.
8. Parr & Yang. Density-Functional Theory of Atoms and Molecules, 1995.
9. J. Kohanoff. Electronic Structure Calculations for Solids and Molecules, Theory and Computational Methods, 2006.
10. S. Datta, Quantum Transport: Atom to Transistor, Cambridge University Press., 2013.

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/Semester I of 1 year MSc
Course Code: PH-DSE5143
Course Name: Quantum Optics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Optics DSE	4	3	1	0	Quantum mechanics - I & II

Duration: 60 Hours(45L+15T)

Course Objective

The main aim of this course is to enable students to gain knowledge and understanding of fundamental and applied concepts in the field of quantum optics, which is the description of the quantum features of light. The goal of the course is to provide an overview of the theory of quantum optics and its uses for both fundamental physics experiments and applications. In the first part of the course, we study the different states of light: thermal states, coherent states emitted by lasers, squeezed states, single-photon states, entangled states. We study the associated notions of coherence, the corresponding statistical distributions, and how they can be measured. The second part of the course is devoted to light-matter interaction at the quantum level.

Contents:

Unit I (12 Hours)

Brief review of lasers: Basic properties of laser light, laser applications in interferometers.

Field quantization: Quantization of the Electromagnetic Field, Fock States, Coherent States, Squeeze States, Hanbury-Brown and Twiss experiments, Photon bunching and antibunching.

Unit II (12 Hours)

Non-classical light: Quantum Phase space distributions, The Wigner functions, P-function and nonclassicality, Husimi Q-function, Entangled states, Schrodinger cat states.

Non-classical light sources: Non-linear polarization, parametric down-conversion, single photon sources.

Unit III (12 Hours)

Quantum coherence functions: Classical coherence functions, Quantum coherence functions, The Mandel Q Parameter, Coherence functions of arbitrary order.

Quantum Beam Splitter: Quantum mechanics of beam splitters, Experiments with single photons, Interferometry with a single photon, Two photon Interference, Hong-Ou-Mandel effect, homodyne detection, Einstein-Podolsky-Rosen states, Bell's inequality.

Unit IV (9 Hours)

Cavity Quantum Electrodynamics: Atom-field interactions, The Rabi model, Jaynes-Cummings model (JCM), The dressed states, Collapse and Revival Phenomena in JCM, weak, strong, ultra-strong and deep strong coupling regimes, Dispersive limit of the JCM, Dissipative Processes and Open system, Experiments with trapped ion and cavity QED system.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will be able to use the fundamental concepts and analytic description of quantized light - from classical light (coherent states) to non-classical light such as single photons, entangled photons and squeezed vacuum. To Understand and be able to use the concepts of coherence, 2nd order coherence, and multi-photon interference. Know quantum optics methodologies and modern applications (quantum technologies). Demonstrate familiarity with the fundamental concepts and analytic description of light-matter interactions.

Suggested Readings

1. Laser fundamentals- W. T. Silfvast, 2nd edition, Cambridge University Press (2008).
2. Principles of Lasers, Orazio Svelto and David C. Hanna, Springer, Fifth Edition (2010).
3. R. W. Boyd, Nonlinear Optics, Academic Press.
4. G. S. Agarwal, "Quantum Optics", Cambridge University (2013).
5. D. F. Walls and G. J. Milburn, "Quantum Optics," 2nd Ed. Springer (2008).
6. M. Fox, "Quantum Optics, an introduction," Oxford (2006).
7. C. C. Gerry and P. L. Knight, "Introductory Quantum Optics," Cambridge (2005).
8. M. O. Scully, and M. S Zubairy, "Quantum Optics," Cambridge (1997)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/Semester I of 1 year MSc
Course Code: PH-DSE5144
Course Name: Atmospheric Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Atmospheric Physics DSE	4	3	1	0	Classical Mechanics, Thermodynamics, Statistical Physics, Electromagnetism, Introductory Fluid Mechanics

Duration: 60 Hours(45L+15T)

Course Objectives

The main aim of this course is to enable students to gain knowledge and understanding of fundamental and applied concepts in the field of Atmospheric Physics. The course aims to provide the students with an opportunity to seriously explore this subject and demonstrate how it is linked to basic aspects of Physics. The course will cover the thermodynamics of the atmosphere and cloud formation. It will also focus on different types of wind patterns and relate these to basic fluid dynamics. Simple chemical aspects of the effect of aerosols, as well as simple chemical reactions, will also be studied. In the end, the issues of climate change and ways to mitigate pollution, as well as aspects of global warming, will be addressed.

Contents:

Unit-I: Brief introduction

(8 Hours)

Structure of Earth's Atmosphere. Simple models of the Earth's atmosphere and their relation to weather and climate. Thermodynamics of the atmosphere. Role of thermodynamics in convection of dry air. Changes to the convection condition due to moisture in the atmosphere. Phase transition and its interplay with thermodynamics in the process of cloud formation. Types of clouds and their properties. Role of aerosols.

Unit-II: Radiative processes in the atmosphere

(8 Hours)

The radiative transfer equation. Role of molecular spectroscopy in absorption of radiation. Absorption, Scattering and Transmission of radiation through the atmosphere. Atmospheric heating and the Green house effect. Different types of Aerosols and their role in radiative transport.

Unit-III Atmospheric Fluid Dynamics

(18 Hours)

Brief discussion of the continuity equation. Navier-Stokes equation to describe the dynamics of fluid packets. Fluid dynamics in a rotating frame like the surface of the Earth. Concepts of Geostrophic flow, pressure coordinates and geopotential.

Vorticity, Boussinesq approximation. Gravity waves and Rossby waves. Boundary layers and instabilities.

Unit-IV: The Physics and Chemistry of the Stratosphere

(11 Hours)

Chemical kinetics in the Stratosphere. Biomolecular reactions in the atmosphere. Photo dissociation and the Antarctic Ozone hole. Chemical transport in the atmosphere. **Remote sensing:** Space-based as well as ground-based atmospheric observations and studies. **Climate change:** Effect of CO₂ on radiative forcing. Linearized energy balance models.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

To understand the role of basic physics, especially Thermodynamics and fluid mechanics in shaping atmospheric phenomenon. To understand the reason for wind flow patterns and their effect on weather. To understand the physics of Convection, cloud formation and their role in precipitation. Role of basic chemical reactions in Atmospheric phenomenon. Role of Aerosols in Cloud formation and Radiative processes in the atmosphere.

Suggested Readings

1. Davis G. Andrews: Introduction to Atmospheric Physics, Cambridge
2. University Press (2010).
3. A. Chandrasekhar, Basic Atmospheric Science: PHI Learning (2010)
4. James R. Holton - An Introduction to Dynamic Meteorology (2004, Academic Press)
5. Wallace J.M., Hobbs P.V. - Atmospheric science (2006, Elsevier AP)
6. M.K. Yau, R R Rogers - A Short Course in Cloud Physics-ButterworthHeinemann (1996)
7. K.N. Liou (Eds.) - An Introduction to Atmospheric Radiation-Academic Press (2002)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5145
Course Name: X-ray Spectroscopic Techniques

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
X-ray Spectroscopic Techniques DSE	4	3	1	0	Solid State Physics, Quantum Mechanics I & II

Duration: 60 Hours(45L+15T)

Course Objectives

The objective of this course is to provide an understanding of X-ray-based spectroscopic techniques used for the structural, electronic, and elemental analysis of materials.

Contents:

Unit I (10 Hours)

X-ray Diffraction (XRD): Bragg's law and diffraction patterns, Powder and single-crystal diffraction, Phase identification and crystallographic structure. X-ray Fluorescence Spectroscopy (XRF): Energy-dispersive, Qualitative and quantitative elemental analysis, Raman Spectroscopy: Raman scattering principles, Differences and synergy with X-ray techniques.

Unit II (15 Hours)

Introduction to X-rays Characteristics & Bremsstrahlung, X-ray tubes and target materials, Interaction of X-rays with matter: absorption, scattering, emission, Synchrotron radiation: principles and advantages, Monochromators, beamlines, and optics.

Unit III (10 Hours)

X-ray Absorption Spectroscopy (XAS): Theory and Applications, Extended X-ray Absorption Fine Structure (EXAFS) and X-ray Absorption near edge structure (XANES), X-ray Emission Spectroscopy (XES)

Unit-IV (10 Hours)

X-ray Photoelectron Spectroscopy (XPS): Photoelectric effect and energy levels; Chemical shifts, Resonant Inelastic X-ray Scattering (RIXS) Principle of inelastic scattering with element-specific resolution Energy-loss features and low-energy excitations & Applications.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students'

conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Upon successful completion of this course, students will acquire a thorough understanding of the interaction of electromagnetic radiation with matter and its applications in modern spectroscopy. They will understand the principles and techniques of absorption, emission, fluorescence, and scattering spectroscopies, and will be able to analyze and interpret spectroscopic data. Students will also develop the ability to select appropriate spectroscopic methods for investigating the structure, purity, and concentration of chemical substances and to solve related analytical problems through informed interpretation of experimental results.

Suggested Readings

1. X-Rays and Extreme Ultraviolet Radiation: Principles and Applications: by David Attwood (Cambridge University Press)
2. X-Ray Absorption and X-Ray Emission Spectroscopy: Theory and Applications: by Jeroen A. van Bokhoven and Carlo Lamberti (Wiley & Sons, Ltd)
3. X-ray Photoelectron Spectroscopy: An Introduction to Principles and Practices by Paul van der Heide (Wiley & Sons, Ltd)
4. Elements of Modern X-ray Physics: by Jens Als-Nielsen and Des McMorrow (Wiley & Sons, Ltd)
5. Modern Techniques of Surface Science: by D. P. Woodruff

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5146
Course Name: Complex Systems

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Complex Systems DSE	4	3	1	0	Mathematics as a subject in high school (Class XI and XII).

Duration: 60 Hours(45L+15T)

Course Objectives

This course deals with the interdisciplinary subject of complex systems, that include, among others, living organisms, ecosystems and human societies. The course emphasizes a unifying theme – complex networks – that cuts across all these systems. It develops the mathematical tools of graph theory and dynamical systems to provide insight into the structure, dynamics and evolution of a variety of complex systems in the physical sciences, life sciences, social sciences and engineering.

Contents:

Unit I (7 Hours)

Overview: Examples of complex systems: organisms, brains, ecosystems, societies, the internet. Components of these systems: molecules, cells, species, agents, computers. Collective phenomena exhibited by these systems. Contrast with other collective phenomena in physics such as phase transitions. Adaptive nature of these systems.

Unit II (10 Hours)

Graph theory and the network structure of complex systems: Complex networks of interaction as a unifying theme underlying complex systems. Undirected, directed and bipartite graphs, hypergraphs. Adjacency matrix of a graph. Graph theoretic measures of network structure. Random graph ensembles, small-world, scale-free, hierarchical and autocatalytic graphs. Network motifs. Nature of graphs that arise in various complex systems

Unit III (14 Hours)

Dynamics of complex systems: Dynamics on a fixed network. Examples of continuous and discrete dynamical systems to be taken from various complex systems such as chemical networks, metabolic networks, ecological food webs, genetic regulatory circuits, neural networks, social and economic networks, epidemiological networks. Fixed point and limit cycle attractors of these systems. The influence of network structure on dynamics.

Unit IV

(14 Hours)

Evolution of complex systems: How networks change over time. Preferential attachment model of scale free networks. The origin of life puzzle. Model of autocatalytic network evolution and self-organization of a complex network. Community assembly models in ecology. Evolution of biological and social networks. Crashes and recoveries in complex systems. Robustness and fragility of complex systems.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Being able to appreciate that complex networks of interacting components underlie many complex systems studied under different disciplines. Learning the similarities and differences between complex systems from the perspective of network structure. Learning certain mathematical methods of graph theory and dynamical systems. Being able to apply these methods to characterize the structure of various complex systems and to model certain phenomena exhibited by them.

Suggested Readings

1. Networks: An Introduction, M. E. J. Newman (Oxford University Press, 2010).
2. Origins of Order, Stuart Kauffman (Oxford University Press, 1993).
3. Handbook of Graphs and Networks: From the Genome to the Internet, S. Bornholdt and H.-G. Schuster (Wiley-VCH, 2003).
4. Dynamics of Complex Systems, Yaneer Bar-Yam (Perseus Books, 1997)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5147
Course Name: Accelerator Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Accelerator Physics DSE	4	3	1	0	Classical Mechanics, Electrodynamics, Mathematical Physics, Solid State Physics Co- requisite Statistical Physics

Duration: 60 Hours(45L+15T)

Course Objectives

This course introduces the fundamental principles of charged particle acceleration and the development of accelerator technology. It aims to build a strong foundation in accelerator types, beam dynamics, and beam optics. The course also familiarizes students with essential accelerator components such as ion sources and vacuum systems and beamline elements.

Contents:

Unit I: Fundamentals of Particle Acceleration (10 Hours)

Historical development (Cockcroft–Walton experiment), Need for accelerators in nuclear and particle physics, Energy, momentum, relativistic effects, Motion of charged particles in electromagnetic fields (Lorentz force), Overview of early accelerators: Cyclotron, Betatron, Synchrotron, LINAC.

Unit II Types of Accelerators (12 Hours)

Electrostatic accelerators: Van de Graaff (single & tandem), Linear accelerators: RF cavities, drift tube LINAC, phase focusing, Circular accelerators: cyclotron, synchrotron, storage rings, Beam injection and extraction methods, Compact accelerators and laser Wakefield accelerators (introductory idea).

Unit III Beam Dynamics and Beam Optics (13 Hours)

Beam trajectory and Hill's equation, Transverse and longitudinal dynamics, Betatron oscillations and phase stability. Beam optics: focusing/defocusing, quadrupole and sextupole magnets, Emittance, dispersion, magnetic rigidity, Introduction to RF cavities and beam bunching.

Unit IV Accelerator Components & Techniques

(10 Hours)

Vacuum techniques: importance, pumps, pressure measurement, Ion sources: types and working principles, Beam diagnostics (basic idea), Beam cooling techniques (qualitative), Introduction to target systems.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will be able to explain the fundamental principles of particle acceleration and distinguish between different types of accelerators. They will analyze beam dynamics and apply beam optics concepts to charged particle motion. Students will also understand key accelerator components such as ion sources and vacuum systems.

Suggested Readings

1. Accelerator Physics, S. Y. Lee, World Scientific, 3rd Edition, 2012.
2. An Introduction to the Physics of Particle Accelerators, M. Conte and W. W. MacKay, World Scientific, 2nd Edition, 2008.
3. Particle Accelerator Physics, H. Wiedemann, Springer, 4th Edition, 2015.
4. The Physics of Particle Accelerators: An Introduction, K. Wille, Oxford University Press, 1st Edition, 2000.
5. Introduction to Accelerator Dynamics, S. Peggs and T. Satogata, Cambridge University Press, 2017.

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DSE5148
Course Name: Research Methodology in Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Research Methodology in Physics DSE	4	3	1	0	Classical Mechanics, Quantum Mechanics, EMT

Duration: 60 Hours(45L+15T)

Course Objectives

The objective of this course is to introduce students to the methodology by which physical knowledge is extracted from data, mathematical structure, and empirical regularities. Emphasis is placed on measurement uncertainty, statistical inference, parameter estimation, testing of physical models, stochastic description of variability, time-series analysis, and approximation methods used to construct effective physical laws. The course develops the ability to relate observables to models, identify dominant physical effects, and assess the reliability and limits of conclusions drawn from theoretical and experimental studies.

Contents:

Unit I: Statistics, Physical Quantities and Scaling Relations (11 Hours)

Measurements and errors in physical data, statistical and systematic uncertainties, propagation of uncertainties, random variables, probability distributions and their moments, central limit theorem and Gaussian distribution, covariance matrix and correlations, physical observables and derived quantities, order of magnitude estimates, dimensional analysis, scaling relations and dimensionless parameters, constraints on physical laws from dimensional consistency, interpretation of empirical relations in terms of scaling behaviour.

Unit II: Parameter Estimation, Hypothesis Testing and Model Construction (11 Hours)

Null hypothesis and statistical formulation, likelihood and parameter estimation, maximum likelihood method, least square fitting, interpolation and extrapolation as approximations of physical relations, confidence intervals, chi-squared test, p-value and statistical significance, comparison between theoretical predictions and data, comparison between competing models, role of assumptions in determining predictive power, formulation of minimal physical models based on measurable quantities, interpretation of empirical laws as effective physical models.

Unit III Stochastic Methods, Fluctuations and Physical Processes (11 Hours)

Random number generation and sampling from probability distributions at conceptual level, Monte Carlo idea as statistical sampling method, random walk and diffusion processes, fluctuations and correlations as origin of measurable quantities, stochastic description of transport and relaxation processes, statistical interpretation of variability in physical data, relation between microscopic randomness and macroscopic laws, optimization and minimization of functions in many variables at conceptual level, extraction of physical insight from stochastic models and simulated data.

Unit IV: Time-Series Analysis and Approximation Methods for Physical Systems

(10 Hours)

Data sampling and resolution, Nyquist theorem, discrete Fourier transform and fast Fourier transform, spectral power analysis, auto-correlation and cross-correlation functions, white and colored noise, extraction of characteristic time scales and frequencies from physical data, approximation methods in physical systems, separation of scales, continuum approximation, mean-field reasoning, interpretation of exponential and power-law relations, emergence of phenomenological laws from microscopic behaviour, limits of validity of approximations.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will learn how experimental data are analysed in physics and how statistical and systematic uncertainties affect interpretation of measurements. Concepts from probability and statistics will help students understand fluctuations, correlations, and extraction of meaningful information from data. The study of parameter estimation and comparison between theoretical predictions and observations will enable students to assess the reliability of physical models. Dimensional analysis, scaling relations, and approximation methods will help students understand how simplified models describe complex physical behaviour within specific validity regimes. Concepts of correlation functions and Fourier analysis will help students interpret time-dependent signals, while empirical relations will be understood as effective descriptions of underlying physical processes with identifiable limits of applicability.

Suggested Readings

1. P. R. Bevington and D. K. Robinson, Data Reduction and Error Analysis for the Physical Sciences, McGraw–Hill.
2. J. R. Taylor, An Introduction to Error Analysis, University Science Books.

3. W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery, Numerical Recipes: The Art of Scientific Computing, Cambridge University Press.
4. M. Newman, Computational Physics, CreateSpace Independent Publishing.
5. E. T. Jaynes, Probability Theory: The Logic of Science, Cambridge University Press.
6. K. Huang, Statistical Mechanics, Wiley.

MASTER of SCIENCE in PHYSICS
Semester I of 1 year MSc
Course Code: PH-DSE5161
Course Name: Quantum Mechanics - I

Course Title and Type	Credits	Credit distribution of the course			Pre-requisite for the course
		Lecture	Tutorial	Practical	
Quantum Mechanics-I DSE	4	3	1	0	Bachelor's degree in Physics

Duration: 60 Hours (45L+15T)

Course Objectives:

The primary objective is to teach the students the physical and mathematical basis of quantum mechanics for non-relativistic systems

Contents:

Unit I (15 hours)

Abstract formulation of Quantum Mechanics: Mathematical properties of linear vector spaces. Dirac's bra and ket notation. Hermitian operators, eigenvalues, and eigenvectors. Orthonormality, completeness, closure. Postulates of quantum mechanics. Matrix representation of operators. Position and momentum representations – connection with wave mechanics. Commuting operators. Generalised uncertainty principle. Change of basis and unitary transformation. Expectation values. Ehrenfest theorem.

Unit II (12 hours)

Quantum Dynamics: Schrodinger picture, Heisenberg picture, Heisenberg equation of motion, classical limit, solution of the simple harmonic oscillator problem by the operator method, general view of symmetries and conservation laws. Spatial translation – continuous and discrete, time translation. parity, time reversal, Density matrices - properties, pure and mixed density matrices, expectation value of an observable, time-evolution, reduced density Matrix, Bloch sphere.

Unit III (9 hours)

Angular Momentum as generator of rotation. Commutation relations of angular momentum operators, eigenvalues, eigenvectors, ladder operators and their matrix representations. Identical particles: Many-particle systems, exchange degeneracy, symmetric and anti-symmetric wavefunctions. Pauli exclusion principle

Unit IV (9 hours)

Approximate Methods: time-independent non-degenerate perturbation theory (Rayleigh-Schrodinger and Brillouin-Wigner), degenerate perturbation theory, variational methods.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

Students will learn the mathematical formalism of Hilbert space, Hermitian operators, eigenvalues, eigenstates, and unitary operators, which form the fundamental basis of quantum theory. Application to simple harmonic oscillators and hydrogen-like atoms will teach the students how to elegantly obtain eigenvalues and eigenstates for such systems. Students will learn to apply first- and second-order non-degenerate and degenerate perturbation theory. The topic of density matrices, which plays a significant role in quantum information theory and statistical mechanics, will also help the students considerably.

Suggested Reading:

1. Quantum Mechanics, B. H. Bransden & C. J. Joachain (Pearson Education, 2000).
2. Principles of Quantum Mechanics, R. Shankar (3rd Ed., Springer, 2008)

3. Quantum Mechanics (Vol. I), Claude Cohen-Tannoudji, Bernard and Frank Laloe (Wiley, 1977).
4. Modern Quantum Mechanics, J.J. Sakurai (Addison-Wesley, 1993).
5. Advanced Quantum Mechanics, F. Schwabl (Springer, 2000).
6. Quantum Mechanics, A.S. Davydov (2nd Ed., Pergamon, 1991).
7. Quantum Mechanics, Eugen Merzbacher (3rd Ed., Wiley, 1997).
8. Quantum Mechanics: Concepts and Applications, Nouredine Zettili (Wiley 2nd edition, 2009).
9. The Principles of Quantum Mechanics, P.A. M. Dirac, (International Series of Monographs on Physics,1981).
10. Quantum Computation and Quantum Information, Michael A. Nielsen, Isaac L. Chuang, (Cambridge University Press, 2010).

MASTER of SCIENCE in PHYSICS**Semester I of 1 year MSc****Course Code: PH-DSE5162****Course Name: Electronics**

Course Title and Type	Credits	Credit distribution of the course			Pre-requisite for the course
		Lecture	Tutorial	Practical	
Electronics DSE	4	3	1	0	Bachelor's degree in Physics

Duration: 60 Hours (45L+15T)

Course Objectives:

To build up on the basic knowledge of electronics with the introduction of advanced topics like circuit analysis and applications of semiconductor devices in analog and digital circuits.

Contents:**Unit I** (10 hours)

Circuit Analysis: Admittance, impedance, scattering and hybrid matrices for two and three port networks and their cascade and parallel combinations. Review of Laplace Transforms. Response functions, location of poles and zeros of response functions of active and passive systems (Nodal and Modified Nodal Analysis).

Unit II (13 hours)

Physics of Semiconductor Devices: p-n junction, Tunnel Diode, JFET, UJT, 4 layer pnpn device (SCR), Introduction of Power devices: DIAC, TRIAC, accumulation, depletion and inversion, MOSFET: I-V, C-V characteristics. Enhancement and depletion mode MOSFET. Ohmic and Rectifying contacts, Schottky diode, I-V, C-V relations.

Unit III (14 hours)

Analog circuits: Active filters and equalizers with feedback, Phase shift and delay. Digital Circuits: Introduction to digital IC parameters (switching time, propagation delay, fan out, fan in etc.). TTL, MOS and CMOS gates, Emitter-coupled logic, MOSFET as transmission gate. A/D and D/A converters. Basics of micro-processor and micro-controller (8-bit AVR).

Unit IV

(8 hours)

Communication Systems: Amplitude, Angle and Pulse-analog modulation: Generation and detection. Model of communication system, classification of signals, representation of signals.

Tutorial Component:

(15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

A student of this course is expected to be able to understand the design and functional performance of electronic circuits using various semiconductor devices. In addition, the student will understand the functional properties and characteristics of semiconductor devices in analog & digital circuits using analog and digital signals.

Suggested Reading:

1. Network Analysis and Synthesis, F.F. Kuo (2nd Ed., Wiley, 2010).
2. Network Analysis with Applications, W.D. Stanley (4th Ed., Pearson, 2003).
3. Electronic Devices and Circuits, J. Millman and C. C. Halkias and S. Jit (4th Ed., McGraw-Hill, 2015).
4. Integrated Electronics, J. Millman, C.C. Halkias and C.D. Parikh (2nd Ed., McGraw-Hill, 2011).

5. Physics of Semiconductor Devices: J.P. Colinge and C. A. Colinge (Kluwer Academic Publishers, New York).
6. Physics of Semiconductor Devices: S.M. Sze (2nd Ed., Wiley Interscience Publications, John Wiley & Sons).
7. Communication Systems, Simon Haykins (5th Ed., Wiley, 2009).
8. Digital Signal Processing, J.G. Proakis and D.G. Manolakis (4th Ed., Pearson, 2007).
9. Solid State Electronic Devices, B.G. Streetman (7th Ed., Pearson, 2015).
10. Digital Design, M. Mano (5th Ed., Pearson, 2013).
11. Digital Principles and Applications, A.P. Malvino and D.P. Leach (8th Ed., McGrawHill, 2014).

MASTER of SCIENCE in PHYSICS

Semester I of 1 year MSc

Course Code: PH-DSE5163

Course Name: Foundational Laboratory in Experimental Physics

Course Title and Type	Credits	Credit distribution of the course			Requisites for the course
		Lecture	Tutorial	Practical	
Foundational Laboratory in Experimental Physics DSE	4	0	0	4	Pre-requisite: Bachelor's degree in Physics, Co-requisite: DSC papers in M.Sc. Physics Sem-I

Duration: 120 Hours

Course Objectives

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Electronics

Unit I: Device Characteristics and Application

1. p-n junction diodes-clipping and clamping circuits.
2. FET – characteristics, biasing and its applications as an amplifier.
3. MOSFET – characteristics, biasing and its applications as an amplifier.
4. UJT – characteristics, and its application as a relaxation oscillator.
5. SCR – Characteristics and its application as a switching device.

Unit II:

- **Linear Circuits**

1. Resonant circuits.
2. Filters-passive and active, all pass (phase shifters).
3. Power supply-regulation and stabilization.

4. Oscillator design and study.
5. Multi-stage and tuned amplifiers.
6. Multivibrators-astable, monostable and bistable with applications.
7. Design and study of a triangular wave generator.
8. Design and study of sample and hold circuits.

- **Digital Circuits and Microprocessors**

1. Combinational.
2. Sequential.
3. A/D and D/A converters.
4. Digital Modulation.
5. Microprocessor application.

Nuclear Physics

Unit III: Detectors

1. G.M. Counters – characteristics, dead time and counting statistics
2. Spark counter-characteristics and range of x-particles in air
3. Scintillation detector-energy calibration, resolution and determination of gamma ray energy
4. Solid State detector – surface barrier detector, its characteristics and applications.

Unit IV:

- **Applications**

1. Gamma ray absorption-half thickness in lead for ^{60}Co gamma-rays.
2. Beta ray absorption – end point energy of beta particles.
3. Lifetime of a short lived radioactive source..

- **High Energy Physics**

1. Study of π - μ -e decay in nuclear emulsions.
2. Study of high energy interactions in nuclear emulsions.

Course Learning Outcome:

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Reading:

Electronics

1. Electronic Instrumentation and Measurement Techniques, W.D. Cooper and A.D. Helfrick (2nd Ed., Phi Learning, 2008).
2. Electronic Devices and Circuits, J. Millman, C.C. Halkias and S. Jit (4th Ed., McGraw-Hill, 2015).
3. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M. Sayer and A. Mansingh (Prentice Hall India, 2010).

Nuclear Physics

4. Radiation Detection and Measurement, G. F. Knoll (3rd Ed, John Wiley & Sons, Inc, 2000).
5. Physics & Engineering of Radiation Detection, S.N. Ahmed (Academic Press, 2007).
6. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer Verlag, 1987).

MASTER of SCIENCE in PHYSICS

Semester I of 1 year MSc

Course Code: PH-DSE5164

Course Name: Experimental Laboratory in Materials and Optical Physics

Course Title and Type	Credits	Credit distribution of the course			Requisites for the course
		Lecture	Tutorial	Practical	
Experimental Laboratory in Materials and Optical Physics DSE	4	0	0	4	Pre-requisite: Bachelor's degree in Physics, Co-requisite: DSC papers in M.Sc. Physics Sem-I

Duration: 120 Hours

Course Objective:

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Solid State Physics

Unit I

Experimental Techniques:

- Production and measurement of low pressures.
- Production and measurement of high pressures.
- Measurement and control of low temperatures.
- Production and characterization of plasma.
- Electron Spin Resonance.
- Nuclear Magnetic Resonance.

Unit II

Electrical Transport Properties:

- Measurement of resistivity – Four probe and van der Paw techniques; determination of band gap.
- Measurement of Hall coefficient – determination of carrier concentration.
- Measurement of magneto resistance.
- Measurement of thermoelectric power.
- Measurement of minority carrier lifetime in semiconductors: Haynes-Shockley experiment.

Phase Transitions and Crystal Structure:

- Determination of transition temperature in ferrites.
- Determination of transition temperature in ferroelectrics.
- Determination of transition temperature in high T_c superconductors.
- Determination of transition temperature in liquid crystalline materials.
- Crystal structure determination by x-ray diffraction powder photograph method.

Waves and Optics**Unit III**

- Velocity of sound in air by CRO method.
- Velocity of sound in liquids – Ultrasonic Interferometer method.
- Velocity of sound in solids – pulse echo method.
- Propagation of EM waves in a transmission line – Lecher wire.
- Determination of Planck's constant.
- Jamin's interferometer – refractive index of air.
- Study of elliptically polarized light.

Unit IV**Optical Spectroscopy:**

- Constant deviation spectrometer-fine structure of Hg spectral lines.
- e/m or hyperfine structure using Fabry Perot's interferometer.
- Band spectrum in liquids.
- Raman scattering using a laser source.
- Luminescence.

Laser Based Experiments:

- Optical interference and diffraction.
- Holography.
- Electro-optic modulation.
- Magneto-optic modulation.
- Acousto-optic modulation.
- Sound modulation of carrier waves.

NOTE:

The list of experiments given above should be considered as suggestive of the standard and available equipment. The teachers are authorized to add or delete from this list whenever considered necessary.

Course Learning Outcome:

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Reading:**Solid State Physics**

1. Introduction to Solid State Physics: Charles Kittel, 8th edition (John Wiley and Sons, inc, 2005).
2. Physics of Semiconductor devices S.M. Sze (Wiley, 2006).

Waves and Optics

1. Lasers: Fundamental and Applications, Graduate Text in Physics, 2nd edition, K. Thyagarajan and Ajoy Ghatak (Springer, 2002).
2. Polarization of light, Ajoy Ghatak and Arun Kumar (McGraw Hill Education, 2012).
3. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000).
4. Teaching laser physics by experiments, Am. J. Phys., (2011), [http://doi.org/10.1119/1-3488984](http://doi.org/10.1119/1.3488984) .

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/Semester I of 1 year MSc
Course Code: PH-SBC5171
Course Name: Workshop skills

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Workshop Skill SBC	2	0	0	2	

Duration: 60 Hours

Course objective:

The aim is to teach them how to handle machines which can be useful for precise cutting in lab accessories useful for experiments.

Content:

Unit I:

Hands-on experience with:

- (a) Lathe machine (Plane turning, step turning, taper turning)
- (b) Drill machine

Unit II:

Hands-on experience with:

- (a) Plate cutting
- (b) Hand tools (hacksaw, drilling, tapping, filing)
- (c) Soldering Skills

Course Learning outcome:

The student will be confident and skilled for handling lab useables and small repairs.
 (Not more than seven students at a time due to space constraints and safety.)

Suggested Readings

1. Workshop Technology, Volume I, W. A. J. Chapman, *(CBS Publishers & Distributors, 2006)*.
2. A Textbook of Workshop Technology: Manufacturing Processes, R. S. Khurmi and J. K. Gupta, *(S. Chand Publishing, 2014)*.
3. Elements of Workshop Technology, Volume I: Manufacturing Processes, S. K. Hajra Choudhury, A. K. Hajra Choudhury, and Nirjhar Roy, *(Media Promoters & Publishers, 2007)*.
4. Machine Tools Handbook: Design and Operation, T. A. Jalil and A. J. M. Majumdar, *(Industrial Press, 2013)*.

5. Basic Workshop Practice, T. Jeyapoovan, (*Vikas Publishing House, 2015*).

MASTER of SCIENCE in PHYSICS

Semester III of 2 year MSc/ Semester I of 1 year MSc

Course Code: SBC5172

Course Name: Strategies for Scientific Dialogue in Research

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Strategies for Scientific Dialogue in Research SBC	2	1	0	1	Bachelor's Degree in branch of Science

Total: (15L+30P) 45 Hours

Course Objectives

Course Objectives: The course is designed to develop and strengthen students' ability to communicate scientific ideas clearly and effectively, both in written and oral formats. It aims to expose students to cutting-edge research through seminars delivered by faculty members and invited experts. Emphasis is on cultivating skills in scientific literature review, critical analysis, and academic discourse. The course also prepares students for academic presentations, thesis defenses, and professional scientific interactions. Recognizing that many students produce excellent research but struggle to present it effectively, this course seeks to bridge that crucial gap.

Course Structure and Activities:

UNIT I (15 hours)

Lecture Attendance & Research Exposure:

➤ Students must attend a minimum of 10 research lectures organized by the department. These may include:

1. Presentations by department faculty on their current research.
2. Lectures by invited national or international experts.

➤ Students will submit comprehensive summaries (approx. 400–500 words) of at least five selected lectures, highlighting key concepts, methods, and findings.

UNIT II (30 hours)

Seminar Preparation and Delivery:

➤ Students will be assigned a research topic or paper, drawn from current research themes or courses offered in the M.Sc. syllabus.

➤ They will receive study materials, including relevant papers, reviews, or resources from the faculty.

- Each student must prepare a written synopsis (~800–1000 words) on the assigned topic.
- Students will then present a seminar (15–20 minutes) based on their understanding, followed by a Q&A session.

The course is structured in the spirit of a Dissertation under the DSE category, but with lower credit weightage and, accordingly, reduced academic rigor. As such, the number of hours assigned is indicative rather than prescriptive, intended to reflect the approximate level of effort expected.

Assessment and Evaluation: Components

- a) Participation in Departmental Lectures.
- b) Written Summaries of Attended Lectures.
- c) Written Review of Assigned Research Topic.
- d) Seminar Presentation (Content, Clarity, Delivery).

Evaluation will be conducted by

- a) A three-member departmental committee for the overall course.
- b) A two-member subcommittee for seminar presentation evaluation.

Notes for Implementation:

- Attendance at department seminars will be tracked.
- Students may optionally include key questions or insights from each attended lecture.
- Emphasis will be on communication skills, depth of understanding, organization of content, and response to questions.
- This course encourages peer learning and academic engagement beyond classroom.

Course Learning Outcome:

Upon successful completion of the course, students will be able to: Comprehend and effectively communicate recent research developments in physics and allied disciplines. Summarize and synthesize scientific literature with clarity, coherence, and critical insight. Prepare and deliver well-structured, confident, and audience-appropriate scientific presentations. Engage thoughtfully in scholarly discussions and respond competently to academic queries. This course will be particularly beneficial for students planning to undertake project work or a dissertation in the third and fourth semesters.

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: SBC5173
Course Name: Advanced Computational Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Computational Physics SBC	2	0	0	2	Computational Physics or Knowledge of Numerical Analysis

Duration: 60 Hours

Course Objective:

In this course, students will apply computational techniques to various real problems of physics.

Content:

Unit-I: Stochastic and Monte Carlo Methods

- Generation of random numbers from Poisson and Gaussian distributions-- Box-Muller method, Importance sampling, and detailed balance.
- Random walk and diffusion, Importance sampling, and detailed balance. Sampling points from arbitrary distributions -- Metropolis sampling and examples.

Unit -II: Classical and quantum mechanics: (This is a suggestive list of applications)

- Harmonic oscillator with damping, forced one, anharmonic, realistic projectile motion with air drag, realistic planetary orbit calculation, etc. Symplectic integration, taking advantage of the conservation principle. Shooting method and Numerov's method, examples of bound states calculation for 1D wells of regular and unusual shapes (those do not admit analytical solutions)
- Quantum harmonic oscillators. Eigenvalue problem in matrix form (finite dimensional basis), and exact (Lanczos) diagonalization, Variational calculation with orthogonal basis states. Time-dependent Schrodinger equation, wave equation, etc

Course Learning Outcomes

A student having taken the course would be expected to be proficient in solving various problems of Physics: Stochastic methods, Classical and Quantum mechanics, using the programming language (Python)

Suggested reading

1. Lab manual for Advanced Computational Physics, Department of Physics and Astrophysics, University of Delhi 2025.
2. <https://www.python.org/doc/>
3. Monte Carlo Simulation in Statistical Physics: An Introduction, Binder, Kurt, Heermann, Dieter (5th Ed., Springer, 2010)
4. Numerical Analysis, Richard L. Burden, J. Douglas Faires, Annette M. Burden (10th Ed., Cengage Learning, 2016)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5174
Course Name: Introductory Innovation Lab

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Introductory innovation Lab SBC	2	0	0	2	

Duration: 60 Hours

Course Objectives

This course aims to cultivate innovative and experimental thinking through hands-on experiments encompassing energy harvesting, sensor technology, materials science, and electronics. The focus is on creativity, prototyping, and practical applications.

Unit-I:

List of Experiments (Perform Any 2 Experiments) or any innovative idea to be implemented

1. Preparation of Hydrophilic and Hydrophobic: Surfaces Students will explore techniques to modify substrate wettability through surface treatment and the formation of self-assembled monolayers (SAMs).
2. Production of Hydrogen Gas from Water: This experiment involves the electrolysis of water using various electrodes to understand the efficiency of hydrogen generation. Students will also study the role of catalysts in electrolysis.
3. Design and Development of Devices for Temperature Sensing: Students will design electronic circuits using thermistors and calibrate them to measure ambient temperature.

Unit-II:

List of Experiments (Perform Any 2 Experiments) or any innovative idea to be implemented

1. Preparation of Flexible Thin Films for Nanogenerator Applications: Techniques such as spin-coating or solution casting will be used to fabricate thin films on flexible substrates. Their energy-harvesting capabilities will be explored under mechanical stress, friction, etc.
2. Generation of Electrical Power from Day-to-Day Friction: This module explores triboelectric nanogenerators, where students will harness mechanical motion (e.g., sliding or tapping) to generate electrical signals using appropriate materials.
3. Electrochemical Transducers for Molecular Sensing: Students will fabricate simple electrochemical sensors/devices and test their response to various analytes.

Course Learning Outcomes

Upon successful completion of this course, students will be able to design, fabricate, and characterize simple functional devices related to energy harvesting, sensing, and advanced materials. They will develop practical skills in experimental design, prototyping, data analysis, and innovation-driven problem-solving for real-world technological applications.

Suggested reading

1. Sensors and Transducers (3rd Edition), D. Patranabis, (*PHI Learning Pvt. Ltd., 2017*).
2. Nanogenerators and Piezotronics: From Theory to Experimental Approaches, Zhong Lin Wang, (*Wiley-VCH, 2014*).
3. Electrochemical Methods: Fundamentals and Applications (2nd Edition), Allen J. Bard and Larry R. Faulkner, (*John Wiley & Sons, 2001*).
4. Materials Science and Engineering: An Introduction (10th Edition), William D. Callister Jr. and David G. Rethwisch, (*John Wiley & Sons, 2018*).
5. Energy Harvesting Technologies, Shashank Priya and Daniel J. Inman (Eds.), (*Springer, 2009*).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5175
Course Name: Introductory Observational Astronomy Laboratory

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Introductory Observational Astronomy Laboratory SBC	2	0	0	2	

Duration: 60 Hours

Course Objective:

To provide foundational training in observational astronomy through hands-on experience in telescope operation, celestial observations, photometric measurements, CCD imaging, and introductory astronomical data analysis. The course aims to develop practical skills in planning, conducting, and analyzing basic astronomical observations using modern observational tools and software.

Unit I: Telescope Operation and Observational Techniques

(30 Hours)

- Components and operation of telescope systems: optical tube, mount, finder scope, and accessories.
- Basic principles of telescope optics: aperture, focal length, magnification, and angular resolution (qualitative).
- Telescope setup, balancing, alignment, calibration, and safe operational practices.
- Celestial object identification and manual telescope pointing using Alt-Azimuth coordinates.
- Use of finder scopes and telescope tracking of the Sun, Moon, planets, and bright stars.
- Determination of time and direction using sundials and shadow methods.
- Assessment of telescope installation sites considering horizon visibility, obstructions, stability, and environmental factors.
- Introduction to amateur and DIY telescope design, calibration procedures, and operational limitations.
- Maintenance of observational records, including observing logs, instrument settings, pointing information, and observing conditions.

Hands-on Training: Practical training in telescope assembly, alignment, calibration, object acquisition, solar and night-sky observations, tracking, site assessment, and preparation of observational logs.

Unit II: Astronomical Measurements, CCD Imaging, and Data Analysis (30 Hours)

- Determination of angular diameters of the Sun and Moon using the drift-transit method.
- Measurement of the Earth–Moon distance using parallax techniques.
- Calibration and operation of photometric systems in B, V, and R bands.
- Determination of stellar colours through differential photometry.
- Introduction to CCD detectors and calibration using bias, dark, and flat-field frames.
- Measurement of angular separations of celestial objects from CCD images.
- Basic image reduction and analysis using IRAF, AstroPy, or equivalent software packages.
- Measurement of atmospheric extinction at different zenith angles and its effect on astronomical observations.

Hands-on Training: Practical exercises involving photometric measurements, CCD data acquisition, image calibration, image reduction, astrometric measurements, atmospheric extinction studies, and analysis of observational data

Learning Outcomes:

Students will be able to operate and align basic telescope systems, perform manual pointing and tracking, and maintaining observational logs. They will be able to carry out elementary astronomical measurements, perform basic photometry and CCD calibration, apply introductory image reduction techniques, and analyse observational data with consideration of uncertainties.

Recommended Readings

1. D. S. Birney, G. Gonzalez, D. Oesper, *Observational Astronomy*
2. P. Duffett-Smith, J. Zwart, *Practical Astronomy with your Calculator or Spreadsheet*
3. S. B. Howell, *Handbook of CCD Astronomy*
4. A. A. Henden, R. H. Kaitchuck, *Astronomical Photometry: A Guide*
5. B. W. Carroll, D. A. Ostlie, *An Introduction to Modern Astrophysics*
6. S. F. Tonkin (Ed.), *Practical Amateur Spectroscopy*
7. IRAF Documentation
8. AstroPy Documentation
9. American Association of Variable Star Observers (AAVSO) Manuals and Guides

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc

Course Code: PH-SBC5176

Course Name: Integrated Analytical Techniques in Electronics, Experimental and Condensed Matter Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Integrated Analytical Techniques in Electronics, Experimental and Condensed Matter Physics SBC	2	0	0	2	Electronics, Modern Physics and Solid State Physics

Total: 60 Hours

Course Objectives

This course is designed to develop analytical and experimental understanding of Electronics, Experimental Methods, and Condensed Matter Physics through an integrated and practice-oriented approach. The course focuses on instrumentation techniques, signal analysis, and the physical properties of condensed matter systems relevant to modern scientific research.

UNIT I: Electronics and Experimental Methods (30 Hours)

Semiconductor devices, optoelectronic devices, operational amplifiers, digital electronics, A/D and D/A converters, microprocessors and microcontrollers, error analysis, least squares fitting, transducers, signal conditioning, impedance matching, filtering, noise reduction, lock-in detection and modulation techniques.

UNIT II: Condensed Matter Physics (30 Hours)

Bravais lattices and reciprocal lattice, diffraction and structure factor, phonons and lattice dynamics, free electron theory, electrical and thermal conductivity, Hall effect, band theory of solids, semiconductors, superconductivity, Josephson junctions, defects, dislocations and liquid crystals.

Course Learning Outcomes

Students will be able to analyze electronic circuits, instrumentation techniques, and experimental data using modern analytical approaches. They will also develop understanding of condensed matter systems, crystal structures, electronic properties of solids, and superconducting phenomena relevant to advanced studies and interdisciplinary research.

Suggested Readings

1. Electronic Principles, Albert Malvino and David Bates, McGraw-Hill Education.

2. Electronic Devices and Circuits, J. Millman and C. C. Halkias and S. Jit (4 th Ed., McGraw-Hill, 2015)
3. Integrated Electronics, J. Millman, C. C. Halkias and C. D. Parikh (2 nd Ed., McGraw-Hill, 2011)
4. Digital Signal Processing, J. G. Proakis and D. G. Manolakis (4th Ed., Pearson, 2007)
5. Measurement Systems: Application and Design, Ernest O. Doebelin, McGraw- Hill.
6. Solid State Physics, Neil W. Ashcroft and N. David Mermin, Brooks/Cole, 1976.
7. Introduction to Solid State Physics, Charles Kittel, Wiley.
8. Solid State Physics, A. J. Dekker (1st Ed., Macmillan India, 2000)

Pedagogical Approach (Non-Conventional Mode)

- Fully practice-oriented theoretical laboratory format
- Live problem-solving sessions instead of lectures
- Previous years' question analysis and pattern recognition
- Timed assignments and mock tests
- Collaborative group work and peer learning
- Error analysis and conceptual debugging sessions

Evaluation Scheme

- Continuous Assessment (Assignments & Tests)
- Laboratory Performance (Analytical Work)
- Final Comprehensive Examination

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc

Course Code: PH-SBC5177

Course Name: Integrated Analytical Techniques in Electromagnetic and Quantum Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Integrated Analytical Techniques in Electromagnetic and Quantum Physics SBC	2	0	0	2	Electromagnetism, Quantum Mechanics and Basic Electronics

Total: 60 Hours

Course Objectives

This course focuses on strengthening conceptual understanding and analytical problem solving skills in Electromagnetic Theory, Electronics, Quantum Mechanics, and Atomic Physics. It aims to integrate theoretical principles with analytical applications relevant to modern physical sciences and advanced research.

UNIT I: Electromagnetic Theory (24 Hours)

Electrostatics and boundary value problems, magnetostatics and electromagnetic induction, Maxwell's equations and electromagnetic waves, polarization, interference and diffraction, waveguides and transmission lines.

UNIT II: Quantum Mechanics & Modern Physics (36 Hours)

Schrödinger equation and eigenvalue problems, angular momentum and spin systems, approximation methods, scattering theory and quantum transitions, identical particles and quantum statistics, atomic structure and spectra, fine and hyperfine interactions, Zeeman and Stark effects, ESR, NMR, molecular spectra, laser physics and radiation processes.

Course Learning Outcomes

Students will be able to analyze electromagnetic and quantum systems using modern theoretical and analytical approaches. They will develop proficiency in solving interdisciplinary problems involving atomic structure, and quantum phenomena with improved conceptual understanding and analytical precision.

Suggested Readings

1. Introduction to Electrodynamics, David J. Griffiths, Pearson Education, 4th Edition, 2013.

2. Classical Electrodynamics, John David Jackson (3rd ed., Wiley, 1998).
3. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, Wiley, 2nd Edition, 2009.
4. Modern Quantum Mechanics, J. J. Sakurai (Addison-Wesley, 1993)
5. Quantum Mechanics, B. H. Bransden and C. J. Joachain (Pearson Education, 2000)
6. Principles of Quantum Mechanics, R. Shankar (3rd Ed., Springer, 2008)

Pedagogical Approach (Non-Conventional Mode)

- Fully practice-oriented theoretical laboratory format
- Live problem-solving sessions instead of lectures
- Previous years' question analysis and pattern recognition
- Timed assignments and mock tests
- Collaborative group work and peer learning
- Error analysis and conceptual debugging sessions

Evaluation Scheme

- Continuous Assessment (Assignments & Tests)
- Laboratory Performance (Analytical Work)
- Final Comprehensive Examination

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5178

Course Name: Integrated Analytical Techniques of Mathematical and Classical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Integrated Analytical Techniques of Mathematical and Classical Physics SBC	2	0	0	2	Undergraduate Mathematics and Mechanics

Total: 60 Hours

Course Objectives

This course is designed to develop analytical and quantitative problem-solving skills in Mathematical Physics and Classical Mechanics through an integrated and practice-oriented approach. The course emphasizes conceptual understanding, mathematical modelling, and theoretical techniques essential for advanced studies, research aptitude, and national-level competitive examinations.

UNIT I: Mathematical Physics (30 Hours)

Vector algebra and vector calculus, matrices, eigenvalues and eigenvectors, ordinary differential equations and special functions, Fourier series, Fourier and Laplace transforms, complex analysis and residues, probability distributions, Green's functions, tensors and introductory group theory.

UNIT II: Classical Mechanics (30 Hours)

Newtonian mechanics and dynamical systems, Lagrangian and Hamiltonian formulations, central force problems and scattering, oscillations and normal modes, canonical transformations and Poisson brackets, Hamilton–Jacobi theory, symmetry principles and conservation laws, elements of special relativity.

Course Learning Outcomes

Upon completion of this course, students will be able to apply advanced mathematical methods and classical formulations to solve complex physical problems. They will develop strong analytical reasoning, problem-solving ability, and conceptual clarity required for research and competitive examinations in physical sciences.

Suggested Readings

1. Mathematical Methods for Physicists, George B. Arfken, Hans J. Weber, Frank E. Harris, Elsevier Academic Press, 7th Edition, 2013.

2. Mathematical Physics, V. Balakrishnan (Ane Books, 2018)
3. Advanced Engineering Mathematics, E. Kreyzig (Pearson, 2002)
4. Elements of Group Theory for Physicists, A.W. Joshi (John Wiley, 1997).
5. Mathematical Physics, H.K. Dass and Rama Verma, S. Chand Publishing.
6. Classical Mechanics, Herbert Goldstein, Charles Poole, John Safko, Pearson, 3rd Edition, 2001.
7. Mechanics, L. D. Landau and E. M. Lifshitz (3 rd Ed., Pergamon, 1976).
8. Classical Mechanics, N. C. Rana and P. S. Jaog (McGraw-Hill, 1991).

Pedagogical Approach (Non-Conventional Mode)

- Fully practice-oriented theoretical laboratory format
- Live problem-solving sessions instead of lectures
- Previous years' question analysis and pattern recognition
- Timed assignments and mock tests
- Collaborative group work and peer learning
- Error analysis and conceptual debugging sessions

Evaluation Scheme

- Continuous Assessment (Assignments & Tests)
- Laboratory Performance (Analytical Work)
- Final Comprehensive Examination

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5179

Course Name: Radiation Safety

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Radiation Safety SBC	2	1	0	1	Bachelor's degree in a branch of science

Duration: 45 hours (15T+30P)

Course Objectives

The primary objective of this course is to provide students with a comprehensive understanding of radiation fundamentals, interaction mechanisms, detection principles, dosimetric techniques, and regulatory frameworks associated with radiation safety and protection. Through theoretical instruction and practical demonstrations, students will gain both conceptual and operational knowledge required for safe handling, measurement, and monitoring of ionizing radiation, along with a sound understanding of national guidelines and protocols for radiation protection and waste management.

Contents

Unit-I:

(15 Hours)

Basics of Radiation: Origin of radiation, binding energy and Q-value, stable and unstable isotopes, radioactive decay (alpha, beta, neutron, and electromagnetic transitions), mean life and half life, Basic idea of different units of activity, radiation quantities; exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, quality factor, radiation and tissue weighting factors, committed equivalent dose, committed effective, radiation dose to individuals from natural radioactivity in the environment and man-made sources

Devices for radiation measurement and survey: Radiation interaction with matter, kinematics of nuclear reactions, slowing down and moderation of neutrons, Interaction of ionizing and non-ionising radiation at the cellular level. introduction to types of radiation detectors; semiconductor, scintillator and gas detectors(Geiger-Muller counters, ionisation chamber and proportional counters). principles of radiation counting statistics, dead time, and calibration standards. types of Radiation Dosimeters: thermoluminescence, radiographic films, calorimetry, semiconductor diodes; Relation between detection and dosimetry.

Regulatory Framework: classification of radioactive sources (A/D classification), the system of radiological protection, justification of practice, optimization of protection, and individual

limits, categories of exposures-occupational, public, and medical exposures, evaluation of external Radiation hazard-effect of distance, time, and shielding, shielding calculation; internal radiation hazards. Personnel and area monitoring, radiation accidents and disaster monitoring, Radioactive waste & classification of Radioactive waste, transport of radioactive sources/waste, responsibilities of licensee regulatory bodies AERB, and the government.

Unit-II:

(30 Hours)

Suggested Exercises / Practical Demonstrations

- Demonstration handling of radiation monitor and survey instruments.
- Demonstration of Distance, Time, and shielding concept of the ALARA principle.
- Demonstration of the Search and Secure procedure for handling radioactive sources
- Measurement of the activity of an unknown radioactive source.
- Radiation Protection Survey of a Radioisotope Laboratory
- Contamination Measurement and Decontamination Procedures
- Calibrate radiation monitors using standard radioactive sources.
- Classification of Radiation facility using AERB guidelines.
- Packing classification and Transport Index (TI) for radioactive isotope/waste transport.

***Note:** a minimum 6 above exercises/Practical Demonstration will be assigned to each student and will be evaluated in continuous assessment mode.*

Course Learning Outcomes

Upon successful completion of this course, students will developed sound understanding of the principles underlying the operation of various radiation detectors, the calculation of radiation doses and permissible exposure levels for different categories of users, the effects of radiation, the use of instrumentation in practical scenarios, proper management of radioactive materials, and strict adherence to safety protocols.

Suggested Readings

1. Nuclear and Particle Physics, W. E. Burcham and M. Jobes (Pearson Education, 1995)
2. Radiation detection and measurement, G. F. Knoll (4th Ed., Wiley, 2010)
3. Thermoluminescence Dosimetry, Mcknlly, A. F., Bristol, Adam Hilger (Medical Physics Hand book 5)
4. Fundamental Physics of Radiology, W. J. Meredith and J. B. Massey (John Wright and Sons, 1989)
5. An Introduction to Radiation Protection, A. Martin and S. A. Harbisor (John Willey & Sons, 1981)
6. Medical Radiation Physics, W. R. Hendee (Medical Publishers Inc., 1981)
7. Nuclear Physics : Principles and applications, John Lilley (Wiley, 2001)

8. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (2nd Ed., Elsevier, 2014)
9. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (2nd Ed., Springer, 2013)
10. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities.
11. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources.

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5180

Course Name: Order of Magnitude Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Order of Magnitude Physics SBC	2	1	0	1	Bachelor's degree in a branch of Science

Duration: 45 hours (15L+30P)

Course Objectives

Often before doing a detailed theoretical calculation or prior to setting up an experiment to measure an effect, One needs to have a rough idea as to whether or not our set up or the calculation is likely to give a meaningful result and whether spending efforts time and funds are worth it. It is in this context that this course is significant. The objective of this course is to train students to make estimates without having to do a detailed calculation or experiment to get a rough idea of how the results could look.

Contents

Unit-I:

(25 Hours)

- **Estimation of Physical quantities using Dimensional Analysis.**

Dimensional analysis in Mechanics: Damping in a pendulum, Free Gravitational collapse of a dust sphere, Oscillation time period of a star, Time taken for photon to diffuse out of sun, Dimensional analysis in Fluid Mechanics: Reynolds', Froude and Strouhal numbers in Fluids, Terminal velocity.

- **Scaling analysis in Classical Physics**

Orbital time period vs Orbital size of planets, Dynamics in a power law potential, Estimating the acceleration due to gravity on the surface of the moon, How high can an animal jump? Orbital time of planets, Scale height of the Atmosphere.

Unit-II:

(20 Hours)

- **Application to different areas in Physics.**

Electrodynamics, Quantum Physics, Waves, Materials.

- **Applications to Integrals and differential equations**

Estimating integrals, steepest descent approximation. Approximate solutions to differential equations.

Course Learning Outcomes

Students will come away from the course with an appreciation of the characteristic scales associated to a physical system, and how to use simple approximate models to estimate a variety of quantities of physical interest. They will also learn approximation techniques for integrals and differential equations.

Suggested Readings

1. Peter Goldreich, Sanjoy Mahajan and Sterl Phinney - Order of Magnitude Physics.
2. Sanjoy Mahajan - Estimating gas mileage: An example of order-of-magnitude physics (arXiv:physics/0512209).
3. Steven Doty and Sandra Doty, Dielectric breakdown of air as order of magnitude physics (Physics teacher Volume 36, Pages 6-9, 1998).

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5181

Course Name: Electronic Circuit and Simulation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electronic Circuit and Simulation SBC	2	0	0	2	Bachelor's degree in a branch of Science

Duration: 60 Hrs (4P/Week)

Course Objectives

To provide hands-on training in the design, simulation, and analysis of electronic circuits using PSpice and in graphical programming, signal analysis, and virtual instrumentation using LabVIEW. The course aims to develop practical skills in circuit modelling, waveform analysis, signal processing, data acquisition, and computer-based measurement relevant to experimental physics.

Contents

Unit-I: Electronic Circuit Design and Simulation Using PSpice (30Hours)

Introduction to the PSpice environment: schematic design, component selection, circuit construction, simulation profiles, and waveform analysis. Simulation of RC and RLC circuits, transient and frequency response, resonance, and Bode plots. Simulation of diode circuits, rectifiers, clippers, clampers, and voltage regulators. Design and analysis of transistor amplifiers and operational amplifier circuits. Simulation of basic combinational and sequential digital circuits.

Suggested Laboratory Exercises: Simulation and analysis of RC/RLC circuits; diode rectifier and wave-shaping circuits; Zener voltage regulator; transistor amplifier and frequency response; op-amp-based amplifier, integrator, differentiator, and active filter circuits; and selected digital logic circuits.

Unit-II: Graphical Programming and Virtual Instrumentation Using LabVIEW

(30 Hours)

Introduction to the LabVIEW environment and data-flow programming. Development of Virtual Instruments (VIs) using controls, indicators, arrays, graphs, charts, loops, Case Structures, and shift registers. Waveform generation and visualization; measurement of signal amplitude, frequency, and phase. Introduction to data acquisition, sampling, signal

conditioning, and computer-based measurements. Basic signal-processing techniques including noise reduction, averaging, filtering, and FFT-based spectral analysis.

Suggested Laboratory Exercises: Development of basic Virtual Instruments; waveform generation and visualization; virtual digital voltmeter and signal-monitoring applications; measurement of signal parameters; noise generation and signal averaging; digital filtering; FFT-based frequency analysis; and a mini-project related to virtual instrumentation or automated measurement.

Course Learning Outcomes

After successful completion of the course, students will be able to: Design and simulate analogue and digital electronic circuits using circuit-simulation software. Analyse transient and frequency responses and interpret simulation results. Develop Virtual Instruments using LabVIEW for waveform generation, measurement, and signal analysis. Apply basic concepts of data acquisition, signal conditioning, filtering, and spectral analysis. Design and implement simulation or virtual-instrumentation solutions relevant to experimental physics and scientific measurements.

Suggested Readings

4. M. H. Rashid, Introduction to PSpice Using OrCAD for Circuits and Electronics, Pearson.
5. P. W. Tuinenga, SPICE: A Guide to Circuit Simulation and Analysis Using PSpice, Prentice Hall.
6. R. H. Bishop, Learning with LabVIEW, Pearson.
7. J. Travis and J. Kring, LabVIEW for Everyone: Graphical Programming Made Easy and Fun, Prentice Hall.
8. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, Pearson.
9. S. Franco, Design with Operational Amplifiers and Analog Integrated Circuits, McGraw Hill.

MASTER of SCIENCE in PHYSICS
Semester III/IV
Course Code: PH-SBC5182
Course Name: Thin Film Fabrication

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Thin Film Fabrication SBC	2	0	0	2	

Duration: 60 Hrs (4P/Week)

Course Objectives

Thin film fabrication course intends to enrich the students with the firsthand information on the fundamental thermodynamic aspects of vacuum technology and thin film nucleation and growth regimes. This course explains in detail the experimental vacuum tools such as pumps and gauges along with the substrate preparation protocols necessary for thin film fabrication.

Contents

LIST OF EXPERIMENTS

Unit-I: Vacuum science and substrate preparation

1. pumps (rotary, diffusion, cryo and turbomolecular)
2. Gauges (pirani, thermocouple and hot cathode ionization)
3. Substrate cleaning (RCA, ultrasonication, UV, plasma etching)
4. Thin film nucleation and growth kinetics
5. Post annealing protocols

Unit-II: Thin film fabrication and thickness measurement

- Drop-cast films
- Spin-coated films
- Thermal evaporated films
- Sputtered films
- Thickness profiler

Note: Each student should choose any two topics in each unit and will be evaluated in continuous assessment mode.

Course Learning Outcomes

Upon successful completion of this course, students will be able to understand and appreciate the effectiveness of different vacuum pumps and gauges and the different thin film fabrication protocols. The students would be able to differentiate structural defects and growth pathways in thin films based on their substrate preparation.

Suggested Readings

10. Ohring, M. (2001). *Materials Science of Thin Films* (2nd ed.). Academic Press.
11. Seshan, K., & Schepis, D. (Eds.). (2018). *Handbook of Thin Film Deposition* (4th ed.). William Andrew.
12. Smith, D. L. (1995). *Thin-Film Deposition: Principles and Practice*. McGraw-Hill.
13. George, S. M. (2010). Atomic layer deposition: An overview. *Chemical Reviews*, 110(1), 111-131.
14. Leng, Y. (2013). *Materials Characterization: Introduction to Microscopic and Spectroscopic Methods* (2nd ed.). Wiley-VCH.
15. Mahan, J. E. (2000). *Physical Vapor Deposition of Thin Films*. Wiley-Interscience.

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5183

Course Name: Material synthesis and characterization

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Material synthesis and characterization SBC	2	0	0	2	

Duration: 60 Hrs (4P/Week)

Course Objectives

Materials synthesis and characterization is the fundamental and core topic for any experimental condensed matter physics research. This course provides the complete background knowledge on the basic aspects of any materials synthesis along with their initial characterization techniques. Students will be trained in different materials synthesis protocols in detail and also undergo rigorous training in multiple characterization tools.

Contents

LIST OF EXPERIMENTS

Unit-I: Materials Synthesis

1. Preparation of nano-particles using sol-gel method and Hydrothermal methods etc.
2. Material purification: Rotatory evaporation, Centrifugation, etc.
3. Ball milling and mechanochemical methods
4. Colloidal synthesis and functionalization

Unit-II: Materials Characterization

1. XRD and its data Analysis
2. UV-Spectroscopy
3. Differential Scanning Calorimetry (DSC) / Thermogravimetric Analysis (TGA)
4. Atomic force microscopy / scanning electron microscopy

Note: Each student should choose any two topics in each unit and will be evaluated in continuous assessment mode.

Course Learning Outcomes

This course will help students understand the finer details of the materials synthesis procedures as well as their basic characterization techniques and allows them to correlate the structure-property functional relationships suitable for enhancing their applications.

Suggested Readings

1. Cao, G., & Wang, Y. (2011). Nanostructures and nanomaterials: Synthesis, properties, and applications (2nd ed.). World Scientific Publishing.
2. Edelstein, A. S., & Cammarata, R. C. (Eds.). (1996). Nanomaterials: Synthesis, properties and applications. CRC Press.
3. Leng, Y. (2013). Materials characterization: Introduction to microscopic and spectroscopic methods (2nd ed.). Wiley-VCH.
4. Schultz, M. J., Ajayan, P. M., & Functional Nanomaterials Group. (2021). Nanomaterials: Biomedical, environmental, and engineering applications. Wiley.

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5184
Course Name: Introductory Plasma Physics Lab

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Introductory Plasma Physics Lab SBC	2	0	0	2	Basic electronics, introductory atomic physics, Fundamentals of electromagnetic theory, Electric circuits and analysis, Basic computational, Fundamentals of solid-state physics

Total: 60 Hours (4 Hours/Week)

Course Objectives

Plasma physics forms the basis of many technologies, such as ion sources, magnetron sputtering, material etching, ion thrusters, nuclear fusion, nano-technology, wastewater treatment, nitrogen fertiliser, etc., that have revolutionised the area of physics research. The plasma physics laboratory provides a great platform for master's students to learn about vacuum technologies, ionisation processes of inert or molecular gases, the collective response of a charged medium, nonlinear dynamics of plasma systems, plasma-matter interactions, waves and instabilities in a dust-grain medium, and image analysis techniques. Through this introductory lab course, students will gain exposure to a young, multidisciplinary branch of physics (plasma physics).

UNIT I:

(45 Hours)

1. Understanding the electric breakdown of inert/molecular gases through the gas breakdown law.
2. To explore the discharge characteristics by measuring the plasma current and resistivity at different parametric regimes.
3. To understand the nonlinear dynamics of DC glow discharge using time series data analysis techniques (FFT, Phase space plots, Recurrence plots (RP), etc.)
4. Understanding the charging and force balance on the solid particles in the plasma background
5. To understand the non-thermal plasma (DBD plasma) and use the concept in developing a plasma Jet, a coaxial DBD reactor, etc.

6. Understanding fundamentals of DBD plasma through emission spectroscopic techniques (types of reactive gaseous species, plasma density, electron temperature, etc.)

UNIT II:

(15 Hours)

1. Exploring the dust-acoustic waves through image analysis tools (MATLAB, ImageJ Software)
2. Understanding the dust particle motion and their velocity distribution through particle tracking tools (PIV, PTV, etc.)
3. Exploring dusty plasma crystal formation and melting in DC discharge through various data analysis techniques (Crystal types through Voronoi diagram, pair correlation function, etc.)

Note: *Minimum two experiments from Unit I and one experiment from Unit II are compulsory to earn the 2 credits.*

Course Learning Outcomes

After completing the plasma physics laboratory course, students will learn how to create plasma (the fourth state of matter) and dusty plasma in the ground-based laboratory. Students will learn about the tools and techniques required for time-series and image analysis across different scientific fields. They gain expertise in handling the vacuum pump, measuring devices, high-voltage power sources, high-frame-rate camera, spectrometer, etc., through this lab course. They will also learn about the applications of low-pressure and low-temperature plasmas across sectors such as water purification, medicine, space, materials science, and agriculture

Suggested Readings

1. Introduction to Plasma Physics by F. F. Chen (Plenum Press, 1984)
2. Principles of Plasma Discharges and Materials Processing by M.A. Liberman and A J Lichtenberg (John Wiley & Sons, Inc., 2005)
3. Introduction to Dusty Plasma Physics by P. K. Shukla and A. A. Mamun, (Institute of Physics, Bristol, 2002)
4. A Review of Recent Advances of Dielectric Barrier Discharge Plasma in Catalysis by Ju Li et al. (<https://doi.org/10.3390/nano9101428>)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5185
Course Name: Lasers and their applications

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Lasers and their applications SBC	2	0	0	2	

Total: 60 Hours (4 Hours/Week)

Course Objectives

Laser technology has become indispensable for a wide range of applications including communications, semiconductor manufacturing, defense, medicine, and industry. This course will provide knowledge of the basic concepts and applications of laser in all walks of life. Students will understand different laser types, beam characteristics, safety practices, and their applications in spectroscopy, imaging, sensing, and advanced photonic technologies.

Contents

LIST OF EXPERIMENTS

UNIT I: (45 Hours)

1. Laser beam characteristics
2. Laser interferometry
3. Birefringence and Faraday effect
4. Optical trapping with lasers

UNIT II: (15 Hours)

1. Raman Effect
2. Optical tweezers
3. Laser Holography and 3D imaging
4. Optical communication

Note: *Each student must choose any one topic from each unit and demonstrate experiments / simulations based on the same which will be evaluated in continuous assessment mode.*

Course Learning Outcomes

The course will equip students with hands-on experience of laser-based metrology techniques and their applications in diverse sectors such as semiconductors, pharmaceuticals, chemicals, and food-processing industries.

Suggested Readings

1. Lasers: Fundamental and Applications, Graduate Text in Physics, K. Thyagarajan, Ajoy ghatak (2nd edition, Springer, 2002)
2. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000)
3. Fundamentals of molecular spectroscopy, C. N. Banwell ((McGraw Hill)

Details of Content of General Elective (GE) courses (to be offered to students of other departments as well in the form of Open electives)

MASTER of SCIENCE in PHYSICS

Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc

Course Code: PH-GEC5101

Course Name: Radiation Safety

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Radiation Safety GEC	4	3	1	0	Bachelor's degree in any discipline

Duration: 60 Hours(45L+15T)

Course Objectives

This course is aimed to introduce the student to practical aspects of nuclear radiation with an understanding of basic quantities and doses, the role of fundamental processes involved in the interaction of X- rays, gamma-rays, charged particles and neutrons with matter, the principles underlying the operation of nuclear detection/dosimetry instruments, areas of applications, awareness of the need and methods for safety protocols for radioactive material and environmental safety.

Contents

Unit I: (11 Hours)

Basics of Radiation: Origin of radiation, binding energy and Q-value, stable and unstable isotopes, radioactive decay (alpha, beta, neutron and electromagnetic transitions), mean life and half life, nuclear reactions, concept of cross sections and attenuation coefficients, Neutron flux, kinematics of nuclear reactions. Slowing down and moderation. Basic idea of different units of activity, radiation quantities: exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, quality factor, radiation and tissue weighting factors, KERMA, Annual Limit of Intake (ALI) and Derived Air Concentration (DAC). .

Unit II: (11 Hours)

Devices for radiation measurement and survey: Radiation interaction with matter. Introduction to types of radiation detectors: semiconductor, scintillator and gas detectors (Geiger-Muller counters, ionisation chamber and proportional counters) Principles of radiation counting statistics, dead time and calibration standards. Types of Radiation Dosimeters: thermoluminescence, radiographic films, calorimetry, semiconductor diodes; Relation between detection and dosimetry; exposure measurements with free air chamber. Interaction of ionising and non-ionising radiation at the cellular level. Application of Nuclear techniques: Medical science (e.g., MRI, PET, Projection Imaging Gamma Camera, Radiation therapy), Art &

Archaeology, Art, Crime detection, Oil & Mining, Water assessment, Industrial usage: Tracing, Gauging, Material modification, Sterilization, Food preservation

Unit III: (12 Hours)

Radiation Protection Standards: Classification of radioactive sources, Radiation dose to individuals from natural radioactivity in the environment and man-made sources, Basic concept of radiation protection standards: historical background, International Commission of Radiological Protection and its recommendations, the system of radiological protection, justification of practice, optimization of protection and individual limits, radiation and tissue weighting factors, committed equivalent dose, committed effective dose, concept of collective dose, potential exposures, dose and dose constraints, system of protection for invention-categories of exposures-Occupational, Public and Medical exposures, Permissible levels for neutron flux, factors governing internal exposure-Radionuclide concentration in air and water –ALI, DAC and contamination levels, effects of inhaled radionuclides on biological systems, impact on humans and society.

Unit IV: (11 Hours)

Regulations, Monitoring, & Radioactive Waste Management: Evaluation of external radiation hazard-effect of distance, time and shielding, shielding calculation, personnel and area monitoring-internal radiation hazards, radio toxicity of different radio nuclides and the classification of laboratories, control of contamination-bioassay and air monitoring, chemical protection, Radiation accidents and disaster monitoring, Sources & classification of Radioactive waste, permissible limits for disposal of waste, general method of disposal, storage management of radioactive waste in facilities. Responsibilities of operator, regulatory bodies, and government .

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.

- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

A knowledge of the principle of operation of various radiation detectors, understanding of radiation dose calculation and permissible doses for different levels of users, and radiation effects, an understanding of instrumentation in practical situations, awareness about the management of radioactive material, and adherence to safety protocols.

Suggested Reading:

1. Nuclear and Particle Physics, W. E. Burcham and M. Jobes (Pearson Education, 1995)
2. Radiation detection and measurement, G. F. Knoll (4th Ed., Wiley, 2010)
3. Thermoluminescence Dosimetry, McKinlay, A. F., Bristol, Adam Hilger (Medical Physics Hand book 5)
4. Fundamental Physics of Radiology, W. J. Meredith and J. B. Massey (John Wright and Sons, 1989)
5. An Introduction to Radiation Protection, A. Martin and S. A. Harbison (John Willey & Sons, 1981)
6. Medical Radiation Physics, W. R. Hendee (Medical Publishers Inc., 1981)
7. Nuclear Physics : Principles and applications, John Lilley (Wiley, 2001)
8. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (2nd Ed., Elsevier, 2014)
9. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (2nd Ed., Springer, 2013)
10. IAEA Publications : (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interium) (2010); (b) Safety Standards Series No. RS-G-1.5 (2002), Rs-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007) (latest version).
11. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities. 12. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources.

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc

Course Code: PH-GEC5102

Course Name: Complex System & Networks

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Complex System & Networks GEC	4	3	1	0	Bachelor's degree in a branch of Science, and Mathematics as a subject in Classes XI, XII

Duration: 60 Hours(45L+15T)

Course Objectives

This course deals with the interdisciplinary subject of complex systems, that include, among others, living organisms, ecosystems and human societies. The course emphasizes a unifying theme – complex networks – that cuts across all these systems. It develops the mathematical tools of graph theory and dynamical systems to provide insight into the structure, dynamics and evolution of a variety of complex systems in the physical sciences, life sciences, social sciences and engineering.

Contents

Unit I: (7 Hours)

Overview: Examples of complex systems: organisms, brains, ecosystems, societies, the internet. Components of these systems: molecules, cells, species, agents, computers. Collective phenomena exhibited by these systems. Contrast with other collective phenomena in physics such as phase transitions. Adaptive nature of these systems.

Unit II: (10 Hours)

Graph theory and the network structure of complex systems: Complex networks of interaction as a unifying theme underlying complex systems. Undirected, directed and bipartite graphs, hypergraphs. Adjacency matrix of a graph. Graph theoretic measures of network structure. Random graph ensembles, small-world, scale-free, hierarchical and autocatalytic graphs. Network motifs. Nature of graphs that arise in various complex systems

Unit III: (14 Hours)

Dynamics of complex systems: Dynamics on a fixed network. Examples of continuous and discrete dynamical systems to be taken from various complex systems such as chemical networks, metabolic networks, ecological food webs, genetic regulatory circuits, neural networks, social and economic networks, epidemiological networks. Fixed point and limit cycle attractors of these systems. The influence of network structure on dynamics.

Unit IV:

(14 Hours)

Evolution of complex systems: How networks change over time. Preferential attachment model of scale free networks. The origin of life puzzle. Model of autocatalytic network evolution and self-organization of a complex network. Community assembly models in ecology. Evolution of biological and social networks. Crashes and recoveries in complex systems. Robustness and fragility of complex systems.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

Being able to appreciate that complex networks of interacting components underlie many complex systems studied under different disciplines. Learning the similarities and differences between complex systems from the perspective of network structure. Learning certain mathematical methods of graph theory and dynamical systems. Being able to apply these methods to characterize the structure of various complex systems and to model certain phenomena exhibited by them.

Suggested Reading:

1. Networks: An Introduction, M. E. J. Newman (Oxford University Press, 2010).
2. Origins of Order, Stuart Kauffman (Oxford University Press, 1993).
3. Handbook of Graphs and Networks: From the Genome to the Internet, S. Bornholdt and H.-G. Schuster (Wiley-VCH, 2003).
4. Dynamics of Complex Systems, Yaneer Bar-Yam (Perseus Books, 1997)

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc
Course Code: PH-GEC5103
Course Name: Introductory Astronomy

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Introductory Astronomy GEC	4	3	1	0	Bachelor's degree in any discipline

Duration: 60 Hours(45L+15T)

Course Objectives

Since this course is an open elective, with students from diverse backgrounds opting for it, the primary objective is to impart a basic knowledge about the oldest branch of physical science in a conceptual mode, relying less on mathematics and more on physical understanding. Since exciting developments have been taking place in astronomy of 20th and 21st centuries, with India playing crucial roles, the aim is to enable students to have a flavour of both historical and modern aspects so that they acquire a perspective of their place in the universe.

Contents

Unit I (7 Hours)

Antiquity of astronomy: Planets and stars in Egyptian and Babylonian civilizations; Possible reference to stars and planets in Indus Valley Civilization; stars and constellations in Rig Veda as well as in other vedic literature; reference to Halley's comet in a Babylonian clay tablet; Far Eastern astronomy - comets and Crab supernova; Reference to cosmic objects in mythologies, Classic literature and science fictions.

Early astronomical measurements: Measurement of Earth's radius by Eratosthenes; Lunar and solar motion studies by Hipparchus - equinoxes and solstices, lunar and solar eclipses; Aryabhatta I and his seminal contributions to astronomy - relative motion, spinning Earth, eclipses, etc.; Varahamihira, Brahmagupta and other siddhantic astronomers of India; symbiotic relation between mathematics and astronomy; evidence of the precession of equinoxes from vedic literature; Jai Singh and his Jantar Mantar.

Unit II (12 Hours)

Solar system: geocentric model - Ptolemy, Tycho Brahe and Samanta Chandrasekhar; retrograde motion of Mars and theory of epicycles; Copernicus and the heliocentric model; Kepler's laws of planetary motion - a formulation based on a set of mathematical laws for the first time in physical sciences; Galileo's pioneering work - length and time measurements, telescope, lunar craters, moons of Jupiter, rings of Saturn, corroboration of Copernican model, Pisa tower and equivalence principle.

Laws of gravitation: motion of the Moon around the Earth, falling bodies, Newton's genius; Halley's comet and laws of gravity; importance of gravity as a force in astronomy; Physics of

the Sun; Thermonuclear reactions; discovery of Neptune and Pluto; asteroid belt, meteors and comets; Tidal forces and the oceanic tides; precession of equinox and change of seasons; dating Rig veda using the precession of equinox; Distances - parallax method; standard candles - Cepheid variables and Henrietta Leavitt, Type Ia Supernovae; Spectroscopy - atomic spectra, emission and absorption lines, their widths and Doppler shifts.

Unit III

(18 Hours)

Stellar population and Hertzsprung-Russell diagram; Meghnad Saha, ionized elements, Saha equation and birth of astrophysics; Wilson-Bappu effect and stellar distances; Stellar structure and evolution- evolution of low mass stars and high mass stars; white dwarfs - Fowler, Chandrasekhar and Eddington; Chandrasekhar's mass limit; Baade and Zwicky - supernova and neutron stars; supernova explosion; pulsars.

Milky Way and other galaxies: Shapley-Curtis debate; measurement of Doppler shift in emission lines by Humason, Slipher and Hubble; Cepheid variable and distances of galaxies; Classification of galaxies - spirals, ellipticals, irregulars, dwarfs, lenticulars, etc.; Hubble's law and birth of cosmology as a scientific discipline; Big bang and steady state models; Hoyle-Narlikar cosmology; Radio source counts, evolution of radio-sources and setback to steady-state theory; angular resolution, radio interferometry and large baselines; detection of apparent superluminal motion; radio telescopes in India - Govind Swarup and collaborators.

Unit IV

(8 Hours)

The Universe: Penzias, Wilson and the cosmic microwave background; corroboration of thermal history in big bang cosmology as predicted by Gamow and his collaborators; Big bang model, singularity and Raychaudhuri equation; clusters of galaxies; Zwicky and the dark matter; observed large scale structure; Vera Rubin and the evidence of dark matter from galactic rotation curves; Type Ia supernovae and accelerating universe; the puzzle of dark energy; new astronomy - X-ray and gamma ray astronomy, gravitational waves, neutrino astronomy, 30 metre telescope and the square kilometre array; discovery of exoplanets.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.

- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome

A historical perspective of the development of Astronomy. Conceptual understanding of basic principles involved. A flavour of current developments in this field and India's role in them. Appreciation of laws of nature that are discovered on Earth but which explain successfully distant cosmic objects and the universe as a whole .

Suggested Reading

1. The Physical Universe, Frank Shu (University Science Books, 1982)
2. Cosmology: The Science of the Universe, Edward Harrison (Cambridge University Press, 2000)
3. From Black Clouds to Black Holes, J. V. Narlikar (World Scientific, 1985)
4. Archeoastronomy - Introduction to the Science of Stars and Stones, Giulio Magli (Springer, 2016)

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc
Course Code: PH-GEC5104
Course Name: Physics of Biological Systems

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics of Biological Systems GEC	4	3	1	0	Bachelor's degree in a branch of Science, and Biology as a subject in Classes XI, XII

Duration: 60 Hours(45L+15T)

Course Objectives

This open elective course will introduce students to selected biological phenomena from the point of view of physics, emphasizing quantitative regularities. It will enable students from non-biology backgrounds to gain an overview of living systems, and those from biology backgrounds to perform mathematical modelling of certain biological processes.

Contents

Unit I (10 Hours)

Length and time scales in biology: Types, sizes and roles of biomolecules - metabolites, proteins, RNA, and DNA. Ranges of cell sizes and interdivision time scales,. Ranges of organism sizes and lifetimes, Scaling laws in biology, Complexity of living systems, Timeline of life on Earth, Time scales in biological evolution. Experimental techniques.

Unit II (14 Hours)

Cellular dynamics: Dynamical systems, coupled ordinary differential equations, Phenomena and models of intracellular chemical dynamics. Reaction-diffusion systems, Ecological interactions: Predator-prey model. The brain: Dynamics of a single neuron, Neural networks, Learning, Memories as attractors of neural network dynamics.

Unit III (9 Hours)

Information in living systems: Probability, entropy and information, Applications of Information theory in genetics. Brownian motion of colloids.

Unit IV (12 Hours)

Random walk in $d=1,2,3$ and Self-avoidance, classification and conformations of polymers and related Scaling, structures of DNA, simulation methods and related experiments.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.

- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome

Gain knowledge of structures and processes in living systems at multiple length and time scales, including at the level of molecules, cells, multi-cellular organisms and ecosystems. Appreciate that life is a consequence of physical processes at the molecular level. Learn certain mathematical methods of dynamical systems, probability and information theory. Also, to learn a few techniques for numerical simulations of proteins or biopolymers. Be able to apply these methods to model certain biological phenomena

Suggested Reading

1. Physics in Molecular Biology, Kim Sneppen and Giovanni Zocchi (CUP 2005).
2. Biological Physics: Energy, Information, Life, Philip Nelson (W.H. Freeman & Co, NY, 2004).
3. Biophysics: Searching for Principles, William Bialek (Princeton University Press, 2012).
4. Physical Biology of the Cell (2nd Edition), Rob Phillips et al (Garland Science, Taylor & Francis Group, 2013).
5. An Introduction to Systems Biology, Uri Alon (Chapman and Hall/CRC, 2013).
6. Mathematical Biology: I. An Introduction, J.D. Murray (3rd Ed., Springer, 2004).

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc
Course Code: PH-GEC5105
Course Name: Physics Education

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics Education GEC	4	3	1	0	Bachelor's degree in a branch of Science, and Physics as a subject in Classes XI, XII

Duration: 60 Hours(45L+15T)

Course Objectives

This course will develop pedagogic knowledge for teaching-learning of physics informed by global best praxis. It will delineate procedural and content knowledge for meaningful laboratory work; and design of appropriate technology enhanced active learning environments.

Contents

Unit I (5 Hours)

Foundations of Teaching-Learning of Physics: Goals of physics teaching. Beliefs and Epistemological Expectations and how they impact teaching-learning of physics. Theoretical models of student learning. Structure of knowledge. Difference between novice learners and experts. Theories of cognition. Constructivist and social theories of learning. Guided Enquiry and Active Learning. Engendering cognitive change.

Unit II (12 Hours)

Effective Teaching-Learning Strategies: Models of Classroom. Traditional instructor centred environment vs Active engagement student centred environment. Physics Education Research (PER): What works and what does not work. Designing Lecture based effective instruction methods: Concept Tests; Peer Instruction; Interactive Lecture demonstrations; Just in Time Teaching; Interactive Tutorials; Cooperative Problem Solving. Modeling. Problem Solving. Enhancing learning through peer, group and collaborative work. Cognitive Apprenticeship. Research-based curricula: Developing hands-on activities. Developing Interactive worksheets/Tutorials.

Unit III (12 Hours)

Evaluating Conceptual Learning: Formative and Summative Evaluation. Designing examinations. Types of questions: MCQ, Representation-translation questions, ranking tasks, context-based reasoning problems, estimation problems, qualitative questions, essay questions. Domain knowledge content surveys and concept probes (Mechanics, Electricity and Magnetism, Vectors, Quantum Mechanics etc).

Unit IV

(16 Hours)

Learning in the Lab: Students' understanding of the nature of scientific investigation and its influence on lab work. Student's perception of concepts of statistics, errors of observation, reliability and validity of observations; graphical representation of data and impact on performance. Developing Procedural and Conceptual Knowledge (PACK) in the Laboratory. Learning to design open-ended experiments and verify hypotheses. Assessment of performance.

Technology Enhanced Learning Environments: Appropriate use of technology. Developing Demonstration experiments and hands-on activities for conceptual learning. Sensor based Data Acquisition Laboratories. Integrating Simulations, Visualization, Video, Modeling for conceptual learning. Designing Technology Enhanced Active Learning. Future of classroom.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome

Understanding the theoretical framework of how students learn; familiarity with a range of effective strategies for teaching-learning; evaluating and enhancing student's conceptual understanding of physics and problem solving abilities; developing effective learning in the lab and open-ended investigations; designing technology enhanced active learning environments;. Designing effective assessment and evaluation tools for student learning; developing innovative teaching-learning resources and curricula.

Suggested Reading

1. Teaching Introductory Physics, Arnold Arons (John Wiley and Sons Inc., 1997).

2. Teaching Physics with the Physics Suite, Edward F. Redish (John Wiley and Sons Inc., 2003).
3. Teaching and Learning in the Science Laboratory, Dimitris Psillos and Hans Niedderer (Editors) (Kluwer Academic Publishers, 2002).
4. Understanding Basic Mechanics, Frederick Reif (John Wiley and Sons Inc., 1995).
5. Peer Instruction, Eric Mazur (Prentice Hall, 1997).
6. Physics by Inquiry. Vol. I and II., Lillian C. Mc Dermott (John Wiley and Sons Inc., 1996).
7. Workshop Physics. The Physics Suite. Priscilla, W. Laws (John Wiley and Sons Inc., 2004)
8. Real Time Physics Active Learning Laboratories. The Physics Suite, David R. Sokoloff, Ronld K. Thornton, Priscilla W. Laws (John Wiley and Sons Inc., 2004)
9. Activity Based Tutorials. The Physics Suite, Michael C. Wittmann, Richard N. Steinberg, Edward F. Redish and the University of Maryland Physics Education Research Group (John Wiley and Sons Inc., 2004)
10. Tutorials in Introductory Physics, Lillian C. Mc Dermott, Peter S. Shaffer and the Physics Education Research Group (John Wiley and Sons Inc., 2003)
11. Modelling in Physics and Physics Education, Proceedings of the GIREP Conference 2006. Ed van den Berg, Ton Ellermeijer and Onne Slooten. GIREP 2006.
12. Five Easy Lessons: Strategies for Successful Physics Teaching, Randall D. Knight.

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSC5201
Course Name: Atomic and Molecular Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Atomic and Molecular Physics DSC	4	3	1	0	Quantum Mechanics - I & II

Duration: 60 Hours (45L+15T)

Course Objectives

The main objective is to teach the students the foundational concepts of atomic and molecular structure and spectroscopy using the quantum mechanical approach. Further, many different applications of these fundamental concepts will be taught, including the realisation of a coherent light source: the Laser, magnetic resonance imaging and relevance in astrophysics and astronomy.

Contents:

Unit I (13 Hours)

Atomic Physics: Fine structure and hyperfine structure of hydrogenic atoms. Lamb shift. Intensity of fine structure lines. Atomic systems in magnetic and electric fields: Zeeman, Paschen-Bach and Stark effects. Two-electron atoms: ground state and first excited state, singlets and triplets. Slater determinant. Many-electron atoms: Central Field Approximation LS and jj coupling schemes, Lande interval rule. Transition probabilities and selection rules for electric and magnetic dipole and multipole radiation.

Unit II (7 Hours)

Molecular Structure: Born-Oppenheimer approximation for diatomic molecules. Electronic and nuclear Hamiltonian. Energy levels of a molecule. Molecular orbital and valence bond methods for H_2^+ and H_2 . Potential energy curve of a diatomic molecule: the Morse potential. Dissociation energy. Electronic configuration of molecules and spectroscopic terms.

Unit III (10 Hours)

Molecular Spectra: Rotational spectra of diatomic molecules- rigid and non-rigid rotors, isotope effect. Vibrational spectra of diatomic molecules- harmonic and anharmonic vibrators. Intensity of spectral lines. Vibration-rotation spectra. Electronic spectra of diatomic molecules- coarse structure and fine structure. P,Q,R branches and the Fortrat diagram.

Intensities in electronic coarse structure- The Franck-Condon principle. Raman spectroscopy.

Unit IV

(15 Hours)

Applications: Lasers: Interaction of atoms with radiation, Multilevel rate equations and saturation. Laser pumping and population inversion. Special properties of laser light. Free-electron laser. Nonlinear phenomenon: Harmonic generation.

Spin resonance spectroscopy: Electron Spin Resonance and Nuclear Magnetic Resonance.

Astrophysics and Astronomy: the 21 cm line, Identification of atomic/molecular/ionic species present in outer space. Fourier Transform Infrared Spectroscopy (FTIR). Fluorescence and Phosphorescence. Optical cooling and trapping: Concept of photon recoil. Auger Electron Spectroscopy.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcomes

Students will learn the details of atomic and molecular structure and spectroscopy in terms of quantum mechanical treatment. The origins of fine and hyperfine structure of spectral lines of hydrogenic atoms; the effect of external electric and magnetic fields on energy levels of atoms and methods to deal with two-electron and multi-electron atoms will be learnt. The rotational, vibrational and electronic energies of molecules and their associated spectroscopies will be discussed. The details of these spectroscopies would serve as the foundational concepts for understanding various experimental results. The diverse applications of these basic principles will be introduced, which include the realisation of lasers and their use in harmonic generation

and optical cooling; the relevance in astrophysics and astronomy; and magnetic resonance imaging to enable them to connect the classroom teaching to real-life studies.

Suggested Readings

1. Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachin (2nd Ed., Pearson Education, 2003)
2. Atomic Spectra and Atomic Structure, G. Herzberg (Dover Publications, 2003)
3. Molecular Spectra and Molecular Structure, G. Herzberg (Van Nostrand, 1950)
4. Atoms, Molecules and Photons, W. Demtroder (Springer, 2006)
5. Fundamentals of Molecular Spectroscopy, C. N. Banwell (McGraw Hill, 1983)
6. Basic atomic & Molecular Spectroscopy, J. M. Hollas (Royal Society of Chemistry, 2002)
7. Principles of Lasers, O. Svelto (5th Ed., Springer, 2010)
8. Laser Spectroscopy, W. Demtroder (3rd Ed., Springer, 2003)
9. Molecular Quantum Mechanics, P Atkins & R. Friedman (Oxford Univ. Press, 2005)
10. Quantum Chemistry, I. N. Levine (7th Ed., Pearson, 2016)

MASTER of SCIENCE in PHYSICS

Semester IV of 2 year MSc/ Semester II of 1 year MSc

Course Code: PH-DSC5202

Course Name: Advanced Classical Dynamics, Fields and Matter

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Classical Dynamics, Fields and Matter DSC	4	3	1	0	Classical Mechanics, Electrodynamics, Statistical Physics, Mathematical Methods

Duration: 60 Hours (45L+15T)

Course Objectives:

To acquire an in-depth understanding of dynamical systems, Hamiltonian formulation, and perturbative methods used in classical physics. To introduce the fundamental principles of elasticity and elastodynamics, including stress-strain relations and wave propagation in elastic media. To study the theory and applications of electromagnetic dipole and quadrupole radiation, radiating systems such as antennae, and the scattering of radiation. To understand collective behavior and emergent phenomena in interacting many-particle systems, specifically, phase transitions and critical phenomena.

Unit I: Dynamical Systems, Conservative Hamiltonian and Applications (13 Hours)

First and second-order autonomous systems. Transformations with rotation and dilation, phase flows, equilibrium, and stability. Classification of fixed points and their determination. Conservative Hamiltonian for systems with one degree of freedom. Examples involving cubic potential, free rotations and the vertical pendulum. Area-preserving flows and Liouville's theorem. Hamilton-Jacobi theory and the Action-angle variables. First-order perturbation theory for conservative Hamiltonians.

Unit II: Elasticity and Basics of Elastodynamics (11 Hours)

Displacement and Strain tensor, Dilation, Shearing Strain, Strain Ellipsoid, Stress Tensor, Moment of force. Conditions for Translational and Rotational equilibrium of elastic bodies. Strain energy and thermodynamics of deformation. Free energy and stress tensor of isotropic solids, Lamé's coefficients and elastic moduli. Elastic properties of solids and Hooke's law. Relationship between elastic constants, limits of Poisson ratio. Translational equilibrium for isotropic solids – bi-harmonic equation. Elastic waves in isotropic media and nature of plane wave solutions. Seismic waves.

Unit III: Electromagnetic Multipole Radiation and Scattering (11 Hours)

Multipole fields in Electrodynamics. Electric/Magnetic dipole and Electric quadrupole radiation. Radiating systems – Antennae. Power emission formulae. Antenna structure and design. Scattering of electromagnetic radiation by free charges – Thomson cross section. Radiation reaction and radiation damping. Dipole scattering at long wavelengths. Rayleigh's law.

Unit IV: Interacting Particles and Emergent Phenomena (10 Hours)

First-order and second-order phase transitions. Order parameters. Phase transition in a magnetic system. Ising model. Landau's theory. Correlation function. Critical behavior and related exponents.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcomes

Upon successful completion of this course, the students will be able to: Analyze dynamical systems from the phase-space of autonomous variables, find the stable configurations thereof. Understand Hamilton's formalism, Hamilton-Jacobi theory and action-angle variables, and apply the perturbation techniques in classical physics. Apply the theory of elasticity to determine stress, strain, elastic equilibrium conditions, and wave propagation characteristics in isotropic solids. Determine Power outputs from electromagnetic multipole radiation, antenna characteristics, scattering cross sections, and understand radiation damping effects which have widespread usage. Explain phase transitions and critical phenomena using order parameters, find correlation functions, and use simple statistical models such as the Ising model. Integrate concepts from

mechanics, statistical physics, elasticity, and electrodynamics to model and analyze complex classical physical systems.

Recommended Readings:

1. Introduction to Dynamics, I. Percival and D. Richards, Cambridge University Press.
2. Classical Mechanics, N.C. Rana and P. S. Joag, Tata McGraw-Hill.
3. Nonlinear Dynamics and Chaos, S.H. Strogatz, Westview Press.
4. Advanced Mathematical Methods for Scientists and Engineers, C.M. Bender and S.A. Orszag, McGraw-Hill.
5. Theory of Elasticity, L.D. Landau and E.M. Lifshitz, Pergamon Press.
6. Elasticity and Fluid Dynamics: Modern Classical Physics, Vol. 3, K.S. Thorne, R.D. Blandford, Princeton University Press.
7. Classical Electrodynamics, J.D. Jackson, 3rd ed., Wiley, 1998.
8. The Classical Theory of Fields, L.D. Landau and E.M. Lifshitz, 4th ed., Butterworth-Heinemann, Elsevier, 1975.
9. Introduction to Electrodynamics, D. J. Griffiths, 3rd ed., Benjamin Cummings, 1999.
10. Statistical Mechanics, R.K. Pathria and P.D. Beale, Academic Press.
11. Equilibrium Statistical Physics, M. Plischke and B. Bergersen, World Scientific.

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5211
Course Name: Physics at the Nanoscale – II (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics at the Nanoscale- II (Theory) DSE	4	3	1	0	Quantum mechanics (Core), Solid State Physics (Core), Statistical Mechanics (Core)

Duration: 60 Hours(45L+15T)

Course Objectives

The main goal of this subject is to provide basic understanding of fabrication and characterization of nano structured materials by different analytical methods. More importantly, the students will have enriched knowledge on the properties of materials at the nanoscale and implementing it for various applications.

Contents:

Unit I (12 Hours)

Growth: Synthesis of metal, semiconductor, carbon and bio nanomaterials. Grains and grain boundaries, distribution of grain sizes, pores, strains. Thin film preparation by thermal evaporation, sputtering and pulsed laser deposition methods. Gas phase synthesis of nanopowders, chemical and colloidal methods, mechanical milling, dispersion in solid-doped glasses and sol gel method; Functionalization of nanoparticles.

Unit II (8 Hours)

Structure and thermodynamics at nanoscale: specific features of the nanoscale growth, control of size, nucleation, growth and aggregation. Crystalline phase transitions and geometric evolution of the lattice in nano crystals, thermodynamics of very small systems. Self-assembling nanostructured molecular materials and devices.

Unit III (10 Hours)

Properties: Chemical- reactivity, Mechanical properties at nanoscale; Mechanical superplasticity. Magnetism at nanoscale; Magnetic and electron transport- GMR and Optical-linear and nonlinear.

Unit IV (15 Hours)

Characterization and Applications of nanomaterials: Characterization by diffraction method and optical methods. Chemical characterizations-Raman spectroscopy, XPS, XAS and EXAFS.

Electronics and Electromagnetics-ceramic capacitors and magnetic recording
Optics-nanophosphors and photonic crystals Mechanics- Biology and environment.
Nanomaterial Devices: Quantum dot heterostructure lasers, all optical switching and optical data storage.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Learners will be able to comprehend basic knowledge on the fabrication and characterization of nanomaterials by different methods. The students will have enhanced knowledge on the physics of nanomaterials and its applications in emerging technological applications.

Suggested Readings

1. Nanostructured Materials and Nanotechnology, H. S. Nalwa (Ed.) (Academic Press, 2002)
2. Nanomaterials and Nanochemistry, C. Brechignac, P. Houdy and M. Lahmani (Springer, 2006)
3. Characterization of Nanophase Materials, Z. L. Wang (Ed.) (Wiley-VCH, 2000)
4. Semiconductor Nanocrystal Quantum Dots, A. L. Rogach (Ed.) (Springer Wien NY, 2008)
5. Introduction to Nanotechnology, C. P. Poole Jr. & F. J. Owens (Wiley-Interscience, 2003)
6. Carbon Nanotubes, S. Reich, C. Thomsen & J. Maultzsch, (Wiley-VCH, 2004)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5212
Course Name: Nanomaterials–II (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nanomaterials-II (Lab.) DSE	4	0	0	4	Nanomaterials-I (Lab.) Co-requisite: Nanomaterials-II (Theory)

Duration: 120 Hours

Course Objectives

The main goal of this subject is to synthesize different classes of materials by various methods. As synthesised nano materials will be characterized by different analytical techniques and analysed with respect to size reduction in the respective physical properties.

Contents:

Unit I: (40-50 Hours)

1. Growth of nanoparticles by chemical routes.
2. Growth of nanophase by sputtering.
3. Growth of quantum dots by thermal evaporation.
4. Growth of nanoparticles by mechanical milling/attrition.
5. Growth of nanomaterials by nanopores-template method.
6. Growth of semiconductor quantum dots in matrices (glass/polymer etc).

Unit II: (32-35 Hours)

1. Structural characterization of nanomaterials by XRD- determination of average grain size, lattice parameters, strains etc.

2. Structural characterization of nanomaterials by TEM - determination of grain size and its distribution.
3. Surface morphological characterization of nanomaterials by AFM.
4. Surface morphological characterization of nanomaterials by SEM.
5. Surface morphological characterization of nanomaterials by TEM.
6. Determination of pores size of nanomaterials.

Unit III

(18-20 Hours)

1. Measurement and analyses of UV/vis Absorption spectrum of nanomaterials.
2. Measurement and analysis of the Photoluminescence spectrum of nanomaterials.
3. Measurement and analysis of Raman spectrum of nanomaterials.
4. Measurement and analysis of photoluminescence/Absorption spectrum of nanomaterials at low temperatures.
5. Determination of optical constants of nanomaterials by ellipsometry.

Unit IV

(12-15 Hours)

1. Measurement of sensor property of nanomaterials.
2. Determination of stoichiometry of nanomaterials by XPS/EDAX/ESCA.
3. Measurement and analysis of ferroelectric properties of nanomaterials.
4. Thermal characterization of polymers by DSC technique.

Course Learning Outcomes

The students will get a better understanding of the concepts studied by them in the theory course and correlate with experimental observations. In addition, the students are exposed to thermal, microscopic, electrical and spectroscopic methods of characterization of nanomaterials. The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment

Suggested Readings

1. Nanotechnology, G. Timp (AIP press, Springer-Verlag, New York, 1999)
2. Nanostructured materials and nanotechnology, Hari Singh Nalwa. (Academic Press, USA, 2002)
3. Hand book of Nanostructured Materials and Technology. Hari Singh Nalwa. (Vol.15, Academic Press, USA, 2000)
4. Handbook of Nanoscience, Engineering and Technology, W. Gaddard, D. Brenner,
5. S. Lysherski and G. J. Infrate. (Electrical Engineering Handbook) (CRC Press, 2012)
6. Sol-Gel Science, C. J. Brinker and G. W. Scherrer (Academic Press, Boston, 1994)
7. Nanoscale Characterization of Surfaces & Interfaces, N. John Dinardo, (Weinheim Cambridge: Wiley-VCH, 2000)
8. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Ray F. Egerton (Springer, 2005)

9. Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology), Roland Wiesendanger (Springer, 1968)
10. Chemistry of nanomaterials: Synthesis, properties and applications, CNR Rao et.al. (Wiley-VCH, 2004)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5213
Course Name: Advanced Electronics – II (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Electronics-II (Theory) DSE	4	3	1	0	Adv. Electronics -I (Theory) Co-requisite: Advanced Electronics-II (Lab)

Duration: 60 Hours(45L+15T)

Course Objectives

To give an understanding about generation, propagation, reception and detection of electromagnetic waves in free space and optical signals in guided media relating to fiber optics communication. Analyze the contribution of inherent noise produced by components, devices and circuits, commonly used in instrumentation/communication systems and learn the effective methods of noise reduction.

Contents:

Unit I (12 Hours)

Communication: EM wave propagation: transmission lines, coaxial cable, waveguide, optical fiber and free space. Propagation of ground wave, space wave and Sky wave. Characteristic impedance, reflection coefficient, Standing wave ratio (microwave components) and measurement of impedance in various media. Fiber optic and wireless communication.

Unit II (12 Hours)

Antennas : Linear dipole antennas, Antenna array techniques, Systems and characterization antenna matching and basic antenna types. Pulse-Digital Modulation: Elements of Pulsed-Code Modulation (PCM). Channel capacity of a PCM system, Digital Multiplexers. Digital transmission and demodulation.

Unit IV (16 Hours)

Digital Signal Processing (DSP): Converting analog to digital signals and vice versa. Timedomain and frequency-domain representation of discrete time signals. Finite and infinite impulse response and digital filter design. Correlation, autocorrelation and cross-correlation of periodic and aperiodic functions.

Unit IV

(5 Hours)

Noise: Signal to noise ratio (SNR) and enhancement of SNR in instrumentation and communication. Noise reduction in electronic circuits. Principles of phase locking and lockin amplifier, Sample and hold circuits.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will have learnt the basic concepts involved with analog to digital conversion of signals, the coding techniques and basic mathematical tools/techniques used for processing of digital signals, signal transmission and high speed data transfer in modern day communication systems and networks.

Suggested Readings

1. Digital Signal Processing, J. G. Proakis and D. G. Manolakis (4th Ed., Pearson, 2007)
2. Electronic Communication, D. Roddy and J. Coolen (4th Ed., Pearson, 1995)
3. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M.Sayer and A. Mansingh (PHI Learning, 2000)
4. Discrete Time Signal Processing, A.V. Oppenheim and R. W. Schaffer (2nd Ed., Pearson, 2006)
5. Electronic Communication systems, W. Tomasi (5th Ed., Pearson, 2008) 1.

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5214
Course Name: Advance Electronics– II (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Electronics-II (Lab.) DSE	4	0	0	4	Adv. Electronics - I (Lab.) Co-requisite: Advanced Electronics-II (Lab.)

Duration: 120 Hours (8P/Week)

Course Objectives

After acquiring the fundamentals of circuit design and troubleshooting, this course aims to further strengthen students' ability to design and develop electronic circuits for a wide range of day-to-day applications. The course emphasizes experiential learning, with students undertaking a project throughout the semester that involves the design, development, testing, and evaluation of an electronic circuit or system.

Contents:

Unit 1: Group A:

Computer aided design using standard software for integrated circuit and device fabrication.
 Project work Entire semester

Unit II: Group B :

Electronic material and device fabrication and characterization (p-n junction, diffusion thin film sensors, optical memory etc.).
 Project work for entire semester

Course Learning Outcomes

The students are able to design innovative and execute projects based on IOT/Machine Learning/ Data Analysis, etc and can independently design complicated circuits.

Suggested Readings

1. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M. Sayer and A. Mansingh (Prentice Hall India, 2010)
2. Solid State Electronic Devices, B.G. Streetman (Prentice Hall India, 2000)

3. Introduction to Semiconductor Materials and Devices, M.S. Tyagi (John Wiley & Sons, 2008)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSEDSE5215
Course Name: Advanced Nuclear Physics II (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Nuclear Physics - II (Theory) DSE	4	3	1	0	Nuclear Physics and Particle Physics (DSC), Quantum Mechanics I & II (DSC), Statistical Physics (DSC), Electrodynamics (DSC).

Duration: 60 Hours(45L+15T)

Course Objectives

The course is designed to provide a continuous and comprehensive understanding of nuclear structure and nuclear reaction dynamics through various theoretical models and experimental approaches. It aims to develop a strong conceptual foundation in scattering theory, direct and compound nuclear reactions, fusion and fission processes, and collective nuclear behaviour. The course further introduces advanced topics such as shell and collective models, heavy-ion collisions, and exotic nuclei, enabling students to appreciate current developments and research challenges in modern nuclear physics and nuclear astrophysics.

Contents:

Unit I: Nuclear Reactions and Scattering Theory (12 Hours)

Nuclear scattering and reaction cross section using partial wave analysis, Phase shift analysis, scattering amplitude, Hard sphere scattering, Shadow scattering, Optical theorem, Potential scattering and resonances, Briet-Wigner resonance formula for $l=0$ and for all l , Elastic scattering using Optical model: Formal theory of optical model, and Empirical optical model, Fraunhofer and Fresnel scattering, In-elastic scattering using coupled channel approach, Direct reactions, Transfer reaction (semi-classical approach) using plane wave Born approximation (PWBA) and distorted wave approximations (DWBA), Direct reaction: tool to shell structure, Charge exchange reactions, Knock-out and pick-up reaction, Break-up reaction. Compound nuclear reaction and statistical models, Compound nucleus decay: Weisskopf - Ewing theory, Hauser-Feshbach theory, Heavy ion collisions.

Unit II: Fusion, Fission, and Nuclear Shell Structure (10 Hours)

Fusion & Fission reaction: Fusion reactions using WKB approximation, Sub-barrier fusion,

Fission: Mass distribution, energy distribution and cross-sections, Isomeric fission, Coulomb excitation (qualitative only).

Shell model: Review of shell Model, magic numbers, single particle shell model, Self-consistent approach, basic concept of Hartee-Fock and Hartee-FockBogallibog methods, Shell correction, Quasi-particle, Seniority Scheme, M and J-scheme, Transformation from M-scheme to J-Scheme, D-Matrix.

Unit III: Collective Motion and Deformed Nuclei (11 Hours)

Collective Model: Rotational and Vibrational Spectra (brief derivation). Beta and Gamma vibration, Nuclear moment of inertia, band head & back bending, Variable moment of inertia Models for normal and deformed nuclei, Nilsson Models and Nilsson Diagram, Particle Rotor Model, Deformed and Rotational Alignment, Nuclear isomers.

Unit IV: Exotic Nuclei and Modern Nuclear Physics (12 Hours)

Exotic Nuclei: Nuclear landscape and drip lines, Production of exotic nuclei – ISOL and Fragmentation technique, Super Heavy Element (SHE) production, Experimental challenges in production and isolation of exotic nuclei, Nuclear Reactions involving exotic nuclei: Reaction cross section, Break-up reaction and momentum distributions, Borromean Nuclei, Reaction Structure of exotic nuclei and application in astrophysics, break down of magic numbers, exotic shapes, Halo nuclei, neutron skin, Giant dipole resonance (GDR) and soft dipole resonance (reaction point of view)

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Upon successful completion of the course, students will develop a comprehensive understanding of nuclear structure and nuclear reaction mechanisms through modern theoretical models and experimental techniques. They will gain knowledge of fusion and fission processes, shell and collective models, heavy-ion collisions, and exotic nuclei, along with their significance in contemporary nuclear physics and nuclear astrophysics.

Suggested Readings

1. Theory of Nuclear Structure, M.K. Pal (Affiliated East-West Press, 1982)
2. Nuclear Structure from a Simple Perspective, R. F. Casten (2nd Ed., Press, Oxford)
3. Theoretical Nuclear Physics, Vol. I, Nuclear Structure, DeShalit & Feshbach (Wiley - Interscience, 1998)

4. Nuclear Reaction and Nuclear Structure, P.E. Hodgson (Clarendon Press, 1971)
5. Heavy ion reactions, Vol. I & II, R. A. Broglia & Aage Winther (Benjamin/Cummings, 1981)
6. Physics with Radioactive Beams, C. A Bertulani, M.S. Hussein, G. Munzenberg (Nova Science, 2002)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSEDSE5216
Course Name: Advanced Nuclear Physics-II (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Nuclear Physics-II (Lab.) DSE	4	0	0	4	Advanced Nuclear Physics-I (Lab.), Advanced Nuclear Physics-I (Theory), Co-Requisite: Advanced Nuclear Physics -II (Theory)

Duration: 120 Hours (8P/Week)

Course Objectives

This course provides advanced training in coincidence techniques, semiconductor detectors, high-resolution spectroscopy, alpha-particle measurements, and radiation imaging systems. Students will gain experience with advanced nuclear instrumentation and data acquisition systems.

Contents:

Unit I: Radiation Interaction and half Life measurement techniques

Experiments

1. Study of radioactive isotopes by thermal neutron activation analysis (Neutron flux, growth of activity and half-life measurements)
2. Determination of the absolute disintegration rate of natural ^{40}K source using UX_2 source as a standard and deduction of the partial beta-decay half-life of ^{40}K
3. Absorption of gamma-rays in material media at different energies
4. Beta end point energy measurement using G-M detector set-up

Each student/group shall perform one experiment from this unit.

Unit II: Advanced Gamma-Ray Spectroscopy and Detector Characterization

Experiments

1. Investigation of energy response and calibration of a NaI(Tl) scintillation spectrometer based on gamma-ray spectroscopy
2. Determination of detection efficiency of a NaI(Tl) scintillation spectrometer
3. Detection of gamma rays using different scintillation detectors and their comparison (Energy response and energy resolution)

4. Gamma-ray spectroscopy using a single crystal HPGe detector: (a) Energy response (b) Energy resolution (c) Detection efficiency determination

Each student/group shall perform one experiment from this unit.

Unit III Radiation Spectroscopy and Coincidence and Timing Measurements

Experiments

1. Beta-ray spectroscopy using an anthracene scintillation spectrometer (Energy calibration and end-point energy measurement using Kurie plot)
2. Study of angular distribution of Compton scattered gamma rays using a scintillation spectrometer and deduction of total scattering cross-section
3. Alpha spectroscopy using a Si surface-barrier detector: (Energy response and energy resolution measurements)
4. Measurement of stopping power of alpha particles using Si surface-barrier detector
5. Directional correlation measurements of cascading gamma rays and determination of cascade anisotropy using ^{60}Co source

Each student/group shall perform one experiment from this unit.

Unit IV Advanced Detector Systems, Nuclear Electronics and Digital Data processing units

Experiments

1. Pulse processing using a digital shaping unit: single and coincidence measurements
2. Comparative study of fast scintillation detectors for timing applications
3. Resolving time of fast and slow coincidence circuits by the method of random coincidence using scintillation detectors and measurement of absolute source strength
4. Advanced detector response and data acquisition studies using nuclear electronics modules
5. Study of position-sensitive detector for imaging and gamma camera applications

Each student/group shall perform one experiment from this unit.

Course Learning Outcomes

After completion of the course, students will be able to: Perform high-resolution gamma-ray spectroscopy using HPGe detectors, Understand and apply coincidence and timing techniques, Carry out alpha-particle spectroscopy and stopping power measurements, Operate semiconductor detectors and advanced nuclear electronics, Analyze detector timing and efficiency characteristics, Gain practical experience in radiation imaging and data acquisition systems.

Suggested Readings

1. Radiation Detection and Measurement, G. F. Knoll (John Wiley & Sons, Inc. 3rd Ed., 2000)
2. Physics & Engineering of Radiation Detection, S. N. Ahmed (Academic Press 2007)

3. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer-Verlag 1987)
4. Nuclear Physics: Principles and Applications, J.S. Lilly (John Wiley & Sons, Inc. 2002)
5. Radiation Detection for Nuclear Physics: Methods and Industrial Applications, David Jenkins (IOP Publishing, 2020)
6. Practical Gamma-ray Spectrometry, Gordon R. Gilmore (John Wiley & Sons, Ltd 2nd Ed., 2008)
7. Measurement and Detection of Radiation, Nicholas Tsoulfanidis (Taylor & Francis, 5th Ed., 2021)

General Note: The list of experiments is tentative and may be modified depending upon: 1) Availability of instruments, 2) Maintenance schedules, 3) Radiation safety considerations, 4) Availability of radioactive sources, 5) Batch strength and laboratory infrastructure. 6) Interested students may also undertake minor project work related to detector development, data acquisition, spectroscopy, or radiation measurements.

A visit to an Indian accelerator facility may be organized, and students may be required to submit a report on the visit. The report will be evaluated as a part of the continuous evaluation process.

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSEDSE5217
Course Name: Advanced Laser Physics (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Laser Physics (Theory) DSE	4	3	1	0	Advanced Laser Physics -I (Theory)

Duration: 60 Hours(45L+15T)

Course Objectives

To familiarise the student with the fundamentals of the characteristics of lasers, their use for experiments in the time domain, high-harmonic generation, the role of lasers in cooling, optical communication, and biomedical applications

Contents:

Unit I (12 Hours)

Laser fundamentals: Rate equations, lasing action, coherence, polarization, width and profile of spectral lines, lasers as spectroscopic sources, spectral characteristics of laser emission, single and multi-mode lasers, Q-switching, Mode Locking Technique, laser tenability.

Unit II (10 Hours)

Time resolved laser spectroscopy: Generation and measurement of ultra-short pulses and life time measurements with lasers, pump and probe techniques.

Unit III (12 Hours)

Non-linear Optics: Concepts of nonlinear phenomena, nonlinear electric polarizability, second harmonic generation, conceptual description of phase matching, parametric up and down conversion, parametric oscillators and amplifiers, third harmonic generation, optical Kerr effect, self-focusing, self-phase modulation, super-continuum generation, cross phase modulation, four wave mixing, optical phase conjugation and its applications.

Unit IV (11 Hours)

Applications: Optical cooling: Photon recoil, optical molasses, magneto-optical trap, limits of cooling, Lasers in material processing; Laser ablation, laser induced lithography for nanopatterning, biomedical applications, laser tweezers.

Fibre-Optics: propagation characteristics

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The course provides students with a working knowledge of laser physics and provides an introduction to nonlinear optics and laser applications for further study in optics and photonics. Advanced knowledge about physics and applications of lasers. Ability to design practical systems based on nonlinear optics, such as harmonic generators, parametric amplifiers, difference frequency generation, modelocked Lasers; time-resolved studies in the femtosecond regime, non-linear optical phenomena, optical cooling and trapping of ions/atoms as an example of state-of-the-art applications of lasers.

Suggested Readings:

1. Laser Spectroscopy, W. Demtroder (3rd Ed., Springer, 2003)
2. Nonlinear Optics, Robert Boyd, (Elsevier Inc. 2008).
3. Introduction to optical electronics by Yariv
4. Principles of Laser Materials Processing, by Elijah Kannatey-Asibu, Jr., John (Wiley & Sons, Inc.)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSEDSE5218
Course Name: Advanced Laser Physics (Lab)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Laser Physics (lab.) DSE	4	0	0	4	Adv. Laser and Spectroscopy (Lab.) - I

Duration: 120 Hours

Course Objectives

Provide an exposure to instrumentation such as light sources, spectrometers, optical detectors, optical and opto-mechanical components, gain experience in spectroscopic techniques for measurement, analyses of various kinds of spectra

Unit I (30 Hours)

1. Optical Fiber
2. Transmission holography.

Unit II (30 Hours)

1. Kerr effect.
2. Pockels effect.

Unit III (30 Hours)

1. Interferometric method for film thickness measurement.
2. Interferometric method for residual strain measurement in the film.

Unit IV (30 Hours)

1. Birefringence and photoelasticity.
2. Measurement of radiant flux density and luminous intensity of an emission source.

NOTE: This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work. The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment

Course Learning Outcomes

The student would be equipped with an in-depth knowledge of laser-based metrologies; spectroscopic techniques that can be applied in wide-ranging fields spanning semiconductors, pharmaceutical, chemical, food-processing industries, to name a few.

Suggested Readings

1. Lasers: Fundamental and Applications, Graduate Text in Physics, K. Thyagarajan, Ajoy ghatak (2nd edition, Springer, 2002)
2. Polarization of light, Ajoy Ghatak and Arun Kumar (Mc GrawHill Education, 2012)
3. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000)
4. Teaching laser physics by experiments, (Am. J. Phys., 2011, <http://doi.org/1-3488984>)
5. Infrared Spectroscopy, Fundamentals and Applications, Barbara Stuart, (Wiley & Sons, 2004)
6. Modern Raman Spectroscopy-a practical approach, E. Smith and G. Dent (John Wiley & Sons, 2004)
7. Spectroscopic Ellipsometry: Principles and Applications, H. Fujiwara (Wiley& Sons, 2007)
12. Introduction to Holography, Vincent Toal, (CRC Press, 2012)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSEDSE5219
Course Name: Advanced Solid State Physics-II (Theory)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Solid State Physics-II (Theory) DSE	4	3	1	0	Advanced Solid State Physics -I (Theory)

Duration: 60 Hours(45L+15T)

Course Objectives

This course intends to provide knowledge of emerging topics in condensed matter physics. In addition, this course aims to provide a general introduction to theoretical and experimental aspects of advanced topics by covering glasses and polymers, liquid crystals, carbon-based materials, and surface physics. More importantly, the students will be exposed to different characterization techniques used in experimental condensed matter physics.

Contents:

Unit I (15 Hours)

Glasses and Polymers: Glass formation, types of glasses and glass transition, radial distribution function and amorphous semiconductors, electronic structure of amorphous solids, localized and extended states, mobility edges, Density of states and their determination, transport in extended and localized states, Optical properties of amorphous semiconductors. Structure of polymers, polymerization mechanism, characterization techniques, optical, electrical, thermal and dielectric properties of polymers.

Liquid crystals: Liquid Crystals. Structural peculiarities and applications, Thermotropic liquid crystals; Classification, Phases and phase transitions; anisotropic materials; symmetry aspects; optics; electro-optics of liquid crystals; ferro-, and antiferroelectric liquid crystals; examples of LCs in nanoscience, photonics and microwave electronics, display devices.

Unit II (6 Hours)

Phase transitions in solids: Landau's theory, first-order and second order transitions, order parameter and critical exponents, examples of phase transitions: Solid-liquid, ferroelectric–paraelectric, ferromagnetic–paramagnetic, superconducting transition, liquid crystals.

Unit III

(12 Hours)

Introduction to Surface Physics: Reconstruction and relaxation, surface electronic structure; Heterostructures; Self-assembled monolayers, Electrified interfaces, Charge transfer at the liquid-solid interfaces. Thin film deposition methods: thermal evaporation and sputtering.

Carbon based materials: Fullerenes, C₆₀, C₈₀ and C₂₄₀ Nanostructures; Properties and Applications (mechanical, optical and electrical). CNT-single walled and multiwalled, graphene.

Unit IV

(12 Hours)

Material characterization: X-ray diffractometer: Determination of lattice parameters, crystallite size, Texture analysis, thin film diffraction and thickness measurements. Electron Diffraction: Basics of electron microscopes, electron beam specimen interaction, Scanning Electron Microscopy and Transmission Electron Microscopy; Transport measurements: Two probe, four probe - Vander Pauw techniques; Scanning probe techniques: Principles of STM and AFM.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The students should be able to elucidate the important features of advanced topics in experimental condensed matter physics.

Suggested Readings

1. Physics of Amorphous Solids, R. Zallen (John Wiley and sons, 1983)
2. Introduction to Polymer Physics, Ulrich Eisele and Stephen D. Pask (Springer-Verlag, 1990)
3. The physics of liquid crystals, Pierre-Gilles de Gennes (2nd Ed., Oxford University Press, 2003)
4. Introduction to Liquid Crystals, Peter J. Wojtowicz, E. Priestly, Ping Sheng (Plenum press, 1975)
5. Carbon Nanotubes: Properties and Applications, Michael J. O'Connell (CRC press, 2006)
6. The Physics of Phase Transitions - Concepts and Applications, P. Papon, J. Leblond, and Paul H. E. Meijer (2nd Ed., Springer-Verlag, 2006)
7. Physical Methods for Materials Characterization, P. E. J. Flewitt, R. K. Wild, (2nd Ed., CRC Press, 2015)

8. Encyclopedia of materials characterization: surfaces, interfaces, thin films, R. C. Brundle et al. (Butterworth-Heinemann, 1992)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSEDSE5220
Course Name: Advanced Solid State Physics-II (Lab.)

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Solid State Physics – II (Lab.) DSE	4	0	0	4	Advanced Solid State Physics-I (Lab.),

Duration: 120 Hours

Course Objectives

To carry out advanced-level experiments to determine the optical, dielectric and magnetic properties of materials. Also, to expose the students to various materials characterisation techniques.

Contents:

Unit-I: Electronic Conductivity of Metal/Semiconductor Materials (32 Hours)

1. Determine the value of the Hall coefficient for the given sample and calculate the value of the mobility of the carriers and the carrier concentration. (Transverse magnetoresistance coefficient is given)
2. Determine the transverse magneto-resistance coefficient and the resistivity for the given sample and calculate the value of the mobility of the carriers and the carrier concentration. (R_H is given).
3. Measure Hall coefficient, dc conductivity and mobility of a semiconductor at different temperatures (77 K to room temperature).
4. Resistivity measurements using four probe technique
5. Resistivity of semiconducting materials using Van-der Pauw method

Unit-II: Semiconducting Devices (28 Hours)

1. Estimating the band gap, the ideal factor of semiconducting materials used in a PN junction from the temperature dependent current-voltage measurements.
2. Transfer characteristics and gain of a FET
3. Photocurrent measurements of semiconducting materials

Unit-III: Ferroelectric, ferromagnetic, and dielectric properties of materials (32 Hours)

1. B-H curve of iron, steel, and nickel
2. Determine the relaxation time for a given sample and find the value of 'g' using electron spin resonance.

3. Determine the Curie temperature of a given ferroelectric material by measuring the temperature dependent capacitance.

Unit-IV: Morphological, structural, optical, and magnetic properties of materials

(28 Hours)

1. A research level small project (individual or Group of students) based on the experiments given in the above units.

NOTE: This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work. The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment

Course Learning Outcomes

The students will get a better understanding of the concepts studied by them and correlate both theory and experiments. The students will learn about the various materials characterization techniques and analysis.

Suggested Readings

1. Optical Properties of Photonic Crystals, K. Sakoda (Springer, 2001)
2. The Rietveld method, R.A.Young (IUCR-Oxford University Press, 1995)
3. Fundamentals of Crystallography, C.Giacovazzo (IUCR-Oxford University Press, 2002)
4. Characterization of nanophase materials, Zhon Ling Wang (Wiley-VCH Verlag GmbH, 2000)
5. Physical Properties of Semiconductors, C. M. Wolfe, J.R.N.Holonyak and G.E.Stillman (Prentice Hall International Inc., London, 1989).
6. Handbook on Semiconductors, Vol. 1-4., T.S. Moss, Ed., by S.P.Keller (NorthHolland, Amsterdam, 1980)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5221
Course Name: Advanced Numerical Techniques

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Numerical Techniques DSE	4	0	0	4	Basic Knowledge of Programming(Python /C)

Duration: 120 Hours

Course Objectives

This course aims to introduce numerical and computational techniques widely used in physics and scientific research, including interpolation, numerical differentiation, curve fitting, and Monte Carlo methods. It develops the skills required to model physical systems, analyze experimental data, solve differential equations numerically, and perform stochastic simulations.

Content:

Unit I:

Error Analysis, Interpolation – Introduction, Polynomial interpolation, Lagrange Interpolation polynomial, Cubic Spline Interpolation.

Unit-II:

Numerical Differentiation, Finite Difference method; Forward and Backward difference methods, Few examples: Heat equations, Wave equations; Introduction to Finite Element method.

Unit-III:

Curve fitting methods – Modeling of Data, Maximum Likelihood Estimator; Pearson chi square; Least Squares method – both without and with errors in dependent variable; Parameter estimations and errors; General Linear Least Squares.

Unit-IV:

Monte Carlo Methods – Introduction; Random Numbers – Uniform and other random deviates, Generation of Random Numbers, Random walk problem in 1, 2, 3 and n dimensions, Simulation – Introduction, Few examples: Coin toss and dice throws, Radioactive Decay Chain, Two-Level Spin System, Ising Model, Scattering - Toy model; Law of Large Number and Central Limit Theorem; Random number generation using arbitrary distributions – inverse

transform method and acceptance-rejection method, generating discrete distributions, Monte Carlo Integration Methods.

Course Learning Outcomes

Students are expected to learn advanced numerical techniques that are useful in various disciplines of Physics and Mathematics. They shall be able to develop and implement Python /C/C++ routines and programs for solving advanced numerical methods, which are encountered in several branches of physics and mathematics.

Suggested reading:

1. Numerical Recipes 3rd Edition: The Art of Scientific Computing, William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery (3rd Ed., Cambridge University Press, 2007)
2. Numerical Analysis, Richard L. Burden, J. Douglas Faires, Annette M. Burden (10th Ed., Cengage Learning, 2016)
3. Data Reduction and Error Analysis for the Physical, Philip Bevington and D. Keith Robinson (3rd Ed., McGraw-Hill Education, 2003)
4. Monte Carlo Simulation in Statistical Physics: An Introduction, Binder, Kurt, Heermann, Dieter (5th Ed., Springer, 2010) .

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/ Semester II of 1 year MSc
Course Code: PH-DSE5222
Course Name: Advanced Observational Astrophysics Lab.

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Observational Astrophysics Lab. DSE	4	0	0	4	Basics of Astronomy and Observational Techniques

Duration: 120 Hours(8 Hours/Week)

Course Objectives:

To train students in observational astrophysics through detector characterisation, atmospheric measurements, solar and stellar observations, time-series analysis, uncertainty propagation, computational reduction pipelines, and prepare an observational project according to the following experimental units. The prepared syllabus aims to provide students with a research environment to define the scientific question, understand instruments, detectors, and software tools, perform calibration, photometry, astrometry, solar and atmospheric analysis, and complete a mini research project. The students will also be encouraged to collaborate and work collectively in a group of 2 or 3 students for the observational project compilation (Unit -IV).

Unit I: Observational Astronomy with Telescope and Literature Survey (25 Hours)

A. Observational Astronomy with Telescope :

Introduction to observational astronomy and modern observatories.
Ground-based and space-based observations across the electromagnetic spectrum.
Effects of Earth's atmosphere on astronomical observations.
Principles and operation of astronomical telescopes.
Characteristics and use of the in-house 11-inch Celestron telescope.
Telescope alignment, tracking, calibration, and observation planning.
Celestial coordinate systems and sky navigation.
Use of softwares for planning observations.
Observation of the objects in the solar system and beyond.
Preparation of observing logs and observational records.

B. Literature Survey and Project Planning (10 Hours)

Use of scientific databases, archives, and literature resources.
Identification of scientific problems, research questions, and anchor papers.
Selection of suitable observational targets, datasets, and methodologies.
Identification of required instruments, numerical tools, and theoretical frameworks.

Preparation of a literature review and project proposal based on an anchor paper.
Development of a project roadmap for subsequent observational and analysis work.

Unit II: Instruments, Data, and Numerical Tools (20 Hours)

Introduction to detectors (in-house CCD versus modern CMOS detectors), filters, spectrographs, and imaging systems.

Detector calibration and instrument characterization: gain, read noise, dark current, linearity,

saturation, flat-field structure, and calibration frames.

Ground-based and space-based observatories and their scientific capabilities.

Astronomical data formats, FITS files, and archive access.

Python-based scientific computing and astronomical software tools.

Use of python-based (Astropy, SunPy, etc.), and other skill-based open source softwares for data analysis (Photutils, IRAF, DS9, TOPCAT, JHelioviewer, etc.).

Tools for data visualization, source extraction, catalogue access, and cross-matching techniques.

Brief exposure to relevant simulation or modelling tools, where appropriate to the selected project.

Unit III: Data Analysis and Interpretation (35 Hours)

Image calibration, photometric reduction, and astrometric calibration.

Detector noise propagation, uncertainty estimation, and quality assessment.

Atmospheric extinction, seeing, transparency measurements, and sky-brightness monitoring.

Differential photometry, stellar light curves, colour indices and differential photometry.

Solar surface photometry, limb darkening, sunspot measurements, and solar rotation studies.

Time-series analysis, statistical methods, and error analysis.

Scientific interpretation of observational results through comparison with published studies and theoretical models.

Unit IV: Compilation into an Observational Project (30 Hours)

Assimilating the understandings gained from literature survey, observation planning, data acquisition using telescope observations and/or archival datasets.

Calibration, reduction, analysis, and interpretation of observational data.

Integration of observational results with numerical tools and theoretical understanding.

Preparing Observing logs, calibration notebook, data-driven assignments, project proposal,

final report, presentation/viva, and internal assessment.

Example - Observational Projects -

Variable stars and stellar variability.

Solar activity and sunspot evolution.

Atmospheric extinction and sky transparency.
Sky brightness and light pollution studies.
Asteroid motion and positional measurements.
Photometric or astrometric catalogue comparison studies.

Course Outcome

Upon successful completion of the course, students will be able to plan and perform astronomical observations, characterize detectors and instruments, analyze photometric, astrometric, solar, and atmospheric data using modern computational tools, evaluate observational uncertainties, interpret results in the context of current scientific literature and theoretical models, and collaboratively complete an independent research-oriented observational astrophysics project.

Note : This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work. The actual number of hours to perform an experiment will also depend upon handling, working condition and availability of the equipment .

Suggested Readings

1. Astrophysical Techniques, C.R. Kitchin (CRC press, 1995)
2. Observational Astrophysics, R. C. Smith (Cambridge Univ. Press, 2000)
3. Telescope C.R. Kitchin (Springer, 1995)
4. Observational Astronomy, D.S. Birney, G Gonzalez & D Oesper (Cambridge Univ. Press, 2006)
5. Observational Astrophysics, P. Lena (Springer, 1986)
6. Practical Astronomy with your calculator, P. Duffet-Smith (Cambridge Univ. Press, 1988)
7. Astronomical Photometry, A. A. Henden & R.H. Kaitchuk (Willmann-Bell, 1990)
8. Photoelectric Photometry, D.S. Hall & R.M. Genet (Willmann-Bell, 1988)
9. Astronomical Spectroscopy, C.R. Kitchin (IOP, 1995)
10. Spectrophysics, A.P. Thorne (Chapman & Hall, 1988)
11. **Electronic Imaging in Astronomy-Detectors and Instrumentation, I.S. Mclean (Springer- Praxis, 2008)**

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5223
Course Name: Machine Learning for Physicists

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Machine Learning for Physicists DSE	4	2	0	2	Basic Python, Mathematical Physics

Duration: 90 Hours (30L+60P)

Course Objective

This course aims to introduce core machine learning concepts from a physicist's perspective. Develop computational tools to analyze and model physical systems. Provide hands-on experience using Machine Learning libraries.

Content

Unit I: Foundations of Machine Learning and Supervised Learning (15 Hours)

Overview of Artificial Intelligence and Machine Learning, Computational foundations: optimization methods, linear algebra, probability, and statistics. Regression methods and their applications. Classification problems and performance metrics. Introduction to neural networks. Training of neural networks using gradient descent and backpropagation algorithms. Support Vector Machines (SVMs) and their applications.

Unit II: Unsupervised Learning and Applications in Physics (15 Hours)

Introduction to unsupervised learning, Clustering techniques with emphasis on the K-Means algorithm, Dimensionality reduction methods, Principal Component Analysis (PCA), Feature extraction and data visualization, Applications of machine learning to physical systems, Case studies: Ising model, materials-property prediction, and other examples from physics.

Unit III: Computational Tools and Supervised Learning Applications (30 Hours)

Laboratory :

- Introduction to Python-based machine learning environments.
- Data handling and visualization using standard scientific Python libraries.
- Implementation of regression techniques on physical and benchmark datasets.
- Classification problems using neural networks and Support Vector Machines.
- Model training, validation, hyperparameter tuning, and performance evaluation.

- Mini exercises based on supervised learning applications in physics.

Unit IV: Unsupervised Learning and Physics-Based Projects

(30 Hours)

Laboratory :

- Implementation of clustering algorithms, including K-Means.
- Dimensionality reduction and visualization using PCA.
- Analysis of multidimensional datasets.
- Applications to physical systems such as the Ising model and materials datasets.
- Development of a small machine-learning project involving data preprocessing, model building, validation, interpretation, and presentation of results.
- Hands-on practice using Python tools and standard datasets relevant to the topics covered in the theory units.

Learning Outcomes

Upon successful completion of this course, students will be able to understand and apply fundamental machine learning techniques, including regression, classification, neural networks, clustering, and dimensionality reduction, to scientific and physical datasets. They will gain practical experience in implementing machine learning algorithms using Python-based tools and will be able to analyze, model, and interpret complex physical systems using data-driven approaches. Students will also develop the skills necessary to evaluate machine learning models and apply them to research problems in physics and related disciplines.

Suggested Readings:

1. Machine Learning for Physicists by Sadegh Raeisi, IOP Publishing Ltd 2023, ISBN: 978-0-7503-4957-4 • Print ISBN: 978-0-7503-4955-0.
2. Introduction to Machine Learning with Python by Andreas C. Müller and Sarah Guido, Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.
3. Introduction to Machine Learning in Physics by Klaus Reygers, I Seminar on Advanced Analysis Methods for Heavy-Ion Data, SS 2021
4. Lab manual Machine learning for Physicists, Department of Physics & Astrophysics, University of Delhi-2025.

Master of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5231
Course Name: General Theory of Relativity and Cosmology-II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
General Theory of Relativity and Cosmology-II DSE	4	3	1	0	Classical Mechanics, Electrodynamics, Mathematical Physics, General Theory of Relativity and Cosmology-I

Duration: 60 Hours(45L+15T)

Course Objectives:

The primary objective is to teach applications of general relativity to relativistic stars, cosmology, gravitational radiation and waves. The requisite mathematical concepts are also intended to cover.

Contents:

Unit I: Perfect fluids, Relativistic Stars, Stellar equilibrium and Gravitational collapse
(12 Hours)

Perfect fluids. Schwarzschild metric for a spherically symmetric stellar interior. Static and non-static configurations. Birkhoff's theorem, Tolmal-Oppenheimer-Volkoff equation for hydrostatic equilibrium. Stability criteria for uniform and non-uniform density stars. Polytropic stars. Comoving coordinate system. Gaussian normal coordinates. Gravitational collapse of spherically symmetric and homogeneous dust-filled stars.

Unit II: Isometries, Killing vectors, Maximal symmetry and Space-time embedding (10 Hours)

Isometries of a metric. Killing equation. Homogeneity and Isotropy. Maximally symmetric spaces and the Killing integrability criterion. Constancy of the curvature. Curved space metric embedding in a higher dimensional flat bulk. Rotations and quasi-translations. Locally Euclidean maximally symmetric spaces. Maximally form-invariant tensors of various ranks. Spaces with maximally symmetric subspaces.

Unit III: Cosmology: (13 Hours)

Olber's paradox. Cosmological principle. Newtonian cosmology. Weyl's postulate and Relativistic cosmology. Robertson-Walker line element. Redshift of galaxies and Hubble's law. Distance measures in cosmology. Magnitude-redshift relation, Hubble's constant and deceleration parameter. Friedmann equations and the critical density. Standard cosmological models. Closed,

flat and open universes. Age of the universe. Non-interacting and Interacting cosmological models. Galaxy clusters and the problem of missing mass or missing light, dark matter. Thermal history of early universe, helium formation, decoupling of matter and radiation. Cosmic microwave background radiation. Cosmological constant and the late time acceleration.

Unit IV: Gravitational Radiation and Gravity waves

(10 Hours)

Weak field approximation and linear wave equation. Plane waves: polarization, helicity and energy-momentum tensor. Emission of radiation by a rotating source. Effect of radiation on a test particle. Detection of the gravity waves.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Those taking this course are expected to have a clear understanding of how General Relativity is used to study relativistic stars, as well as Cosmology, i.e. the study of the origin, composition and evolution of the universe, and the requisite mathematical concepts, such as the isometries and Killing vectors. On the other hand, Gravitational perturbation theory in the last unit of the course lays the platform to study Gravitational radiation. It also provides an exposure to the detectors for the Gravity waves, which are being installed in the country.

Suggested Reading

1. *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*, Steven Weinberg (John Wiley & Sons, 1972).
2. *Introducing Einstein's Relativity*, Ray d'Inverno (Clarendon Press, Oxford, 1992).
3. *The Classical Theory of Fields: Volume 2 (Course of Theoretical Physics Series)*, L.D. Landau and E.M. Lifshitz (Butterworth-Heinemann, Elsevier).
4. *Classical Fields: General Relativity and Gauge Theory*, Moshe Carmeli (World Scientific, 2001).
5. *A First Course in General Relativity (Second Edition)*, Bernard F. Schutz (Cambridge University Press, 2009).
6. *An Introduction to Relativity*, Jayant V. Narlikar (Cambridge University Press, 2010).
7. *Spacetime and Geometry: An Introduction to General Relativity*, Sean M. Carroll (Pearson Education, publishing as Addison-Wesley, 2004).
8. *Cosmology*, Steven Weinberg (Oxford University, 2008).
9. *Introduction to Cosmology*, J. V. Narlikar (Cambridge University Press, 2002).

Master of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5232
Course Name: Condensed Matter Physics-II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Condensed Matter Physics-II , DSE	4	3	1	0	Solid state physics, Quantum Mechanics I & II

Duration: 60 Hours(45L+15T)

Course Objectives

The primary objective of this course is to provide an understanding of the quantum theory underlying advanced topics, including magnetism, superconductivity, and the quantum Hall effect. It aims to develop a theoretical foundation and conceptual clarity in these topics, enabling students to analyze and interpret their physical significance.

Contents:

Unit I (12 Hours)

Magnetic properties of Solids: Diamagnetism, Paramagnetism of atoms with permanent magnetic moment, Pauli paramagnetism of conduction electrons including temperature corrections, magnetic exchange interaction, Heisenberg model for ferro and antiferromagnetic insulators, magnon in ferro and antiferromagnets, magnon contribution to specific heat.

Unit II (10 Hours)

Strongly Correlated Electron Systems: Second quantization (brief), Hubbard model and its significance, Stoner theory of ferromagnetism of itinerant electrons (brief), Mott Insulator: Mott- Hubbard and impurity induced insulating behavior, Local moment formation in metals, Anderson impurity model, brief discussion of Kondo effect and Heavy fermion systems.

Unit III (10 Hours)

Special topics: Integral and fractional quantum Hall effect: electron in a strong magnetic field, Landau levels and their degeneracy, simple explanation of IQHE, FQHE, Laughlin wave function; Landau theory of Fermi liquid, Mott variable range hopping, Bose- Einstein condensation.

Unit IV (13 Hours)

Superconductivity: Introduction and materials, Meissner effect, thermodynamics of superconductors, London's phenomenological theory, flux quantization, Copper instability,

BCS theory of superconductivity, Coulomb pseudo-potential, strong coupling effects, Josephson effects, Ginzburg- Landau theory.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

A student of this course is expected to understand extensively both basic and advanced theoretical concepts in magnetism, superconductivity and Hall effect and can apply theoretical frameworks to explain physical behavior in related systems. Further, the students are encouraged to widen their research interests in these topics and explore current research trends and problems in these areas.

Suggested Readings

1. Condensed Matter Physics, Michael P. Marder
2. Quantum Theory of Solids, Charles Kittel
3. Condensed Matter Physics: A modern prospective, Saurabh Basu
4. Quantum Theory of Magnetism, Wolfgang Nolting, Anupuru Ramakanth
5. Condensed Matter In a Nutshell, Gerald D. Mahan
6. Solid State Physics, Gerald Burns (Academic Press, 1985)
7. Solid State Physics, Walter A. Harrison (Dover Publications, 1980)
8. Solid State Physics : An introduction to Principles of Materials Science, Harald Ibach and Hans Luth (Springer, 2003)
9. Solid State Physics, Advances in research and applications, Supplement 3, F. Seitz and D. Turnbull (Eds.) (Academic Press, 1958)
10. Quantum Theory of Solids Part A & B, Callaway (Academic Press, 1974)
11. Introduction to Superconductivity, Michael Tinkham
12. Superconductivity, V. L. Ginzburg and E. A. Andryushin (World Scientific, 1994)
13. Introduction to Superconductivity and high-Tc materials, Michel Cyrot and Davor Pavuna, (World Scientific, 1992)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5233
Course Name: Plasma Physics II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Plasma Physics II, DSE	4	3	1	0	Quantum Mechanics I, Plasma physics-I

Duration: 60 Hours(45L+15T)

Course Objectives

The primary objectives of this course are to introduce the two-fluid approach and the single-fluid (magnetohydrodynamic) model to understand waves and the stability of laboratory magnetised plasmas, as well as space plasmas, including the solar corona and ionospheric plasma. The course also covers plasma production in laboratories and its characterization with electrostatic probes. The applications of low-temperature plasma in material synthesis, wastewater treatment, and agriculture are explored to advance knowledge of plasma technologies in various sectors. The focus of this course is to equip the students with the plasma physics skills necessary to drive the global nuclear fusion program forward.

Contents:

UNIT-I (11 Hours)

Fluid description of plasmas, Moment equations. Two-fluid model to single-fluid model, Magneto-hydrodynamic (MHD) equations. Ideal MHD, Generalized Ohm's law, flux conservation, and decay of magnetic fields. MHD equilibrium, concept of beta, magnetic Raynold number, cylindrical Pinch effect.

UNIT-II (10 Hours)

Waves in magnetized plasma: Alfven waves, Magneto-acoustic waves, Dissipative effect, O-wave and X-wave (brief overview), L and R electromagnetic wave, Lower hybrid and Upper hybrid Wave (brief overview), KDV equation

UNIT-III (11 Hours)

Magneto-hydrodynamic (MHD) instabilities, Energy principle, Normal mode analysis and its application to Rayleigh-Taylor and Kelvin Helmholtz instabilities, Pinch instability, Jean's instability. Magnetic reconnection

UNIT-IV (13 Hours)

Production of plasma in laboratory: DC and RF glow discharge plasma, Paschen curve, plasma

sheath, Langmuir probe, plasma application in material science, DBD plasma and its applications. Controlled thermonuclear fusion, Lawson criteria, Gravitational confinement, Magnetic confinement (Tokamak). Concept of ITER, toroidal force balance and Grad-Shafranov equation, State-of-the-art and open problems in fusion.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes:

On completion of the course, the student shall be able to Understand the fluid approaches to explain the dynamics of magnetized plasma. Define the stability and confinement of high-temperature, high-density plasma in nuclear fusion machines. Explain the excitation of electromagnetic waves in magnetized plasma and MHD waves. Classify the energy transfer in magneto-conducting fluid via Alfvén and magnetosonic waves. Define and determine the basis of MHD stability through the normal mode analysis and energy principle. Explain the physical mechanism behind nonlinear wave excitation in plasmas. Understand the production of plasma in laboratory devices and plasma diagnostics. Apply the low-temperature plasma technology in various sectors for a better future.

Suggested Readings:

1. Introduction to Plasma Physics by F. F. Chen (Plenum Press, 1984)
2. Principles of Plasma Physics by N. A. Krall and Trivelpiece (San Francisco Press, 1986)
3. Physics of High Temperature Plasmas by G. Schindt (2nd Ed., Academic Press, 1979)
4. The framework of Plasma Physics by R.D. Hazeltine & F.L. Waelbroeck (Perseus Books, 1998)
5. Introduction to Plasma Physics by R.J. Goldston and P.H. Rutherford (IOP, 1995)
6. Plasma Physics via Computer Simulation, C.K. Birdsall, A.B Langdon, 2004 by CRC Press
7. Plasma Physics and Engineering by A. Fried and L.A. Kennedy (Taylor and Francis Group-2011).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5234
Course Name: Particle Physics II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Particle Physics II, DSE	4	3	1	0	Particle Physics I, Quantum Field Theory I Co-requisite: Quantum Field Theory II.

Duration: 60 Hours(45L+15T)

Course Objectives

The main objective of this course is to provide deep knowledge in emerging topics in particle physics. More specifically, the students will have excellent opportunity to get acquainted with our current understanding of the most fundamental constituents of matter and the primary forces of nature. In addition, the course would cover briefly and discuss quark model and develop the concept of non-abelian gauge theories based on SU(2) and SU(3). After a discussion of Spontaneous Symmetry Breaking (SSB) and Higgs Mechanism, the learners will be able to construct the electroweak model.

Contents:

Unit I (14 Hours)

Rutherford and Mott cross sections; electron-muon scattering; Electron-proton scattering : elastic and inelastic Structure functions. Deep-inelastic scattering and the quark hypothesis Gluon emission and three-jets. Drell-Yan, neutrino-DIS, and the extraction of parton densities Bjorken and Ellis-Jaffe sum rules

Unit II (18 Hours)

Four-fermi theory; Charged– and neutral-currents, CVC and PCAC, Sudarshan-Marshak theory, Unitarity and need for intermediate vector bosons; electroweak scale, The need to go beyond IVB theory, Why SU(2) X U(1) ? Fermion quantum number assignments, Spontaneous Breaking of SU(2) X U(1); Determination of W, Z and Higgs properties (masses, mixings, decays etc)

Unit III (8 Hours)

Fermion Mass generation and mixing; Mixing in the Kaon-system, GIM mechanism and the necessity of charm. CP violation and the necessity of the third generation, Neutrino oscillations.

Unit IV

(5 Hours)

Running of gauge couplings in the SM. Running of Higgs mass and self-coupling. Need for physics beyond SM. Preliminary discussion of some possibilities.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

CVC and PCAC as tools to understand weak interactions. Intermediate Vector bosons. Formulation of the electroweak theory, including the Higgs mechanism. Phenomenological understanding of meson mixing and CP violation. Microscopic derivation within the Standard Model. Unraveling the structure of proton through high-energy electron-proton scattering. QCD .

Suggested Readings

1. An Introductory Course of Particle Physics, Palash B. Pal (CRC Press, 2015)
2. Quarks & Leptons: An Introductory Course in Modern Particle Physics, Halzen, F., and A. D. Martin (John Wiley & Sons, 1984)
3. Gauge Theory of Elementary Particle Physics: Problems and Solutions, T. P. Cheng and Ling-Fong Li (Oxford, 2000)
4. Introduction to Elementary Particles, Griffiths D. (Wiley-VCH 2008)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5235
Course Name: Quantum Field theory II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Field Theory II DSE	4	3	1	0	Quantum Field Theory I

Duration: 60 Hours(45L+15T)

Course Objectives

This course is in continuation to Quantum Field Theory I and advanced topics in the field will be presented. By introducing more techniques deeper problems in Quantum Field theory will be addressed. The aim is to broaden the understanding of the students so that they are able to appreciate and address these problems.

Contents:

Unit I (12 Hours)

Green's functions in functional integrals; Non-abelian gauge theory, Path integral quantization of vector fields (Faddeev-Popov) ; Dyson-Schwinger and Ward identities.

Unit II (4 Hours)

Spontaneous breaking of symmetry; Goldstone Theorem; Higgs mechanism in U(1)

Unit III (15 Hours)

Loop diagrams : Counting of Ultraviolet Divergences Regularization in ϕ^4 theory : Cut-off, Pauli-Villars and Dimensional Renormalization of pure-scalar theory. Renormalization in QED. Lamb shift and anomalous magnetic moment of the electron.

Unit IV (14 Hours)

LSZ Reduction Theorem, Optical Theorem, Renormalization Group and Effective Field Theories Beta-function for QED, Bremsstrahlung and other soft divergences.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The students will learn various new techniques and examples in Quantum Field Theory. Ultraviolet and Infrared Divergences in Quantum field theory will be introduced and methods to address these fundamental issues will be taught. The understanding of the students will further be enhanced through concepts such as Spontaneous Symmetry Breaking, Renormalization Group and Effective Field Theories.

Suggested Readings

1. The Quantum Theory of Fields, Volume 1: Foundations, Steven Weinberg (Oxford University Press, 2005)
2. An Introduction to Quantum Field Theory, M. E. Peskin & D.V. Schroeder (Westview Press, 1995)
3. Lectures on Quantum Field Theory, Ashok Das (World Scientific, 2008)
4. Relativistic Quantum Mechanics, J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
5. Relativistic Quantum Fields, J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
6. Quantum Field Theory, C. Itzykson and J-B Zuber (McGraw-Hill, 1980)
7. Introduction to Relativistic Quantum Field Theory, S. Schweber (Row, Peterson, 1961)
8. Quantum Field Theory, L. H. Ryder (Cambridge University Press, 1996)
9. Introduction to Quantum Field Theory, P. Roman (John Wiley, 1969)
10. The Quantum Theory of Fields, Vol.2: Modern Applications, S. Weinberg (Oxford Univ.Press, 2005)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5236
Course Name: Nuclear Astrophysics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nuclear Astrophysics DSE	4	3	1	0	Quantum Mechanics -I & II, Statistical Physics, Classical Mechanics, Electrodynamics, Mathematical Physics, Nuclear & Particle Physics

Duration: 60 Hours(45L+15T)

Course Objectives

It is an emerging field in physics. The course will address one of the particularly important problems to determine rates for the nuclear reactions that occur in astrophysical environments. It will provide the idea of synthesizing heavier elements in the universe.

Contents:

Unit I: Foundations of Nuclear Astrophysics (12 Hours)

Introduction to nuclei in the cosmos: background and scope of nuclear astrophysics. Physical understanding of stars and stellar interiors. Abundances of elements and nuclear physics aspects. Thermonuclear reactions and sources of nuclear energy. Stellar reaction rates and their determination. Astrophysical S-factors. Forward and reverse reactions. Non-resonant and resonant reactions. Mean lifetime of nuclei. Maxwell-Boltzmann velocity distribution. Gamow peak and its significance in stellar reactions.

Unit II Stellar Structure and Evolution (10 Hours)

Stellar structure: Hertzsprung-Russell (H-R) diagram and classification of stars. Classical stars and degenerate stars. Main sequence stars and their properties. Contraction of stars and role of virial theorem (conceptual). Advanced stages of stellar evolution. Physical interpretation of stellar equilibrium and energy transport mechanisms.

Unit III Stellar and Cosmological Nucleosynthesis (13 Hours)

Cosmological Nucleosynthesis, Lithium problem, Stellar (hydrostatic) nucleosynthesis: Hydrogen burning processes: Proton-Proton (p-p) chain. CNO cycle and its astrophysical importance. Other cycles: NeNa and MgAl cycles. Helium production and light element abundances. Beryllium bottleneck and triple-alpha process. Creation and survival of Carbon-12. Solar neutrinos and observational evidence.

Unit IV Advanced and Experimental Nuclear Astrophysics

(10 Hours)

Explosive nucleosynthesis and abundance of elements. Nucleosynthesis beyond iron peak. Silicon burning and supernova mechanisms. Core collapse and neutron star formation. Production of heavy nuclei: r-process, s-process, and gamma-process. Experimental methods in nuclear astrophysics: Coulomb dissociation method, Trojan Horse Method, ANC method. Recent developments using radioactive ion beams and modern experimental techniques.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The student should be able to account for the theoretical models that explain the origin of elements in the universe, nucleosynthesis processes. They will gain knowledge about relevant nuclear and astrophysical measurements and observations and by using some of the relevant theoretical models to perform basic calculations of nuclear astrophysical processes.

Suggested Readings

1. Supernovae and Nucleosynthesis, D. Arnett (Princeton University Press, Princeton 1996)
2. Nuclear Physics of Stars, Christian Iliadis (Wiley-VCH 2007)
3. An Introduction to Nuclear Astrophysics, Richard N. Boyd (The University of Chicago Press, 1988)
4. Nuclear Reactions for Astrophysics, I. J. Thompson and F. M. Nunes (Cambridge University Press, 2009)
5. Principles of Stellar Evolution and Nucleosynthesis, D. Clayton (The University of Chicago Press, 1983)
6. Cauldrons in the Cosmos: Nuclear Astrophysics (Theoretical Astrophysics Series), C E Rolfs & W S. Rodney (The University of Chicago Press, 1988)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5237
Course Name: Supersymmetric Quantum Mechanics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Supersymmetric quantum Mechanics DSE	4	3	1	0	Quantum Mechanics -I & II

Duration: 60 Hours(45L+15T)

Course Objectives

To introduce students to a simple and elegant class of quantum mechanical systems with supersymmetry, and to explore what it can teach us about the geometry of low-dimensional surfaces.

Contents:

Unit-I: Supersymmetry in Quantum Mechanics (12 Hours)

Supersymmetry in zero dimensions. Supersymmetry algebra in quantum mechanics and its implications for the spectrum of quantum mechanical systems. Spontaneous breaking of supersymmetry.

Unit-II: Path Integrals & Witten Index (12 Hours)

Path integrals in quantum mechanics, The Witten index. Supersymmetric actions. The partition function and the Witten index as a path integral. Instantons, tunneling, and the dilute gas approximation. Zero modes and determinants.

Unit-III: Instantons (6 Hours)

Instantons, tunneling, and the dilute gas approximation. Fermionic zero modes and computing determinants, a particle on a circle..

Unit-IV Morse Theory & Index Theorem (15 Hours)

Singular homology and homology groups. Differential forms and de Rham cohomology. Betti numbers. de Rham's theorem. Hodge operators. Harmonic forms. Sigma models. Supersymmetry and Morse theory, Atiyah-Singer Index Theorem.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present

assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will learn about supersymmetry in its simplest setting: ordinary quantum mechanics. They will also learn about its relation to Morse theory and the topology of low dimensional surfaces, a beautiful example of the synergy between physics and mathematics. Students keen on specialising in theoretical high-energy physics and string theory will find this course particularly useful.

Suggested Readings:

1. Supersymmetric Methods in Quantum and Statistical Physics, Georg Junker, (*Springer-Verlag, 1996*).
2. Supersymmetry and Equivariant de Rham Theory, Victor W. Guillemin and Shlomo Sternberg, (*Springer, 1999*).
3. Geometry, Topology and Physics (2nd Edition), Mikio Nakahara, (*Taylor & Francis/CRC Press, 2003*).
4. Quantum Field Theory and Topology, Albert S. Schwarz, (*Springer-Verlag, 1993*).
5. Mirror Symmetry, Kentaro Hori, Sheldon Katz, Albrecht Klemm, Rahul Pandharipande, Richard Thomas, Cumrun Vafa, Ravi Vakil, and Eric Zaslow, (*American Mathematical Society, 2003*).
6. Topology, Geometry and Gauge Fields: Foundations, Gregory L. Naber, (*Springer, 2011*).
7. Differential Forms in Algebraic Topology, Raoul Bott and Loring W. Tu, (*Springer, 1982*).
8. Quantum Mechanics: Path Integrals and Symmetries, Kurt Sundermeyer, (*Springer, 2014*).
9. Introduction to Supersymmetry and Supergravity (2nd Edition), Peter West, (*World Scientific, 1990*).
10. The Geometry of Physics: An Introduction (3rd Edition), Theodore Frankel, (*Cambridge University Press, 2011*).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5238
Course Name: Spintronics: Fundamentals and Applications

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Spintronics: Fundamentals and Applications DSE	4	3	1	0	Quantum Mechanics I & II, Solid State Physics

Duration: 60 Hours(45L+15T)

Course Objective

The course seeks to deliver an in-depth introduction to the domain of spin electronics, focusing on the utilization of electron spin for data processing and storage. This necessitates a comprehensive grasp of magnetism, spin-spin interactions, and related concepts. The spin state and interaction influence electron transport in spintronic devices. Knowledge on devices like magnetic memory components, sensors, and spin transistors are crucial for contemporary technologies, including magnetic storage, MRAM, sensing, and computing.

Content:

Unit-I (11 Hours)

Overview of spin electronics and spin transport: Classes of magnetic materials; Quantum Mechanics of spin, spin-orbit interaction, Thermodynamics of spin-dependent transport: spin-polarized current, Diffusion equation and spin diffusion length. Spin-induced Interface Resistance, spin dependent tunneling, Andreev Reflection at ferromagnet and Superconductor interfaces; Spin-transfer torques. Case study of magnetic multilayers (GMR effect), Spin Hall effect.

Unit-II (11 Hours)

Spin Injection and spin Relaxation: Mechanisms of spin injection (Elliott-Yafet, DyakonovPerel), spin accumulation, and the generation of spin currents, Various mechanisms of spin relaxation, Spin relaxation in quantum dots and the spin Galvanic effect. Spin flip processes.

Unit-III (11 Hours)

Spintronics Devices: MRAM and STT-MRAM, Logic devices Sensors, Quantum spintronics (Qubits and coherence), Spin transistors, Magnetic tunnel junctions (MTJ), spin Hall device, hard drive read heads.

Unit-IV

(12 Hours)

Spintronics Materials and Experimental Techniques: Half-metals and magnetic semiconductors, Topological insulators, 2D materials in spintronics (e.g., graphene, MoS₂, etc.), Magneto-optical Kerr effect (MOKE), Ferromagnetic Resonance (FMR), SQUID and VSM magnetometry, Spin-polarized tunneling and ARPES.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

A thorough understanding of magnetic materials, Spin based transport and the spin dynamics that is essential of the spintronic devices. Materials required to prepare spintronic devices, Basic experimental techniques to study, understand the performance of spin based devices

Suggested Readings

1. "Introduction to Spintronics" by Supriyo Bandyopadhyay & Marc Cahay (CRC Press, 2020).
2. "Concepts in Spin Electronics" Edited by Sadamichi Maekawa (Oxford University Press, 2006)
3. Spintronics: Fundamentals and Applications, Igor Zutic, J. Fabian, and S. Das Sarma,, (Rev. Mod. Phys. 76, 323 2004.)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5239
Course Name: Molecular Electronics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Molecular Electronics DSE	4	3	1	0	Quantum Mechanics I & II

Duration: 60 Hours(45L+15T)

Course Objective

The course intends to provide fundamental knowledge of Molecular devices. How the charge transport governs devices at the molecular level.

Contents:

Unit I (2 Hours)

Introduction: Recent past, the present and its challenges, Future, Overview of basic Nanoelectronics.

Unit II (21 Hours)

Molecular Electronics Components: Characterization of switches and complex molecular devices, polyphenylene based, Molecular rectifying diode switches. OLEDs and heterojunctions based organic solar cells Single Electron Devices, Quantum Mechanical Tunnel, Devices, Quantum Dots & Quantum wires

Unit III (12 Hours)

Nanoelectronic & Nanocomputer architectures and nanotechnology: Introduction to nanoelectronic and nanocomputers, Quantum DOT cellular Automata (QCA), Single electron circuits, molecular circuits Nanocomputer Architecture.

Unit IV (10 Hours)

Molecular Spintronics: Introduction, Overview, History & Background, Generation of Spin Polarization, Theories of spin Injection, spin relaxation and spin dephasing, Spintronic devices and applications, spin filters, spin diodes, spin transistors

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present

assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will understand the basic concepts that govern the behaviour of electronic devices at molecular level. The course will be useful in understanding the physical properties which include electrical response of various circuits at molecular level.

Suggested Readings

1. Nanoelectronics & Nanosystems: From Transistor to Molecular & Quantum Devices: Karl Goser, Jan Dienstuhl, (Springer, 2004)
2. Concepts in Spintronics – Sadamichi Maekawa (Oxford University Press, 2006)
3. Spin dependent transport in magnetic nanostructures, Sadamichi Maekawa, (CRC, 1999)
4. Spin Electronics, David Awschalom, (Springer, 2002)
5. From Atom to Transistor, Supriyo Datta, (Cambridge University Press, 2005)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5240
Course Name: Astrophysics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Astrophysics DSE	4	3	1	0	Electrodynamics, Statistical Physics, Thermodynamics, Classical Mechanics,

Duration: 60 Hours(45L+15T)

Course Objectives

The goal of the course is to understand the formation, structure and evolution of stars and how stars of different masses end up in a variety of compact objects. In addition, the course will provide a general introduction to galaxies and an overview of modern astronomy.

Contents:

Unit I (20 Hours)

Stellar Structure and Evolution: Virial Theorem, Formation of Stars, Hydrostatic Equilibrium, Integral Theorems on pressure, density and temperature, Homologous Transformations, Polytropic gas spheres – Lane Emden Equation and its solution, Energy generation in stars, P-P and C-N cycles, Radiative and Convection transport of energy, Equations of stellar structure and their solution, Evolution of stars of different masses, pre- and post main-sequence evolution.

Unit II (8 Hours)

Compact objects: Fate of massive stars, Degenerate electron and neutron gases, White dwarfs – mass limit, mass-radius relation, Neutron stars and pulsars.

Unit III (9 Hours)

Galaxies: The milky way Galaxy, Distribution of stars, Morphology, Kinematics, Interstellar medium, Galactic center. Classification of galaxies, Hubble sequence, Ellipticals, Lenticulars and spiral galaxies and their properties, distribution of light and mass in galaxies.

Unit IV (8 Hours)

Overview of Modern Astronomy: 21-cm hydrogen line, cosmic radio sources, quasars, gravitational lensing, Expansion of the Universe and determination of Hubble's constant, gamma ray bursters. Sources of Gravitational Waves.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will demonstrate an understanding of the processes of star formation and evolution off and on the main sequence and the stellar end states. In addition, students will be able to describe modern concepts like expansion of the Universe and the detection of gravitational waves.

Suggested Readings

1. Stellar Interiors - Physical Principles, Structure, and Evolution, C. J. Hansen, S. D. Kawaler, V. Trimble (Springer, 2004)
2. Stellar Structure and Evolution, R. Kippenhahn and A. Weigert (Springer, 1996)
3. Basics of Astronomy -- IGNOU course book PHE-15 Astronomy and Astrophysics, 2006
4. Modern Astrophysics, Carrol & Ostlie (Addison Wesley, 1996)
5. The Physical Universe, F. Shu (University Science Books, 1982)
6. Principles of Stellar Structure Vol. I & II, J. P. Cox & R. T. Giuli (Gordon & Breach, 1968)
7. An Introduction to the Study of Stellar Structure, S. Chandrasekhar (Dover, 1968)
8. Stellar Interiors, D. Menzel, P. L. Bhatnagar & H. K. Sen (Chapman & Hall, 1963)
9. Galactic Astronomy, J. Binney & M. Merrifield (Princeton Univ. Press, 1998)
10. Textbook of Astronomy & Astrophysics, V. B. Bhatia (Narosa, 2001)

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5241
Course Name: Soft Matter Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Soft mater Physics DSE	4	3	1	0	Statistical Mechanics. Thermodynamics.

Duration: 60 Hours(45L+15T)

Course Objectives

This course intends to provide knowledge of Soft Matter systems and simple theoretical understanding to account for their behaviour.

Contents:

Unit I (8 Hours)

Introduction to Soft materials: Material properties of gases, liquids, solids; phase behaviour and phase transitions, atomic, molecular and inter-particle interactions; viscous, elastic and viscoelastic behaviour of materials; Reynolds number, review of basic thermodynamic and statistical mechanics relevant to the study of soft materials. Relevance and application of soft matter science.

Unit II (7 Hours)

Interfacial phenomena: Surface and interfacial tension, dynamics of wetting, viscosity capillary rise and meniscus, adhesion, shapes of droplets – solid substrates and liquid substrates, droplet spreading dynamics, wetting of films and fibres. Marangoni flow and coffee ring effect. Characterizing wetting behaviour using contact angle measurements.

Unit III (18 Hours)

Polymers and Colloids: The ideal chain structure, statistical mechanics of chain structure, polymer solution and melts, fractals in polymers – disorder and scale invariance, random aggregation, diffusion limited aggregation (DLC) and DLCA, glass transition, amorphous and crystalline polymers, block polymers. Applications of rubbers, plastics, biopolymers like proteins, DNA, viscoelastic fluids and synthetic materials Simple experimental methods of preparation of some of the polymers. Characterization of polymers using thermogravimetric analysis. From flexible polymers to colloids as hard spheres, inter-particle and surface properties and interactions, Brownian motion of colloidal particles and Langevin equation,

Diffusion, colloids as model systems and particle packing, frustration, phase diagram of hard spheres, thermodynamics of colloidal system, stable and unstable colloidal suspensions, NonNewtonian rheology, Applications in inks, food colloids, sedimentation and flotation. Simple methods of preparation of colloidal particles and characterizing colloids using optical microscopy and dynamic light scattering.

Unit IV

(12 Hours)

Amphiphiles and Liquid Crystals: Thermodynamics of self assembly, micellar shape from spherical micelles to rods to fluid membranes to bilayers and vesicles, microemulsions, effect of interaction between aggregates, phase behaviour, curvature energy and elasticity of monolayers and bilayers, Applications – soaps and detergents, thin films, foams and biological cells. Formation of liquid crystalline phases in Amphiphiles, Nematic liquid crystals order, singularity, elasticity, display application, lamellar properties, Cholesterics, Lamellar systems – structures, and properties, chiral systems. Smectics and Columnar systems – structures and properties, phase transitions. Characterization of liquid crystalline phase using polarizing optical microscopy, and small angle scattering techniques.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will understand the basic theoretical concepts that govern the complex behaviour of soft materials like polymers, gels, colloids, liquid crystals. Further, the course will be useful in understanding the physical properties of these materials including their structure, dynamics and mechanical response. Further, this course will also learn how to characterize various soft matter systems using a range of experimental techniques.

Suggested Readings

1. Soft Condensed Matter, Richard A. L. Jones (Oxford University Press, 2002)
2. Structured Fluids: Polymers, Colloids, Surfactants, Thomas A. Witten (Oxford University Press, 2004)
3. Scaling concepts in Polymers, P. G. De Gennes (Cornell University Press, 1979)
4. Principles of condensed matter, Sections 1,2 and 6, P M Chaikin, T C Lubensky (Cambridge University Press, 1995)
5. Soft Matter Physics: An Introduction, Maurice Kleman, Oleg D Laverntovich, J. Firedel, 6. (Springer, 2000)
7. Intermolecular and Surface Forces, Jacob N. Israelachvili, (Academic Press, 2011).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/ Semester II of 1 year MSc
Course Code: PH-DSE5242
Course Name: Advanced Course on Quantum Computing

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advance Course on quantum computing DSE	4	2	0	2	Basic linear algebra, quantum information & quantum computation - I, basic coding in Python

Duration: (30L+60P) 90 Hours

Course Objectives

This course is designed to introduce students to advanced and research-oriented topics in Quantum Computing, with a focus on both theoretical foundations and practical implementations. Students will be exposed to Cutting-edge developments, emerging paradigms, and Hands-on experience using Qiskit.

Contents:

Unit I: Advanced Quantum Algorithms and Variational Methods (15 Hours)

Review of quantum circuits, quantum gates, and computational complexity, Quantum Phase Estimation and Iterative Quantum Phase Estimation, variational quantum algorithms: Variational Quantum Eigensolver (VQE) and variational ansätze, SWAP test and quantum state comparison, adiabatic quantum computation and quantum optimization, introduction to quantum simulation algorithms and Hamiltonian evolution, Linear Combination of Unitaries (LCU) and its applications in Hamiltonian simulation and quantum algorithms.

Unit-II: Quantum Noise, Error Correction, Simulation, and Hardware Platforms (15 Hours)

Review of open quantum systems: density matrix formalism, quantum channels, Kraus representation, master equations, and decoherence, decoherence-free subspaces and subsystems, principles of quantum error correction, quantum error models, Shor code, stabilizer formalism, and introduction to stabilizer codes and quantum code construction, the Gottesman–Knill theorem, Fault-tolerant quantum computation, error mitigation techniques, introduction to Noisy Intermediate-Scale Quantum (NISQ) computing, and challenges in large-scale quantum computation.

Computer Simulation Laboratory Work:

Unit-III: Quantum Algorithms and Circuit Implementation using Qiskit (30 Hours)

- Introduction to Qiskit and quantum circuit design.
- Quantum state preparation and measurement.
- Implementation of single- and multi-qubit gates.
- Quantum Fourier Transform (QFT).
- Bernstein–Vazirani algorithm.
- Grover's search algorithm.
- Quantum Phase Estimation (QPE).

Unit-IV: Quantum Simulation, Noise Modelling, and Error Mitigation (30 Hours)

- Iterative Quantum Phase Estimation.
- Shor's algorithm (demonstration and implementation of key subroutines).
- SWAP test and state overlap estimation.
- Variational Quantum Eigensolver (VQE): ground-state energy estimation.
- Noise modelling and decoherence in quantum circuits.
- Quantum error-correction demonstrations (bit-flip, phase-flip, and Shor code).

Course Learning Outcomes

Students will learn advanced topics on quantum computation theory oriented to research and application. Moreover, this course will equip the students to simulate various advanced quantum computing protocols in software like Qiskit and learn about errors in the presence of hardware noise and methods of error mitigation.

Suggested Readings

1. Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information, 10th Anniversary Edition, Cambridge University Press, 2010. ISBN: 9781107002173.
2. N. David Mermin, Quantum Computer Science: An Introduction, Cambridge University Press, 2007. ISBN: 9780521876582.
3. John Preskill, Lecture Notes on Quantum Computation. Available at: <https://theory.caltech.edu/~preskill/ph219/index.html>
4. Thomas G. Wong, Introduction to Classical and Quantum Computing, Rooted Grove, 2022.
5. Phillip Kaye, Raymond Laflamme, and Michele Mosca, An Introduction to Quantum Computing, Oxford University Press, 2007. ISBN: 9780198570004.
6. Eleanor G. Rieffel and Wolfgang H. Polak, Quantum Computing: A Gentle Introduction, MIT Press, 2011. ISBN: 9780262015066.
7. Daniel A. Lidar and Todd A. Brun (Eds.), Quantum Error Correction, Cambridge University Press, 2013. ISBN: 9780521897877.

8. Heinz-Peter Breuer and Francesco Petruccione, The Theory of Open Quantum Systems, Oxford University Press, 2007. ISBN: 9780199213900.
9. John Preskill, Lecture Notes on Quantum Error Correction. Available through the Caltech Quantum Computation lecture series.
10. IBM Quantum Learning Platform and Qiskit Documentation:
<https://learning.quantum.ibm.com>

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/ Semester II of 1 year MSc
Course Code: PH-DSE5243
Course Name: String Theory

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
String Theory DSE	4	3	1	0	Classical Mechanics, Relativity, Quantum Mechanics, QFT, Basic mathematical methods including group theory, algebra and differential geometry

Duration: 60 Hours(45L+15T)

Course Objectives

This course aims to introduce MSc students to the foundations of (super)string theory as a consistent framework for quantum gravity, while developing strong conceptual understanding through the study of bosonic string theory and its theoretical innovations. It seeks to inspire exploration of broader areas of modern physics through the perspective of quantum gravity.

Contents:

Unit I (12 Hours)

Motivation for string theory, What is string theory, Types of String theory, Classical action for relativistic point particles, Reparametrization invariance, Generalization to p-Branes and the string action, Global and local symmetries of the Bosonic string theory worldsheet, Field equations for Polyakov action and their solution.

Unit II (12 Hours)

Symmetries and conserved quantities using Noether methods, Hamiltonian and the energy momentum tensor, Classical mass formula for Bosonic string and Witt algebra, Canonical quantization, Virasoro algebra and the physical states, Spurious states and their removal, Lightcone gauge quantization, mass shell quantization and mass spectrum.

Unit III (10 Hours)

Introduction to conformal field theory (CFT), conformal group in d dimension, conformal algebra in 2 dimension, CFTs in d dimension and specialization to 2D. Constraints of conformal invariance, Roles of CFTs in string theory, Radial quantization, Conserved currents and symmetry generators, Operator product expansion (OPEs).

Unit IV

(11 Hours)

OPE Redux, Virasoro algebra and physical states, Free massless Bosonic fields, Charges of the conformal symmetry current, Representation theory of the Virasoro algebra, Conformal Ward identities, BRST quantization of the Bosonic strings, Ward identity, Cohomology and the physical states, Ghost CFT, BRST current and charge, Vacuum of the BRST quantized string theory.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Upon successful completion of the course, students will acquire a sound working knowledge of modern theoretical physics concepts in string theory, develop strong analytical and conceptual skills, and gain motivation to pursue advanced studies and research in quantum gravity and related areas of natural sciences.

Suggested Readings

1. Superstring Theory, Volume-I, Michael B. Green, John H. Schwarz and Edward Witten (Cambridge Monograph on Mathematical Physics, 1988)
2. String Theory, Volume-I, Joseph Polchinski (Cambridge University Press, 1998)
3. A First Course in String Theory, Barton Zwiebach (Cambridge University Press, 2004)
4. Introduction to Strings and Branes, Peter West (Cambridge University Press, 2012)
5. String Theory and M-Theory: A Modern Introduction. Becker, K., Becker, M. and Schwartz, J. (Cambridge University Press, New York City.)

MASTER of SCIENCE in PHYSICS
Semester IV of 2-year MSc Semester II of 1-year MSc
Course Code: PH-DSE5244

Course name: Superconductivity, Superfluidity & Critical Phenomenon

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Superconductivity, Superfluidity & Critical Phenomena DSE	4	3	1	0	Classical Mechanics, Quantum Mechanics I & II, Statistical Mechanics

Duration: 60 Hours(45L+15T)

Course Objectives

This course aims to develop a unified theoretical approach to understand the interacting many-body systems. It begins with the limitations of the wavefunction-based description and then towards the emergence of density-based approaches. It focuses on foundational approximations such as Thomas-Fermi and Hartree-Fock. It helps to build understanding toward microscopic and phenomenological theories of superconductivity and superfluidity, including BCS theory, Ginzburg-Landau formalism, and quantum fluids. The course further establishes a deep connection between these phenomena and critical behaviour near phase transitions, culminating in the renormalization group framework.

Contents:

Unit I: Many-body theory (8 Hours)

Limitations of the Wavefunction Approach, Density as a Fundamental Variable, Thomas Fermi Theory, Shortcomings of Thomas-Fermi theory, Hartree-Fock approximation (HFA), Exchange energy of electron gas in HFA, Shortcomings of HFA, Thomas-Fermi Screening in an electron gas.

Unit II: Theory of Superconductivity (17 Hours)

BCS model of superconductivity, Variational Determination of the Ground-State Wavefunction Ground-State Energy and Isotope Effect, Coherence Length, The Bogoliubov-Valatin Canonical Transformation, Specific Heat of Superconductors, Order Parameter in Superconductors and the Ginzburg-Landau (GL) Equations, The Phenomenological Parameters of the GL Equations, Magnetic Flux Quantization, Type-I and Type-II Superconductors, Cooper Pair Tunnelling and Josephson Effects, Introduction to Unconventional and High T_c Superconductivity.

Unit III: Superfluid ³He (6 Hours)

Classical and quantum fluids, The macroscopic wave function, Flow quantization in superfluid He, Superfluidity of liquid ^3He , Singlet and triplet state pairing interaction in Superfluid ^3He , Phases of superfluid ^3He .

Unit IV: Critical Phenomena, Phase Transition and Renormalization Group (14 Hours)

Mean field approximation, critical exponents of mean field Ising model, Landau's theory of phase transitions. Critical exponents, Ginzburg Criterion, Critical dimensionality, Kadanoff's scaling hypothesis, The renormalization group (RG), RG for the 1D Ising chain, Flow diagram and Fixed points, Calculation of fixed point for the 2D Ising model on the triangular lattice.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

After completing this course, students will be able to understand and analyse many-body interacting quantum systems. They will be able to recognize the limitations of wavefunction-based methods and the utility of density-based descriptions. They will be able to apply approximation techniques such as Hartree-Fock in order to understand the screening and exchange effects in many electron systems. Students will develop a rigorous understanding of superconductivity and superfluidity through both microscopic and macroscopic frameworks. Furthermore, they will be able to characterize phase transitions using critical exponents, scaling theory, and renormalization group methods, and be able to appreciate the concept of universality across different physical systems.

Suggested Readings

1. Solid State Physics, Grosso & Parravicini (3rd Ed., Elsevier)
2. Advanced Solid State Physics, Philip Phillips (2nd Ed., Cambridge University Press)
3. Superfluidity and Superconductivity, D. R. Tilley and John Tilley (3rd Ed., IOP Publishing Ltd., 1990)
4. Superconductivity, Superfluids and Condensates, James F. Annett (Oxford University Press)
5. Introduction to Superconductivity, M. Tinkham (CBS Publishers & Distributors, 2008)
6. Elements of Phase Transitions & Critical Phenomena, Hidetoshi Nishimori & Gerardo Ortiz
7. Statistical Mechanics of Phase Transition, J. M. Yeomans (Clarendon Press, Oxford, 1999)

Semester IV of 2 year MSc/Semester II of 1 year MSc**Course Code: PH-DSE5245****Course Name: Accelerator Applications**

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Accelerator Applications DSE	4	3	1	0	Classical Mechanics, Electrodynamics, Mathematical Physics, Solid State Physics, Nuclear & Particle Physics & Accelerator Physics

Duration: 60 Hours(45L+15T)

Course Objectives

This course focuses on advanced accelerator concepts, applications, and modern developments. It aims to develop understanding of radioactive ion beam facilities, accelerator-based analytical techniques, and societal applications. The course also introduces advanced topics such as thin-film preparation and emerging accelerator technologies.

Contents:

Unit I: Radioactive Ion Beam Accelerators (10 Hours)

Concept and importance of Radioactive Ion Beam (RIBs), Production techniques: ISOL and in-flight, Major facilities (global and Indian initiatives), Challenges: beam purity, short half-life, Applications in nuclear astrophysics and exotic nuclei.

Unit II Accelerator Applications (12 Hours)

Medical applications: proton therapy, radioisotope production, Industrial applications: ion implantation, material analysis, Security applications: cargo scanning, Ion beam analysis techniques (PIXE, RBS, NRA), Role in nanotechnology and materials science.

Unit III Accelerator Mass Spectrometry & Advanced Techniques (10 Hours)

Principles of AMS, System design and isobar separation, Applications: radiocarbon dating, geology, nuclear forensics, Target preparation and thin-film deposition techniques, Surface modification using ion beams.

Unit IV Indian Programs & Future Trends (13 Hours)

Indian facilities: IUAC, VECC, RRCAT, TIFR, Synchrotron radiation sources and Pelletron accelerators, International collaborations (CERN, FAIR, etc.), Emerging technologies: plasma

accelerators, muon colliders, Future accelerator projects (ILC, FCC), Role of accelerators in research, policy, and society.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Students will be able to explain advanced accelerator technologies and their applications in science, medicine, and industry. They will understand radioactive ion beam production and accelerator-based analytical techniques. Students will also gain knowledge of thin-film preparation and modern research facilities, along with emerging trends in accelerator physics.

Suggested Readings

1. Accelerator Physics, S. Y. Lee, World Scientific, 3rd Edition, 2012.
2. Particle Accelerator Physics, H. Wiedemann, Springer, 4th Edition, 2015.
3. An Introduction to the Physics of Particle Accelerators, M. Conte and W. W. MacKay, World Scientific, 2nd Edition, 2008.
4. Applications of Accelerators in Research and Industry, C. Johnson (Ed.), AIP Conference Proceedings, Vol. 1525, 2013.
5. Handbook of Accelerator Physics and Engineering, A. W. Chao and M. Tigner (Eds.), World Scientific, 2nd Edition, 2013.

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5246
Course Name: Metamaterials, Plasmonics and Photonics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Metamaterials, plasmonics and photonics DSE	4	3	1	0	EMT, Solid state Physics

Duration: 60 Hours(45L+15T)

Course Objective:

This course introduces the principles of nanophotonics – an emerging frontier at the nexus of nanotechnology and photonics. NanoPhotonics plays an important role in current (and future) ultra-small and ultra-sensitive sensing, imaging, optical communication, optical circuitry, and data storage. The aim is to provide a comprehensive view of nanoscale optical materials and photonics to students by starting at a very elementary level, and gradually guiding them to the very frontier of current research such as photonics, plasmonics, metamaterials and their applications in everyday life.

Contents:

Unit. I: Elements of Plasmonics

(15 Hours)

Propagation of electromagnetic waves in metals: dielectric function and complex conductivity of materials, complex index of refraction, Kramers-Kronig relations. Examples of polariton dispersion relations: bulk photon polaritons, bulk plasmon polaritons. Propagation of electromagnetic waves at metal-dielectric interfaces: Surface plasmon polaritons (SPP)-single interface, principles of SPP excitations, Surface plasmon Resonance, Application of SPP – planar waveguides, sensors. Interaction of EM waves with nanoparticles: Mie theory of scattering and absorption of electromagnetic radiation by a sphere. Quasi-static approximation. Scattering, absorption and extinction cross-section. Application of LSP – resonant plasmonic antennas, surface enhanced spectroscopies (SERS, SEF, SEIRA).

Unit II: Semiconductor nanoparticles–applications

(10 Hours)

Optical luminescence and fluorescence from direct, band gap semiconductor nanoparticles, surface trap passivation in core-shell nanoparticles, carrier injection, polymer nanoparticle LED's and solar cells, Sensing, electroluminescence; barriers to nanoparticle lasers; doping nanoparticles, MnZnSe phosphors; light emission from indirect semiconductors, light emission from Si nanodots.

Unit III: Physics of Photonic Crystals (10 Hours)

Maxwell's Equations, Bloch's Theorem, Photonic Band Gap and Localized Defect States, Transmission Spectra, Guided Modes in Photonic Crystals Slab, Photonic Crystals as Couplers, Waveguides, High-Q Cavities, etc, Photonic Crystal Fibers, Tunable Photonic Crystal Filters, Fabrication of 1D, 2D and 3D photonic crystals.

Unit IV: Metamaterials and Metasurfaces (10 Hours)

Design of metamaterials with specified effective material parameters: artificial plasmas, artificial dielectrics, artificial resonant magnetic materials, Ideas of homogenization and effective medium theories, negative refractive index, perfect absorption, Introduction to metasurfaces and flat optics, Nature inspired artificial materials.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

To learn how to control optical fields at nanoscale. To understand and apply the plasmonic principles to guide and focus light below the diffraction limit. To understand photonic crystals and their similarity to semiconductors. To learn about artificially structured materials and how to design materials with desired optical constants such as negative refractive index, graded index materials and perfect absorbers.

Suggested Readings

1. Springer Handbook of Nanotechnology, Bharat Bhushan, (*Springer, 2017, 4th Edition*).
2. Encyclopedia of Nanotechnology, Hari Singh Nalwa (Ed.), (*Springer, 2015*).
3. Optical Properties of Photonic Crystals (2nd Edition), Kazuaki Sakoda, (*Springer, 2005*).
4. Introduction to Nanophotonics, Paras N. Prasad, (*John Wiley & Sons, 2004*).
5. Nanoplasmonics: From Fundamentals to Applications, Volumes 1 & 2, Satoshi Kawata and Hiroshi Masuhara (Eds.), (*Elsevier/Kluwer Academic Publishers, 2008*).
6. Plasmonics: Fundamentals and Applications, Stefan A. Maier, (*Springer, 2007*).
7. Optical Metamaterials: Fundamentals and Applications, Wenshan Cai and Vladimir M. Shalaev, (*Springer, 2010*).
8. Introduction to Solid State Physics (8th Edition), Charles Kittel, (*John Wiley & Sons, 2005*).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-DSE5247
Course Name: Nuclear Safety and Security

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nuclear Safety and Security DSE	4	3	1	0	Nuclear & Particle Physics, Statistical Mechanics

Duration: 60 Hours(45L+15T)

Course Objectives

Introduction to radioactive sources/materials and their classification; technical aspects of research reactors; awareness of the wide-ranging scenarios pertaining to nuclear safety, safeguard and security; appraisal of national and international frameworks, legislations and regulations.

Contents

Unit I (12 Hours)

Radioactive Sources: Radioactive sources/materials and their applications, Radiation Basics and Consequences of Exposure to Radiation, Categorization of Radioactive Sources, overview of Nuclear and Radiation facilities.

Reactor Fundamentals: Introduction to Reactor physics, neutron induced fission, energy release in fission, concept of neutron flux and cross-section, neutron cycle in thermal reactors, criticality, nuclear power output calculation, breeder reactions. fissile and fertile materials. thermal and fast reactors; plutonium and higher isotopes, Reactor control and operation, neutron lifetime and delayed neutrons.

Unit II (11 Hours)

Safety, Safeguard and Security Frameworks: Introduction to and overview of IAEA Nuclear Safety and Security Series Publications, Treaties, auditing and review legal compliance of nuclear establishments, ISO Standards Concept of safety, security and safeguards

Nuclear Safety; Fundamentals of Nuclear Safety; Nuclear Safety Standards, Defense in the Depth approach, Safety classification, Mitigation of radiological consequences of significant release, Human performance and surveillance programs.

Unit III (11 Hours)

Nuclear Security: Overview of Nuclear Security Principle, Nuclear Security Threats and Risks in Nuclear Materials and Facilities, Physical Protection, Transport Security, Nuclear Material

Accounting and Control, Preventive and Protective Measures against Insider Threats, Nuclear Security of Materials Outside of Regulatory Control, Use of Radiation Detection Instruments in Nuclear security, Radiological Crime Scene Management, Impact minimization, case studies, Safety and security of sources during storage, use, transportation and disposal, administrative and technical provisions, Radioactive waste management (modern and accelerators driven techniques), graded approach in security and safety waste management.

Unit IV (11 Hours)

National & International Resources and Legislations: Atomic Energy Regulatory Board (AERB), International Atomic Energy Agency (IAEA), Codes, standards, guidelines, manuals, Regulatory Controls; Licensing, inspection and enforcements, Responsibilities of Employers, Licensee, Radiological Safety officer (RSO) and radiation workers. Import and export procedures, Importance of International Cooperation, Emergency preparedness and Response in an event/emergency in nuclear/radioactive event.

Knowledge sharing, Best practices.

Tutorial Component (15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

The student would have technical knowledge about radioactive sources/materials and research reactors; quantitative idea about permissible doses for different levels of users; knowledge about various regulatory authorities, understanding of multi-dimensional aspects of nuclear safety and security, national and international legislation, regulations and resources; knowledge about the management of radioactive material and adherence to safety protocols.

Suggested Readings

1. Introduction to Nuclear Reactor Physics, Robert E. Masterson (CRC Press, 2017)
2. Understanding Radioactive Waste, Taylor Francis, R. L. Murray (4th Ed., Battelle Press, 1994)
3. Radiation Biophysics, Edward L Alpen (2nd Ed., San Diego Academic Press, 1998)
4. Fundamentals of Nuclear Reactor Physics, Elmer E. Lewis, Academic Press (Elsevier imprint), 2008.
5. Nuclear Fuel Management, H. W. Graves (John Wiley & Sons, 1979)
6. Nuclear Security: The Problems and Solutions, Bahman Zohuri, Springer, 2023
7. Nuclear Security: A Reference Handbook (2nd Edition), Jeffrey A. Larsen, ABC-CLIO, 2023

8. Nuclear Safeguards, Security and Nonproliferation, James Doyle (Editor), Elsevier, 2023 (Updated Edition).
9. An Engineer's Guide to Nuclear Reactor Core Materials, Malcolm Griffiths, Elsevier 2025
10. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities.
11. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources.
12. IAEA Publications (latest) : (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interim) (2010); (b) Safety Standards Series No. RS-G-1.5 (2002), RS-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/ Semester II of I year MSc.
Course Code: PH-DSE5248
Course Name: Advanced Statistical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced statistical Physics) DSE	4	3	1	0	Statistical Mechanics, Mathematical Physics and QM I)

Duration: 60 Hours(45L+15T)

Course Objective:

This course introduces advanced concepts in statistical mechanics, including nonequilibrium phenomena, transport processes, and phase transitions. It develops modern theoretical tools such as stochastic dynamics, linear response theory, and the renormalization group, and explores their applications to complex physical systems.

Unit-I: Nonequilibrium Statistical Mechanics (13 Hours)

Systems out of equilibrium. Stochastic processes and Brownian motion, Langevin equation and Fokker-Planck equation: connection between two approaches, fluctuation-dissipation theorem, Einstein relation.

Unit-II: Transport and correlation (8 Hours)

Correlation functions: time correlation functions, linear response theory, Kubo formalism for transport coefficients; Onsager relations and symmetry principles.

Unit-III: Phase Transitions: Microscopic models, field theories and renormalization group (12 Hours)

Ising model, mean-field theory, exact solution in one dimension using Transfer matrix, elementary idea of two-dimensional Ising model, Landau theory of phase transitions; Ginzburg–Landau theory and order parameter fluctuations. Critical exponents, The renormalization group (RG), RG for the 1D Ising chain, Flow diagram and Fixed points.

Unit IV: Applications in a few systems (12 Hours)

Polymer collapse transition, protein folding, phase transition in liquid crystals, XY model-BKT transition, active particles- single particle behavior and collective phenomena, entropy production in active particle trajectory.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

This course provides a deeper understanding of collective behavior in many-body systems, both at equilibrium and out-of-equilibrium. Students learn how macroscopic phenomena such as phase transitions emerge from microscopic many-body interactions. The course introduces key theoretical frameworks like the Ising model, Landau theory, and stochastic dynamics. It also builds intuition about fluctuations, correlations, and response in physical systems. By the end, students are able to connect statistical principles with real physical processes such as transport and diffusion. Overall, it provides a foundation for advanced research in statistical physics and related areas.

Suggested Readings

1. Statistical Mechanics (2nd Edition), Kerson Huang, (*John Wiley & Sons, 1987*).
2. Statistical Mechanics (3rd Edition), R. K. Pathria and Paul D. Beale, (*Elsevier, 2011*).
3. Statistical Mechanics, Shang-Keng Ma, (*World Scientific Publishing, 1985*).
4. Statistical Physics of Particles, Mehran Kardar, (*Cambridge University Press, 2007*).
5. Statistical Mechanics: Entropy, Order Parameters, and Complexity, James P. Sethna, (*Oxford University Press, 2006*).
6. Statistical Mechanics, Donald A. McQuarrie, (*University Science Books, 2000*).
7. Principles of Condensed Matter Physics, P. M. Chaikin and T. C. Lubensky, (*Cambridge University Press, 1995*).
8. Lectures on Phase Transitions and the Renormalization Group, Nigel Goldenfeld, (*CRC Press/Addison-Wesley, 1992*).
9. Statistical Physics of Fields, Mehran Kardar, (*Cambridge University Press, 2007*).
10. Elements of Nonequilibrium Statistical Mechanics, V. Balakrishnan, (*CRC Press, 2021*).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/ Semester II of 1 year MSc
Course Code: PH-DSE5249
Course Name: Biophysics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Biophysics DSE	4	3	1	0	Statistical Physics

Duration: 60 Hours(45L+15T)

Course Objectives

This elective course will introduce students to selected biological phenomena from the point of view of physics, emphasizing quantitative regularities. It will enable students from a Physics background to gain an overview of living systems and the patterns arising from various complex interactions. It will also help students to perform mathematical modelling of certain biological processes.

Contents:

Unit I (8 Hours)

Length and time scales in biology: Types, sizes and roles of biomolecules - metabolites, proteins, RNA, and DNA. Ranges of cell sizes and interdivision time scales,. Ranges of organism sizes and lifetimes, Scaling laws in biology, Complexity of living systems, Timeline of life on Earth, Time scales in biological evolution.

Unit II (15 Hours)

Cellular dynamics: Dynamical systems, coupled ordinary differential equations, Phenomena and models of intracellular chemical dynamics. Ecological interactions, Lotka-Volterra and other ecological dynamics, models of ecosystems. Dynamics of a single neuron, Neural networks, Learning, Memories as attractors of neural network dynamics.

Unit III (16 Hours)

Information in living systems: Probability, entropy and information, Applications of Information theory in genetics. Introduction to stochastic processes in biology. Random walk, conformations of polymers and related Scaling, polymer melts, structures of DNA, force effects on DNA, simulation methods and related experiments, bio-membranes and gels

Unit IV (6 Hours)

Advanced Molecular Simulation Techniques. Empirical force field for biomolecular simulations, Potential energy function (Bond length potential, Bond angle potential, Torsional potential, van der Waals potential, and Coulomb potential, Classical representation of

electrostatics, Geometry optimisation and energy minimisation, Molecular dynamics simulations, Monte Carlo simulations.

Tutorial Component

(15 Hours)

The tutorial component is closely integrated with the theoretical content of all four units and primarily consists of structured problem-solving exercises designed to strengthen students' conceptual understanding and analytical skills. Students will be required to solve and present assigned problems, including analytical and, where appropriate, computational approaches, while their performance will be evaluated through regular assessments and assignments in accordance with university guidelines.

Course Learning Outcomes

Gain an understanding of the structures and processes in living systems across various length and time scales, from molecules and cells to multicellular organisms and ecosystems. Recognize that life arises from numerous physical and chemical processes at the molecular level, and understand the significance of stochastic processes in their dynamics. Familiarize yourself with mathematical methods related to dynamical systems, probability, and information theory. Additionally, learn about various numerical techniques used in computer simulations as well as experiments involving biomolecules and proteins.

Suggested Readings

1. Physics in Molecular Biology, Kim Sneppen and Giovanni Zocchi (CUP 2005).
2. Biological Physics: Energy, Information, Life, Philip Nelson (W. H. Freeman & Co, NY, 2004).
3. Biophysics: Searching for Principles, William Bialek (Princeton University Press, 2012).
4. Physical Biology of the Cell (2nd Edition), Rob Phillips et al (Garland Science, Taylor & Francis Group, 2013).
5. An Introduction to Systems Biology, Uri Alon (Chapman and Hall/CRC, 2013).
6. Mathematical Biology: I. An Introduction, J. D. Murray (3rd Ed., Springer, 2004).
7. Biomolecules under mechanical force: Physics Reports, S. Kumar & M. S. Li. (Elsevier, 2009).
8. Understanding Molecular Simulations. Academic Press. D. Frenkel & B. Smit (2002).
9. Molecular Modelling: Principles & Applications, Andrew R. Leach, Prentice Hall.
10. The art of Molecular Dynamics Simulation. Rapport, Cambridge University. Cambridge University.

MASTER of SCIENCE in PHYSICS
Semester II of 1 year MSc
Course Code: PH-DSE5
Course Name: Quantum Mechanics-II

Course Title and Type	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Mechanics-II DSE	4	3	1	0	Bachelor's degree in Physics

Duration: 60 hours (45L+15T)

Course Objectives

The primary objective is to teach the students various approximation methods in quantum mechanics. The important topic of quantum scattering is also dealt with. Also some aspects of non-Hermitian systems and Relativistic quantum theory, such as the Dirac equations, are covered.

Contents:

Unit I (13 hours)

WKB method, hydrogen-like atoms, and spherical harmonics. Spin-half particle: nonrelativistic (Pauli theory) and relativistic (Dirac equation and plane wave solution), Addition of angular momenta. Clebsch-Gordan coefficients, Wigner-Eckart theorem, application of approximate methods.

Unit II (13 hours)

Approximation Methods for time-dependent perturbations: Interaction picture. Time-dependent perturbation theory. Transition to a continuum of final states – Fermi's Golden Rule. Application to constant and harmonic perturbations, sudden and adiabatic Approximations.

Unit III (12 hours)

Scattering: Wave packet description of scattering. Lippmann-Schwinger Equations, Formal treatment of scattering by Green's function method. Born approximation and applications. Definition and properties of S-Matrix Partial wave analysis. Optical theorem.

Unit IV (7 hours)

Introduction to non-Hermitian systems: energy eigenvalues, eigenvectors and their spectral properties, exceptional points, PT symmetric systems.

Tutorial Component:

(15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

Students will learn how to use perturbation theory to obtain corrections to energy eigenstates and eigenvalues when an external electric or magnetic field is applied to a system. Scattering theory will teach them how to use projectiles to infer details about the target quantum system. Exposure to Dirac's equation and non-hermitian systems.

Suggested Reading:

1. Quantum Mechanics, L.I. Schiff, McGraw-Hill, 2017.
2. Principles of Quantum Mechanics, R. Shankar, Springer, 2011.
3. Introduction to Quantum Mechanics, D.J. Griffiths, Cambridge, 2018.
4. A Modern Approach to Quantum Mechanics, J.S. Townsend, Viva Books.
5. E. Merzbacher, Quantum Mechanics, John Wiley and Sons.
6. F. Schwabl, Advanced Quantum Mechanics, Springer.
7. A. Das, Hours on Quantum Mechanics, Hindustan Book Agency.
8. M. Le Bellac, Quantum Physics, Cambridge University Press.
9. J. J. Sakurai, Modern Quantum Mechanics, Pearson.
10. S. Flügge, Practical Quantum Mechanics, Springer.

11. K. Gottfried and T.-M. Yan, Quantum Mechanics: Fundamentals, Springer.
12. R.P. Feynman, Feynman Hours on Physics (Vol. III), Addison-Wesley.
13. C. Cohen-Tannoudji, B. Diu and F. Laloe, Quantum Mechanics (Vols. I & II), Wiley.
14. A. Messiah, Quantum Mechanics (Vols. I and II), Dover.
15. P.A.M. Dirac, The Principles of Quantum Mechanics (International Series of Monographs on Physics).

Semester II of 1 year MSc
Course Code: PH-DSE4203
Course Name: Solid State Physics

Course Title and Type	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Solid State Physics DSE	4	3	1	0	Bachelor's degree in Physics

Duration: 60 hours (45L+15T)

Course Objectives:

This course intends to provide knowledge of conceptual solid-state physics. In addition, this course aims to provide a general introduction to theoretical and experimental topics in solid state physics.

Contents:

Unit I (16 hours)

Metals: Drude theory, DC conductivity, magneto-resistance, thermal conductivity, thermoelectric effects, Fermi-Dirac distribution, thermal properties of an electron gas, Wiedemann-Franz law, critique of free-electron model.

Crystal Lattices: Diffraction of electromagnetic waves by crystals: X-rays, Electrons and Neutrons, Symmetry operations and classification of Bravais lattices, common crystal structures, reciprocal lattice, Brillouin zone, X-ray diffraction, Bragg's law, Von Laue's formulation, diffraction from non-crystalline systems. Geometrical factors of SC, FCC, BCC and diamond lattices; Basis of quasi crystals.

Unit II (8 hours)

Crystal Binding: Bond classifications – types of crystal binding, covalent, molecular and ionic crystals, London theory of van der Waals, hydrogen bonding, cohesive and Madelung energy. Defects and Diffusion in Solids: Point defects: Frenkel defects, Schottky defects, examples of colour centres, line defects and dislocations.

Unit III (12 hours)

Lattice Dynamics: Failure of the static lattice model, adiabatic and harmonic approximation, vibrations of linear monoatomic lattice, one-dimensional lattice with basis, models of three-dimensional lattices, quantization of lattice vibrations, Einstein and Debye theories of specific heat, phonon density of states, neutron scattering.

Band theory of Solids: Periodic potential and Bloch's theorem, weak potential approximation, density of states in different dimensions, energy gaps, Fermi surface and Brillouin zones. Origin of energy bands and band gaps, effective mass, tight-binding approximation and calculation of simple band-structures. Motion of electrons in lattices, Wave packets of Bloch electrons, semi-classical equations of motion, motion in static electric and magnetic fields, theory of holes, cyclotron resonance.

Unit IV (9 hours)

Semiconductors: General properties and band structure, carrier statistics, impurities, intrinsic and extrinsic semiconductors, drift and diffusion currents, mobility, Hall effect.

Superconductors: Phenomenology, review of basic properties, thermodynamics of superconductors, London's equation and Meissner effect, Type-I and Type-II superconductors, BCS theory of superconductors.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

The students should be able to elucidate the important features of solid state physics by covering crystal lattices and binding, lattice dynamics, band theory of solids and semiconductors.

Suggested Reading:

1. Introduction to Solid State Physics, C. Kittel (8th Ed., Wiley, 2012).
 2. Solid State Physics, N. W. Ashcroft and N. D. Mermin (1st Ed., Cengage Learning, 2003).
 3. Principles of the Theory of Solids, J. M. Ziman (2nd Ed., Cambridge University Press, 1972).
 4. Solid State Physics, A. J. Dekker (1st Ed., Macmillan India, 2000).
 5. Solid State Physics, G. Burns (1st Ed., Academic Press, 1985).
- Condensed Matter Physics, M. P. Marder (Wiley, 2010).

Course Code: PH-DSE5263

Course Name: Foundational Laboratory in Experimental Physics

Course Title and Type	Credits	Credit distribution of the course			Requisites for the course
		Lecture	Tutorial	Practical	
Foundational Laboratory in Experimental Physics DSE	4	0	0	4	Pre-requisite: Bachelor's degree in Physics, Co-requisite: DSC papers in M.Sc. Physics Sem-I

Duration: 120 Hours

Course Objectives

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Electronics

Unit I: Device Characteristics and Application

1. p-n junction diodes-clipping and clamping circuits.
2. FET – characteristics, biasing and its applications as an amplifier.
3. MOSFET – characteristics, biasing and its applications as an amplifier.
4. UJT – characteristics, and its application as a relaxation oscillator.
5. SCR – Characteristics and its application as a switching device.

Unit II:

● **Linear Circuits**

1. Resonant circuits.
2. Filters-passive and active, all pass (phase shifters).
3. Power supply-regulation and stabilization.
4. Oscillator design and study.
5. Multi-stage and tuned amplifiers.

6. Multivibrators-astable, monostable and bistable with applications.
7. Design and study of a triangular wave generator.
8. Design and study of sample and hold circuits.

- **Digital Circuits and Microprocessors**

1. Combinational.
2. Sequential.
3. A/D and D/A converters.
4. Digital Modulation.
5. Microprocessor application.

Nuclear Physics

Unit III: Detectors

5. G.M. Counters – characteristics, dead time and counting statistics
6. Spark counter-characteristics and range of x-particles in air
7. Scintillation detector-energy calibration, resolution and determination of gamma ray energy
8. Solid State detector – surface barrier detector, its characteristics and applications.

Unit IV:

- **Applications**

1. Gamma ray absorption-half thickness in lead for ^{60}Co gamma-rays.
2. Beta ray absorption – end point energy of beta particles.
3. Lifetime of a short lived radioactive source..

- **High Energy Physics**

1. Study of π - μ -e decay in nuclear emulsions.
2. Study of high energy interactions in nuclear emulsions.

Course Learning Outcome:

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Reading:

Electronics

1. Electronic Instrumentation and Measurement Techniques, W.D. Cooper and A.D. Helfrick (2nd Ed., Phi Learning, 2008).
2. Electronic Devices and Circuits, J. Millman, C.C. Halkias and S. Jit (4th Ed., McGraw-Hill, 2015).
3. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M. Sayer and A. Mansingh (Prentice Hall India, 2010).

Nuclear Physics

4. Radiation Detection and Measurement, G. F. Knoll (3rd Ed, John Wiley & Sons, Inc, 2000).
5. Physics & Engineering of Radiation Detection, S.N. Ahmed (Academic Press, 2007).
6. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer Verlag, 1987).

MASTER of SCIENCE in PHYSICS

Semester II of 1 year MSc

Course Code: PH-DSE5264

Course Name: Experimental Laboratory in Materials and Optical Physics

Course Title and Type	Credits	Credit distribution of the course			Requisites for the course
		Lecture	Tutorial	Practical	
Experimental Laboratory in Materials and Optical Physics DSE	4	0	0	4	Pre-requisite: Bachelor's degree in Physics, Co-requisite: DSC papers in M.Sc. Physics Sem-I

Duration: 120 Hours

Course Objective:

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Solid State Physics

Unit I

Experimental Techniques:

- Production and measurement of low pressures.
- Production and measurement of high pressures.
- Measurement and control of low temperatures.
- Production and characterization of plasma.
- Electron Spin Resonance.
- Nuclear Magnetic Resonance.

Unit II

Electrical Transport Properties:

- Measurement of resistivity – Four probe and van der Paw techniques; determination of band gap.
- Measurement of Hall coefficient – determination of carrier concentration.
- Measurement of magneto resistance.
- Measurement of thermoelectric power.
- Measurement of minority carrier lifetime in semiconductors: Haynes-Shockley experiment.

Phase Transitions and Crystal Structure:

- Determination of transition temperature in ferrites.

- Determination of transition temperature in ferroelectrics.
- Determination of transition temperature in high T_c superconductors.
- Determination of transition temperature in liquid crystalline materials.
- Crystal structure determination by x-ray diffraction powder photograph method.

Waves and Optics

Unit III

- Velocity of sound in air by CRO method.
- Velocity of sound in liquids – Ultrasonic Interferometer method.
- Velocity of sound in solids – pulse echo method.
- Propagation of EM waves in a transmission line – Lecher wire.
- Determination of Planck's constant.
- Jamin's interferometer – refractive index of air.
- Study of elliptically polarized light.

Unit IV

Optical Spectroscopy:

- Constant deviation spectrometer-fine structure of Hg spectral lines.
- e/m or hyperfine structure using Fabry Perot's interferometer.
- Band spectrum in liquids.
- Raman scattering using a laser source.
- Luminescence.

Laser Based Experiments:

- Optical interference and diffraction.
- Holography.
- Electro-optic modulation.
- Magneto-optic modulation.
- Acousto-optic modulation.
- Sound modulation of carrier waves.

NOTE:

The list of experiments given above should be considered as suggestive of the standard and available equipment. The teachers are authorized to add or delete from this list whenever considered necessary.

Course Learning Outcome:

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Reading:

Solid State Physics

1. Introduction to Solid State Physics: Charles Kittel, 8th edition (John Wiley and Sons, inc, 2005).
2. Physics of Semiconductor devices S.M. Sze (Wiley, 2006).

Waves and Optics

1. Lasers: Fundamental and Applications, Graduate Text in Physics, 2nd edition, K. Thyagarajan and Ajoy Ghatak (Springer, 2002).
2. Polarization of light, Ajoy Ghatak and Arun Kumar (McGraw Hill Education, 2012).
3. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000).
4. Teaching laser physics by experiments, Am. J. Phys., (2011), [http://doi.org/10.1119/1-3488984](http://doi.org/10.1119/1.3488984) .

Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-SBC5271
Course Name: Workshop skills

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Workshop Skill SBC	2	0	0	2	

Duration: 60 Hours

Course objective:

The aim is to teach them how to handle machines which can be useful for precise cutting in lab accessories useful for experiments.

Content:

Unit I:

Hands-on experience with:

- (a) Lathe machine (Plane turning, step turning, taper turning)
- (b) Drill machine

Unit II:

Hands-on experience with:

- (a) Plate cutting
- (b) Hand tools (hacksaw, drilling, tapping, filing)
- (c) Soldering skills

Course Learning outcome:

The student will be confident and skilled for handling lab useables and small repairs.
 (Not more than seven students at a time due to space constraints and safety.)

Suggested Readings

1. Workshop Technology, Volume I, W. A. J. Chapman, (*CBS Publishers & Distributors, 2006*).
2. A Textbook of Workshop Technology: Manufacturing Processes, R. S. Khurmi and J. K. Gupta, (*S. Chand Publishing, 2014*).
3. Elements of Workshop Technology, Volume I: Manufacturing Processes, S. K. Hajra Choudhury, A. K. Hajra Choudhury, and Nirjhar Roy, (*Media Promoters & Publishers, 2007*).
4. Machine Tools Handbook: Design and Operation, T. A. Jalil and A. J. M. Majumdar, (*Industrial Press, 2013*).
5. Basic Workshop Practice, T. Jeyapoovan, (*Vikas Publishing House, 2015*).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/ Semester II of 1 year MSc
Course Code: PH-SBC5272
Course Name: Strategies for Scientific Dialogue in Research

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Strategies for Scientific Dialogue in Research SBC	2	1	0	1	Bachelor's Degree in branch of Science

Total: (15L+30P) 45 Hours

Course Objectives

Course Objectives: The course is designed to develop and strengthen students' ability to communicate scientific ideas clearly and effectively, both in written and oral formats. It aims to expose students to cutting-edge research through seminars delivered by faculty members and invited experts. Emphasis is on cultivating skills in scientific literature review, critical analysis, and academic discourse. The course also prepares students for academic presentations, thesis defenses, and professional scientific interactions. Recognizing that many students produce excellent research but struggle to present it effectively, this course seeks to bridge that crucial gap.

Course Structure and Activities:

UNIT -I

(15 hours)

Lecture Attendance & Research Exposure:

- Students must attend a minimum of 10 research lectures organized by the department. These may include:
 1. Presentations by department faculty on their current research.
 2. Lectures by invited national or international experts.
- Students will submit comprehensive summaries (approx. 400–500 words) of at least five selected lectures, highlighting key concepts, methods, and findings.

UNIT -II

(30 hours)

Seminar Preparation and Delivery:

- Students will be assigned a research topic or paper, drawn from current research themes or courses offered in the M.Sc. syllabus.
- They will receive study materials, including relevant papers, reviews, or resources from the faculty.
- Each student must prepare a written synopsis (~800–1000 words) on the assigned topic.

- Students will then present a seminar (15–20 minutes) based on their understanding, followed by a Q&A session.

The course is structured in the spirit of a Dissertation under the DSE category, but with lower credit weightage and, accordingly, reduced academic rigor. As such, the number of hours assigned is indicative rather than prescriptive, intended to reflect the approximate level of effort expected.

Assessment and Evaluation: Components

- a) Participation in Departmental Lectures.
- b) Written Summaries of Attended Lectures.
- c) Written Review of Assigned Research Topic.
- d) Seminar Presentation (Content, Clarity, Delivery).

Evaluation will be conducted by

- a) A three-member departmental committee for the overall course.
- b) A two-member subcommittee for seminar presentation evaluation.

Notes for Implementation:

- Attendance at department seminars will be tracked.
- Students may optionally include key questions or insights from each attended lecture.
- Emphasis will be on communication skills, depth of understanding, organization of content, and response to questions.
- This course encourages peer learning and academic engagement beyond classroom.

Course Learning Outcome:

Upon successful completion of the course, students will be able to: Comprehend and effectively communicate recent research developments in physics and allied disciplines. Summarize and synthesize scientific literature with clarity, coherence, and critical insight. Prepare and deliver well-structured, confident, and audience-appropriate scientific presentations. Engage thoughtfully in scholarly discussions and respond competently to academic queries. This course will be particularly beneficial for students planning to undertake project work or a dissertation in the third and fourth semesters.

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-SBC5273
Course Name: Detector Design and Simulation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Detector Design and Simulation SBC	2	0	0	2	

Duration: 60 Hours

Course Objectives

To introduce the principles and technologies behind radiation detector design and signal processing. To understand detector performance parameters and optimize geometry and materials for specific applications. To provide practical experience in detector simulation using modern tools (e.g., GEANT4, ROOT, SRIM, Garfield++). To build capability for research and development in detector systems for high-energy physics, nuclear physics, and medical imaging.

Content:

Unit I: Detector Physics and Simulation Fundamentals

1. Introduction to Detector Physics and Classification: Types of detectors: gaseous, semiconductor, scintillators. Performance parameters: resolution, efficiency, gain, threshold. Applications in HEP, medical imaging, and homeland security. Lab: Introduction to ROOT, histogram, plotting experimental data
2. Interaction of Radiation with Matter: Ionisation, excitation, bremsstrahlung, Compton scattering, photoelectric effect, Stopping power and range. Lab: SRIM simulation – energy loss and range of ions in matter
3. Gaseous Detector Design Principles: Ionisation chambers, proportional counters, Geiger-Müller tubes, Avalanche multiplication, drift, gain, quenching. Lab: Garfield++ basics – simulate ionisation and drift in gas chambers
4. Scintillation Detector Fundamentals: Light generation, quenching, energy resolution, Photomultiplier tubes (PMTs), light guides, time response. Lab: Optical photon tracking in GEANT4 – scintillator block with PMT
5. Semiconductor Detectors (Si, Ge, CZT): Charge carrier generation, depletion, leakage current, p-n junction design, energy resolution. Lab: TCAD or simple Python-based Si detector response model

6. Signal Formation and Readout: Shockley-Ramo theorem, preamplifiers, shaping circuits, Noise sources, signal-to-noise ratio (SNR). Lab: Simulating signal response in ROOT using Gaussian convolution

Unit II: Detector Modelling, Performance Analysis, and Applications

1. GEANT4 Basics and Setup: Geometry definition, materials, particle tracking, Event generators and physics lists. Lab: GEANT4: Set up a basic detector geometry and simulate MIPs (e.g., muons)
2. Energy Deposition and Resolution Analysis: Energy spectrum interpretation, Full energy peak, Compton edge, backscatter peak. Lab: GEANT4 simulation of a NaI or HPGe detector for gamma ray spectrum
3. Detector Efficiency and Angular Response: Geometrical vs intrinsic efficiency, Dead layers, shielding, collimation. Lab: Simulate varying detector thickness/angle and extract detection efficiency
4. Pulse Processing and Digital Signal Simulation. Sampling, shaping, digitization. Rise time, decay time, pulse pile-up. Lab: ROOT/Matplotlib: simulate pulse shapes and extract timing information
5. Time-of-Flight and Fast Timing Detectors: TOF measurement principles, timing resolution, Scintillators and MCPs for fast timing. Lab: GEANT4 timing simulation of TOF system
6. Detector Array Design and Spatial Resolution: Segmented detectors, pixellated and strip designs, Crosstalk and cluster algorithms, Lab: GEANT4 simulation of a pixel detector and event hit mapping
7. Radiation Damage and Detector Ageing: Effects of radiation on gas gain, leakage current, charge collection, Annealing, hardness factor. Lab: Varying material properties in simulation to simulate radiation damage effects

Skill Development Tools and Software

- GEANT4: Full detector geometry and particle-transport simulation.
- Garfield++: Gaseous detector and electron-drift simulations.
- ROOT: Data analysis, histogramming, spectrum analysis, and pulse simulation.
- SRIM/TRIM: Ion stopping-power and range calculations.
- Python: Signal modelling, data analysis, visualization, and detector-response simulations.
- MATLAB (optional): Digital signal processing and pulse-shaping studies.

Course Learning Outcomes

By the end of the course, students will be able to: Describe the operating principles, design considerations, and key performance metrics of common detectors (e.g., Si, scintillators, gas detectors). Perform simulations to study energy deposition, charge transport, and response of different detector geometries. Use GEANT4 and other tools to simulate particle interaction

with matter and evaluate detector efficiency and resolution. Design and optimize detectors for specific use cases in physics, medicine, security, or industry.

Suggested Readings

1. Radiation Detection and Measurement, Glenn F. Knoll, John Wiley & Sons, 4th Edition, 2010.
2. Techniques for Nuclear and Particle Physics Experiments: A How-to Approach, W.R. Leo, Springer-Verlag, 2nd Edition, 1994.
3. GEANT4 User's Guide for Application Developers, GEANT4 Collaboration, CERN, latest online edition, continuously updated.
4. ROOT Data Analysis Framework Tutorials, ROOT Development Team, CERN, online resources, continuously updated.
5. SRIM – The Stopping and Range of Ions in Matter, J.F. Ziegler, M.D. Ziegler, J.P.
6. Biersack, SRIM Co., SRIM-2013 or latest, 2013.
7. Garfield++ Simulation Toolkit Tutorials, H. Schindler et al., CERN, online resources, continuously updated

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-SBC5274
Course Name: Interdisciplinary Innovation Lab

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Interdisciplinary Innovation Lab SBC	2	0	0	2	

Duration:60 Hours

Course Objectives

This course aims to cultivate innovative and experimental thinking through hands-on experiments encompassing energy harvesting, sensor technology, materials science, and electronics. The focus is on creativity, prototyping, and practical applications.

Unit-I:

List of Experiments (Perform Any 2 Experiments) or any innovative idea to be implemented

1. Preparation of Hydrophilic and Hydrophobic: Surfaces Students will explore techniques to modify substrate wettability through surface treatment and the formation of self-assembled monolayers (SAMs).
2. Production of Hydrogen Gas from Water: This experiment involves the electrolysis of water using various electrodes to understand the efficiency of hydrogen generation. Students will also study the role of catalysts in electrolysis.
3. Design and Development of Devices for Temperature Sensing: Students will design electronic circuits using thermistors and calibrate them to measure ambient temperature.

Unit-II:

List of Experiments (Perform Any 2 Experiments) or any innovative idea to be implemented

1. Preparation of Flexible Thin Films for Nanogenerator Applications: Techniques such as spin-coating or solution casting will be used to fabricate thin films on flexible substrates. Their energy-harvesting capabilities will be explored under mechanical stress, friction, etc.
2. Generation of Electrical Power from Day-to-Day Friction: This module explores triboelectric nanogenerators, where students will harness mechanical motion (e.g., sliding or tapping) to generate electrical signals using appropriate materials.
3. Electrochemical Transducers for Molecular Sensing: Students will fabricate simple electrochemical sensors/devices and test their response to various analytes.

Course Learning Outcomes

Upon successful completion of this course, students will be able to design, fabricate, and characterize simple functional devices related to energy harvesting, sensing, and advanced materials. They will develop practical skills in experimental design, prototyping, data analysis, and innovation-driven problem-solving for real-world technological applications.

Suggested reading

6. Sensors and Transducers (3rd Edition), D. Patranabis, (*PHI Learning Pvt. Ltd., 2017*).
7. Nanogenerators and Piezotronics: From Theory to Experimental Approaches, Zhong Lin Wang, (*Wiley-VCH, 2014*).
8. Electrochemical Methods: Fundamentals and Applications (2nd Edition), Allen J. Bard and Larry R. Faulkner, (*John Wiley & Sons, 2001*).
9. Materials Science and Engineering: An Introduction (10th Edition), William D. Callister Jr. and David G. Rethwisch, (*John Wiley & Sons, 2018*).
10. Energy Harvesting Technologies, Shashank Priya and Daniel J. Inman (Eds.), (*Springer, 2009*).

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-SBC5275
Course Name: Physics-Informed Machine Learning

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics-Informed Machine Learning SBC	2	1	0	1	Linear algebra, differential equations, and introductory Python programming.

Duration: (15L+30P) 45 Hours

Course Objectives

Introduce machine learning methods integrated with physical laws Solve differential equations using neural networks, and apply PIML to real physical systems

UNIT I: (15 Hours)

Foundations of Scientific ML and Neural Networks: Introduction to scientific machine learning: data-driven vs physics-based models, Review of Partial Differential Equations (heat, wave, diffusion equations), Review of graph theory in some physics problems, Basics of neural networks: architecture, activation functions, loss functions, Gradient descent and optimization, Automatic differentiation: advantage over other methods and its role in physics problems

Physics-Informed Neural Networks and Applications: Physics-Informed Neural Networks (PINNs): formulation and loss functions, PINNs for ODEs and PDEs, Boundary and initial condition enforcement, Inverse problems and parameter estimation Applications: heat transfer, fluid dynamics, quantum systems

UNIT II: Laboratory Work (30 Hours)

- Python refresher: NumPy, Matplotlib, Numerical solution of PDEs using the finite difference method.
- Implementation of simple neural networks using PyTorch. Function approximation using neural networks.
- Computing derivatives using automatic differentiation PINN for a simple ODE (harmonic oscillator).
- PINN for 1D heat equation Comparison: numerical methods vs PINNs
- Inverse problem (parameter estimation): some basic physics problems
- Mini project (any one): 2nd order non-linear ODE, Schrödinger equation, Diffusion system, Fluid flow problem

Course Learning Outcomes

Upon successful completion of this course, students will be able to apply machine learning techniques, particularly Physics-Informed Neural Networks (PINNs), to solve ordinary and partial differential equations arising in physical systems. They will develop the skills to integrate physical laws with data-driven models, implement scientific machine learning algorithms using modern computational tools, and address forward and inverse problems in physics and engineering.

Suggested Readings

1. A hands-on introduction to Physics-Informed Neural Networks for solving partial differential equations with benchmark tests taken from astrophysics and plasma physics, by Hubert Baty, <https://hal.science/hal-04491808/file/pinnsf.pdf>
2. Physics-informed Machine Learning, George Em Karniadakis et al., [Nature Reviews Physics](#) volume 3, pages 422–440 (2021)
3. Solving differential equations using physics informed deep learning: a hand-on tutorial with benchmark tests, H Baty and L Baty, <https://arxiv.org/abs/2302.12260>
4. Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations, P. Perdikaris, G. E. Karniadakis, [Journal of Computational Physics](#), 378, 686-707 (2019).

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc

Course Code: PH-SBC5276

Course Name: Integrated Analytical Techniques in Electronics, Experimental and Condensed Matter Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Integrated Analytical Techniques in Electronics, Experimental and Condensed Matter Physics SBC	2	0	0	2	Electronics, Modern Physics and Solid State Physics

Total: 60 Hours

Course Objectives

This course is designed to develop analytical and experimental understanding of Electronics, Experimental Methods, and Condensed Matter Physics through an integrated and practice-oriented approach. The course focuses on instrumentation techniques, signal analysis, and the physical properties of condensed matter systems relevant to modern scientific research.

UNIT I: Electronics and Experimental Methods

(30 Hours)

Semiconductor devices, optoelectronic devices, operational amplifiers, digital electronics, A/D and D/A converters, microprocessors and microcontrollers, error analysis, least squares fitting, transducers, signal conditioning, impedance matching, filtering, noise reduction, lock-in detection and modulation techniques.

UNIT II: Condensed Matter Physics

(30 Hours)

Bravais lattices and reciprocal lattice, diffraction and structure factor, phonons and lattice dynamics, free electron theory, electrical and thermal conductivity, Hall effect, band theory of solids, semiconductors, superconductivity, Josephson junctions, defects, dislocations and liquid crystals.

Course Learning Outcomes

Students will be able to analyze electronic circuits, instrumentation techniques, and experimental data using modern analytical approaches. They will also develop understanding of condensed matter systems, crystal structures, electronic properties of solids, and superconducting phenomena relevant to advanced studies and interdisciplinary research.

Suggested Readings

1. Electronic Principles, Albert Malvino and David Bates, McGraw-Hill Education.
2. Electronic Devices and Circuits, J. Millman and C. C. Halkias and S. Jit (4 th Ed., McGraw-Hill, 2015)
3. Integrated Electronics, J. Millman, C. C. Halkias and C. D. Parikh (2 nd Ed., McGraw-Hill, 2011)
4. Digital Signal Processing, J. G. Proakis and D. G. Manolakis (4th Ed., Pearson, 2007)
5. Measurement Systems: Application and Design, Ernest O. Doebelin, McGraw- Hill.
6. Solid State Physics, Neil W. Ashcroft and N. David Mermin, Brooks/Cole, 1976.
7. Introduction to Solid State Physics, Charles Kittel, Wiley.
8. Solid State Physics, A. J. Dekker (1st Ed., Macmillan India, 2000)

Pedagogical Approach (Non-Conventional Mode)

- Fully practice-oriented theoretical laboratory format
- Live problem-solving sessions instead of lectures
- Previous years' question analysis and pattern recognition
- Timed assignments and mock tests
- Collaborative group work and peer learning
- Error analysis and conceptual debugging sessions

Evaluation Scheme

- Continuous Assessment (Assignments & Tests)
- Laboratory Performance (Analytical Work)
- Final Comprehensive Examination

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc

Course Code: PH-SBC5277

Course Name: Integrated Analytical Techniques in Electromagnetic and Quantum Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Integrated Analytical Techniques in Electromagnetic and Quantum Physics SBC	2	0	0	2	Electromagnetism, Quantum Mechanics and Basic Electronics

Total: 60 Hours

Course Objectives

This course focuses on strengthening conceptual understanding and analytical problem solving skills in Electromagnetic Theory, Electronics, Quantum Mechanics, and Atomic Physics. It aims to integrate theoretical principles with analytical applications relevant to modern physical sciences and advanced research.

UNIT I: Electromagnetic Theory (24 Hours)

Electrostatics and boundary value problems, magnetostatics and electromagnetic induction, Maxwell's equations and electromagnetic waves, polarization, interference and diffraction, waveguides and transmission lines.

UNIT II: Quantum Mechanics & Modern Physics (36 Hours)

Schrödinger equation and eigenvalue problems, angular momentum and spin systems, approximation methods, scattering theory and quantum transitions, identical particles and quantum statistics, atomic structure and spectra, fine and hyperfine interactions, Zeeman and Stark effects, ESR, NMR, molecular spectra, laser physics and radiation processes.

Course Learning Outcomes

Students will be able to analyze electromagnetic and quantum systems using modern theoretical and analytical approaches. They will develop proficiency in solving interdisciplinary problems involving atomic structure, and quantum phenomena with improved conceptual understanding and analytical precision.

Suggested Readings

1. Introduction to Electrodynamics, David J. Griffiths, Pearson Education, 4th Edition, 2013.

2. Classical Electrodynamics, John David Jackson (3rd ed., Wiley, 1998).
3. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, Wiley, 2nd Edition, 2009.
4. Modern Quantum Mechanics, J. J. Sakurai (Addison-Wesley, 1993)
5. Quantum Mechanics, B. H. Bransden and C. J. Joachain (Pearson Education, 2000)
6. Principles of Quantum Mechanics, R. Shankar (3rd Ed., Springer, 2008)

Pedagogical Approach (Non-Conventional Mode)

- Fully practice-oriented theoretical laboratory format
- Live problem-solving sessions instead of lectures
- Previous years' question analysis and pattern recognition
- Timed assignments and mock tests
- Collaborative group work and peer learning
- Error analysis and conceptual debugging sessions

Evaluation Scheme

- Continuous Assessment (Assignments & Tests)
- Laboratory Performance (Analytical Work)
- Final Comprehensive Examination

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5278

Course Name: Integrated Analytical Techniques of Mathematical and Classical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Integrated Analytical Techniques of Mathematical and Classical Physics SBC	2	0	0	2	Undergraduate Mathematics and Mechanics

Total: 60 Hours

Course Objectives

This course is designed to develop analytical and quantitative problem-solving skills in Mathematical Physics and Classical Mechanics through an integrated and practice-oriented approach. The course emphasizes conceptual understanding, mathematical modelling, and theoretical techniques essential for advanced studies, research aptitude, and national-level competitive examinations.

UNIT I: Mathematical Physics

(30 Hours)

Vector algebra and vector calculus, matrices, eigenvalues and eigenvectors, ordinary differential equations and special functions, Fourier series, Fourier and Laplace transforms, complex analysis and residues, probability distributions, Green's functions, tensors and introductory group theory.

UNIT II: Classical Mechanics

(30 Hours)

Newtonian mechanics and dynamical systems, Lagrangian and Hamiltonian formulations, central force problems and scattering, oscillations and normal modes, canonical transformations and Poisson brackets, Hamilton–Jacobi theory, symmetry principles and conservation laws, elements of special relativity.

Course Learning Outcomes

Upon completion of this course, students will be able to apply advanced mathematical methods and classical formulations to solve complex physical problems. They will develop strong analytical reasoning, problem-solving ability, and conceptual clarity required for research and competitive examinations in physical sciences.

Suggested Readings

1. Mathematical Methods for Physicists, George B. Arfken, Hans J. Weber, Frank E. Harris, Elsevier Academic Press, 7th Edition, 2013.

2. Mathematical Physics, V. Balakrishnan (Ane Books, 2018)
3. Advanced Engineering Mathematics, E. Kreyzig (Pearson, 2002)
4. Elements of Group Theory for Physicists, A.W. Joshi (John Wiley, 1997).
5. Mathematical Physics, H.K. Dass and Rama Verma, S. Chand Publishing.
6. Classical Mechanics, Herbert Goldstein, Charles Poole, John Safko, Pearson, 3rd Edition, 2001.
7. Mechanics, L. D. Landau and E. M. Lifshitz (3 rd Ed., Pergamon, 1976).
8. Classical Mechanics, N. C. Rana and P. S. Jaog (McGraw-Hill, 1991).

Pedagogical Approach (Non-Conventional Mode)

- Fully practice-oriented theoretical laboratory format
- Live problem-solving sessions instead of lectures
- Previous years' question analysis and pattern recognition
- Timed assignments and mock tests
- Collaborative group work and peer learning
- Error analysis and conceptual debugging sessions

Evaluation Scheme

- Continuous Assessment (Assignments & Tests)
- Laboratory Performance (Analytical Work)
- Final Comprehensive Examination

MASTER of SCIENCE in PHYSICS
Semester IV of 2 year MSc/ Semester II of 1 year MSc
Course Code: PH-SBC5279

Course Name: Integrated Analytical Techniques in Statistical and Nuclear Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Integrated Analytical Techniques in Statistical and Nuclear Physics SBC	2	0	0	2	Thermodynamics, Modern Physics and Nuclear Physics

Total: 60 Hours

Course Objectives

This course aims to provide integrated analytical understanding of Statistical Physics and Nuclear Physics through application-oriented learning and problem-solving techniques. The course emphasizes conceptual clarity, quantitative analysis, and interpretation of microscopic and macroscopic physical phenomena relevant to advanced studies and research.

UNIT I: Thermodynamics and Statistical Physics (30 Hours)

Laws of thermodynamics, thermodynamic potentials, Maxwell relations, phase equilibria, ensembles and partition functions, classical and quantum statistics, Bose–Einstein and Fermi–Dirac distributions, blackbody radiation, phase transitions, Ising model, diffusion equation and non-equilibrium processes.

UNIT II: Nuclear and Particle Physics (30 Hours)

Basic nuclear properties, binding energy, semi-empirical mass formula, nuclear forces, shell model, alpha, beta and gamma decay, nuclear reactions, fission and fusion, elementary particles and their quantum numbers, quark model, conservation laws, symmetry principles and relativistic kinematics.

Course Learning Outcomes

Students will be able to apply statistical and thermodynamic principles to many-body systems and equilibrium phenomena. They will also gain analytical understanding of nuclear structure, nuclear reactions, and elementary particle physics relevant to advanced studies, interdisciplinary research, and competitive examinations.

Suggested Readings

1. Statistical Mechanics, R.K. Pathria and Paul D. Beale, Elsevier, 3rd Edition, 2011.
2. Thermal Physics, Charles Kittel and Herbert Kroemer, W.H. Freeman.
3. Nuclear Physics: Principles and Applications, John Lilley, Wiley, 1st Edition, 2001.

4. Introducing Nuclear Physics, K. S. Krane (Wiley India, 2008)
5. Nuclear Physics in A Nutshell, C. A. Bertulani (1st Ed., Princeton University Press, 2007)
6. Concept of Nuclear Physics, B. L. Cohen (McGraw – Hill, 2003)
7. Introduction to Elementary Particles, D. Griffiths (Academic Press, 2nd Ed. 2008)

Pedagogical Approach (Non-Conventional Mode)

- Fully practice-oriented theoretical laboratory format
- Live problem-solving sessions instead of lectures
- Previous years' question analysis and pattern recognition
- Timed assignments and mock tests
- Collaborative group work and peer learning
- Error analysis and conceptual debugging sessions

Evaluation Scheme

- Continuous Assessment (Assignments & Tests)
- Laboratory Performance (Analytical Work)
- Final Comprehensive Examination

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5280

Course Name: Radiation Safety

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Radiation Safety SBC	2	1	0	1	Bachelor's degree in a branch of science

Duration: 45 hours (15T+30P)

Course Objectives

The primary objective of this course is to provide students with a comprehensive understanding of radiation fundamentals, interaction mechanisms, detection principles, dosimetric techniques, and regulatory frameworks associated with radiation safety and protection. Through theoretical instruction and practical demonstrations, students will gain both conceptual and operational knowledge required for safe handling, measurement, and monitoring of ionizing radiation, along with a sound understanding of national guidelines and protocols for radiation protection and waste management.

Contents

Unit-I:

(15 Hours)

Basics of Radiation: Origin of radiation, binding energy and Q-value, stable and unstable isotopes, radioactive decay (alpha, beta, neutron, and electromagnetic transitions), mean life and half life, Basic idea of different units of activity, radiation quantities; exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, quality factor, radiation and tissue weighting factors, committed equivalent dose, committed effective, radiation dose to individuals from natural radioactivity in the environment and man-made sources

Devices for radiation measurement and survey: Radiation interaction with matter, kinematics of nuclear reactions, slowing down and moderation of neutrons, Interaction of ionizing and non-ionising radiation at the cellular level. introduction to types of radiation detectors; semiconductor, scintillator and gas detectors(Geiger-Muller counters, ionisation chamber and proportional counters). principles of radiation counting statistics, dead time, and calibration standards. types of Radiation Dosimeters: thermoluminescence, radiographic films, calorimetry, semiconductor diodes; Relation between detection and dosimetry.

Regulatory Framework: classification of radioactive sources (A/D classification), the system of radiological protection, justification of practice, optimization of protection, and individual

limits, categories of exposures-occupational, public, and medical exposures, evaluation of external Radiation hazard-effect of distance, time, and shielding, shielding calculation; internal radiation hazards. Personnel and area monitoring, radiation accidents and disaster monitoring, Radioactive waste & classification of Radioactive waste, transport of radioactive sources/waste, responsibilities of licensee regulatory bodies AERB, and the government.

Unit-II:

(30 Hours)

Suggested Exercises / Practical Demonstrations

- Demonstration handling of radiation monitor and survey instruments.
- Demonstration of Distance, Time, and shielding concept of the ALARA principle.
- Demonstration of the Search and Secure procedure for handling radioactive sources
- Measurement of the activity of an unknown radioactive source.
- Radiation Protection Survey of a Radioisotope Laboratory
- Contamination Measurement and Decontamination Procedures
- Calibrate radiation monitors using standard radioactive sources.
- Classification of Radiation facility using AERB guidelines.
- Packing classification and Transport Index (TI) for radioactive isotope/waste transport.

***Note:** a minimum 6 above exercises/Practical Demonstration will be assigned to each student and will be evaluated in continuous assessment mode.*

Course Learning Outcomes

Upon successful completion of this course, students will developed sound understanding of the principles underlying the operation of various radiation detectors, the calculation of radiation doses and permissible exposure levels for different categories of users, the effects of radiation, the use of instrumentation in practical scenarios, proper management of radioactive materials, and strict adherence to safety protocols.

Suggested Readings

12. Nuclear and Particle Physics, W. E. Burcham and M. Jobes (Pearson Education, 1995)
13. Radiation detection and measurement, G. F. Knoll (4th Ed., Wiley, 2010)
14. Thermoluminescence Dosimetry, Mcknlly, A. F., Bristol, Adam Hilger (Medical Physics Hand book 5)
15. Fundamental Physics of Radiology, W. J. Meredith and J. B. Massey (John Wright and Sons, 1989)
16. An Introduction to Radiation Protection, A. Martin and S. A. Harbisor (John Willey & Sons, 1981)
17. Medical Radiation Physics, W. R. Hendee (Medical Publishers Inc., 1981)
18. Nuclear Physics : Principles and applications, John Lilley (Wiley, 2001)

19. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (2nd Ed., Elsevier, 2014)
20. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (2nd Ed., Springer, 2013)
21. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities.
22. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources.

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5181

Course Name: Order of Magnitude Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Order of Magnitude Physics SBC	2	1	0	1	Bachelor's degree in a branch of Science

Duration: 45 hours (15L+30P)

Course Objectives

Often before doing a detailed theoretical calculation or prior to setting up an experiment to measure an effect, One needs to have a rough idea as to whether or not our set up or the calculation is likely to give a meaningful result and whether spending efforts time and funds are worth it. It is in this context that this course is significant. The objective of this course is to train students to make estimates without having to do a detailed calculation or experiment to get a rough idea of how the results could look.

Contents

Unit-I:

(25 Hours)

- **Estimation of Physical quantities using Dimensional Analysis.**

Dimensional analysis in Mechanics: Damping in a pendulum, Free Gravitational collapse of a dust sphere, Oscillation time period of a star, Time taken for photon to diffuse out of sun, Dimensional analysis in Fluid Mechanics: Reynolds', Froude and Strouhal numbers in Fluids, Terminal velocity.

- **Scaling analysis in Classical Physics**

Orbital time period vs Orbital size of planets, Dynamics in a power law potential, Estimating the acceleration due to gravity on the surface of the moon, How high can an animal jump? Orbital time of planets, Scale height of the Atmosphere.

Unit-II:

(20 Hours)

- **Application to different areas in Physics.**

Electrodynamics, Quantum Physics, Waves, Materials.

- **Applications to Integrals and differential equations**

Estimating integrals, steepest descent approximation. Approximate solutions to differential equations.

Course Learning Outcomes

Students will come away from the course with an appreciation of the characteristic scales associated to a physical system, and how to use simple approximate models to estimate a variety of quantities of physical interest. They will also learn approximation techniques for integrals and differential equations.

Suggested Readings

16. Peter Goldreich, Sanjoy Mahajan and Sterl Phinney - Order of Magnitude Physics.
17. Sanjoy Mahajan - Estimating gas mileage: An example of order-of-magnitude physics (arXiv:physics/0512209).
18. Steven Doty and Sandra Doty, Dielectric breakdown of air as order of magnitude physics (Physics teacher Volume 36, Pages 6-9, 1998).

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5182

Course Name: Electronic Circuit and Simulation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electronic Circuit and Simulation SBC	2	0	0	2	Bachelor's degree in a branch of Science

Duration: 60 Hrs (4P/Week)

Course Objectives

To provide hands-on training in the design, simulation, and analysis of electronic circuits using PSpice and in graphical programming, signal analysis, and virtual instrumentation using LabVIEW. The course aims to develop practical skills in circuit modelling, waveform analysis, signal processing, data acquisition, and computer-based measurement relevant to experimental physics.

Contents

Unit-I: Electronic Circuit Design and Simulation Using PSpice (30Hours)

Introduction to the PSpice environment: schematic design, component selection, circuit construction, simulation profiles, and waveform analysis. Simulation of RC and RLC circuits, transient and frequency response, resonance, and Bode plots. Simulation of diode circuits, rectifiers, clippers, clampers, and voltage regulators. Design and analysis of transistor amplifiers and operational amplifier circuits. Simulation of basic combinational and sequential digital circuits.

Suggested Laboratory Exercises: Simulation and analysis of RC/RLC circuits; diode rectifier and wave-shaping circuits; Zener voltage regulator; transistor amplifier and frequency response; op-amp-based amplifier, integrator, differentiator, and active filter circuits; and selected digital logic circuits.

Unit-II: Graphical Programming and Virtual Instrumentation Using LabVIEW

(30 Hours)

Introduction to the LabVIEW environment and data-flow programming. Development of Virtual Instruments (VIs) using controls, indicators, arrays, graphs, charts, loops, Case Structures, and shift registers. Waveform generation and visualization; measurement of signal amplitude, frequency, and phase. Introduction to data acquisition, sampling, signal

conditioning, and computer-based measurements. Basic signal-processing techniques including noise reduction, averaging, filtering, and FFT-based spectral analysis.

Suggested Laboratory Exercises: Development of basic Virtual Instruments; waveform generation and visualization; virtual digital voltmeter and signal-monitoring applications; measurement of signal parameters; noise generation and signal averaging; digital filtering; FFT-based frequency analysis; and a mini-project related to virtual instrumentation or automated measurement.

Course Learning Outcomes

After successful completion of the course, students will be able to: Design and simulate analogue and digital electronic circuits using circuit-simulation software. Analyse transient and frequency responses and interpret simulation results. Develop Virtual Instruments using LabVIEW for waveform generation, measurement, and signal analysis. Apply basic concepts of data acquisition, signal conditioning, filtering, and spectral analysis. Design and implement simulation or virtual-instrumentation solutions relevant to experimental physics and scientific measurements.

Suggested Readings

19. M. H. Rashid, Introduction to PSpice Using OrCAD for Circuits and Electronics, Pearson.
20. P. W. Tuinenga, SPICE: A Guide to Circuit Simulation and Analysis Using PSpice, Prentice Hall.
21. R. H. Bishop, Learning with LabVIEW, Pearson.
22. J. Travis and J. Kring, LabVIEW for Everyone: Graphical Programming Made Easy and Fun, Prentice Hall.
23. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, Pearson.
24. S. Franco, Design with Operational Amplifiers and Analog Integrated Circuits, McGraw Hill.

MASTER of SCIENCE in PHYSICS
Semester III/IV
Course Code: PH-SBC5183
Course Name: Thin Film Fabrication

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Thin Film Fabrication SBC	2	0	0	2	

Duration: 60 Hrs (4P/Week)

Course Objectives

Thin film fabrication course intends to enrich the students with the firsthand information on the fundamental thermodynamic aspects of vacuum technology and thin film nucleation and growth regimes. This course explains in detail the experimental vacuum tools such as pumps and gauges along with the substrate preparation protocols necessary for thin film fabrication.

Contents

LIST OF EXPERIMENTS

Unit-I: Vacuum science and substrate preparation

6. pumps (rotary, diffusion, cryo and turbomolecular)
7. Gauges (pirani, thermocouple and hot cathode ionization)
8. Substrate cleaning (RCA, ultrasonication, UV, plasma etching)
9. Thin film nucleation and growth kinetics
10. Post annealing protocols

Unit-II: Thin film fabrication and thickness measurement

- Drop-cast films
- Spin-coated films
- Thermal evaporated films
- Sputtered films
- Thickness profiler

***Note:** Each student should choose any two topics in each unit and will be evaluated in continuous assessment mode.*

Course Learning Outcomes

Upon successful completion of this course, students will be able to understand and appreciate the effectiveness of different vacuum pumps and gauges and the different thin film fabrication protocols. The students would be able to differentiate structural defects and growth pathways in thin films based on their substrate preparation.

Suggested Readings

25. Ohring, M. (2001). *Materials Science of Thin Films* (2nd ed.). Academic Press.
26. Seshan, K., & Schepis, D. (Eds.). (2018). *Handbook of Thin Film Deposition* (4th ed.). William Andrew.
27. Smith, D. L. (1995). *Thin-Film Deposition: Principles and Practice*. McGraw-Hill.
28. George, S. M. (2010). Atomic layer deposition: An overview. *Chemical Reviews*, 110(1), 111-131.
29. Leng, Y. (2013). *Materials Characterization: Introduction to Microscopic and Spectroscopic Methods* (2nd ed.). Wiley-VCH.
30. Mahan, J. E. (2000). *Physical Vapor Deposition of Thin Films*. Wiley-Interscience.

MASTER of SCIENCE in PHYSICS

Semester III/IV

Course Code: PH-SBC5184

Course Name: Material synthesis and characterization

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Material synthesis and characterization SBC	2	0	0	2	

Duration: 60 Hrs (4P/Week)

Course Objectives

Materials synthesis and characterization is the fundamental and core topic for any experimental condensed matter physics research. This course provides the complete background knowledge on the basic aspects of any materials synthesis along with their initial characterization techniques. Students will be trained in different materials synthesis protocols in detail and also undergo rigorous training in multiple characterization tools.

Contents

LIST OF EXPERIMENTS

Unit-I: Materials Synthesis

5. Preparation of nano-particles using sol-gel method and Hydrothermal methods etc.
6. Material purification: Rotatory evaporation, Centrifugation, etc.
7. Ball milling and mechanochemical methods
8. Colloidal synthesis and functionalization

Unit-II: Materials Characterization

5. XRD and its data Analysis
6. UV-Spectroscopy
7. Differential Scanning Calorimetry (DSC) / Thermogravimetric Analysis (TGA)
8. Atomic force microscopy / scanning electron microscopy

Note: Each student should choose any two topics in each unit and will be evaluated in continuous assessment mode.

Course Learning Outcomes

This course will help students understand the finer details of the materials synthesis procedures as well as their basic characterization techniques and allows them to correlate the structure-property functional relationships suitable for enhancing their applications.

Suggested Readings

5. Cao, G., & Wang, Y. (2011). Nanostructures and nanomaterials: Synthesis, properties, and applications (2nd ed.). World Scientific Publishing.
6. Edelstein, A. S., & Cammarata, R. C. (Eds.). (1996). Nanomaterials: Synthesis, properties and applications. CRC Press.
7. Leng, Y. (2013). Materials characterization: Introduction to microscopic and spectroscopic methods (2nd ed.). Wiley-VCH.
8. Schultz, M. J., Ajayan, P. M., & Functional Nanomaterials Group. (2021). Nanomaterials: Biomedical, environmental, and engineering applications. Wiley.

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5185
Course Name: Introductory Plasma Physics Lab

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Introductory Plasma Physics Lab SBC	2	0	0	2	Basic electronics, introductory atomic physics, Fundamentals of electromagnetic theory, Electric circuits and analysis, Basic computational, Fundamentals of solid-state physics

Total: 60 Hours (4 Hours/Week)

Course Objectives

Plasma physics forms the basis of many technologies, such as ion sources, magnetron sputtering, material etching, ion thrusters, nuclear fusion, nano-technology, wastewater treatment, nitrogen fertiliser, etc., that have revolutionised the area of physics research. The plasma physics laboratory provides a great platform for master's students to learn about vacuum technologies, ionisation processes of inert or molecular gases, the collective response of a charged medium, nonlinear dynamics of plasma systems, plasma-matter interactions, waves and instabilities in a dust-grain medium, and image analysis techniques. Through this introductory lab course, students will gain exposure to a young, multidisciplinary branch of physics (plasma physics).

UNIT I:

(45 Hours)

7. Understanding the electric breakdown of inert/molecular gases through the gas breakdown law.
8. To explore the discharge characteristics by measuring the plasma current and resistivity at different parametric regimes.
9. To understand the nonlinear dynamics of DC glow discharge using time series data analysis techniques (FFT, Phase space plots, Recurrence plots (RP), etc.)
10. Understanding the charging and force balance on the solid particles in the plasma background
11. To understand the non-thermal plasma (DBD plasma) and use the concept in developing a plasma Jet, a coaxial DBD reactor, etc.

12. Understanding fundamentals of DBD plasma through emission spectroscopic techniques (types of reactive gaseous species, plasma density, electron temperature, etc.)

UNIT II:

(15 Hours)

4. Exploring the dust-acoustic waves through image analysis tools (MATLAB, ImageJ Software)
5. Understanding the dust particle motion and their velocity distribution through particle tracking tools (PIV, PTV, etc.)
6. Exploring dusty plasma crystal formation and melting in DC discharge through various data analysis techniques (Crystal types through Voronoi diagram, pair correlation function, etc.)

Note: *Minimum two experiments from Unit I and one experiment from Unit II are compulsory to earn the 2 credits.*

Course Learning Outcomes

After completing the plasma physics laboratory course, students will learn how to create plasma (the fourth state of matter) and dusty plasma in the ground-based laboratory. Students will learn about the tools and techniques required for time-series and image analysis across different scientific fields. They gain expertise in handling the vacuum pump, measuring devices, high-voltage power sources, high-frame-rate camera, spectrometer, etc., through this lab course. They will also learn about the applications of low-pressure and low-temperature plasmas across sectors such as water purification, medicine, space, materials science, and agriculture

Suggested Readings

5. Introduction to Plasma Physics by F. F. Chen (Plenum Press, 1984)
6. Principles of Plasma Discharges and Materials Processing by M.A. Liberman and A J Lichtenberg (John Wiley & Sons, Inc., 2005)
7. Introduction to Dusty Plasma Physics by P. K. Shukla and A. A. Mamun, (Institute of Physics, Bristol, 2002)
8. A Review of Recent Advances of Dielectric Barrier Discharge Plasma in Catalysis by Ju Li et al. (<https://doi.org/10.3390/nano9101428>)

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-SBC5186
Course Name: Lasers and their applications

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Lasers and their applications SBC	2	0	0	2	

Total: 60 Hours (4 Hours/Week)

Course Objectives

Laser technology has become indispensable for a wide range of applications including communications, semiconductor manufacturing, defense, medicine, and industry. This course will provide knowledge of the basic concepts and applications of laser in all walks of life. Students will understand different laser types, beam characteristics, safety practices, and their applications in spectroscopy, imaging, sensing, and advanced photonic technologies.

Contents

LIST OF EXPERIMENTS

UNIT I: (45 Hours)

5. Laser beam characteristics
6. Laser interferometry
7. Birefringence and Faraday effect
8. Optical trapping with lasers

UNIT II: (15 Hours)

5. Raman Effect
6. Optical tweezers
7. Laser Holography and 3D imaging
8. Optical communication

Note: *Each student must choose any one topic from each unit and demonstrate experiments / simulations based on the same which will be evaluated in continuous assessment mode.*

Course Learning Outcomes

The course will equip students with hands-on experience of laser-based metrology techniques and their applications in diverse sectors such as semiconductors, pharmaceuticals, chemicals, and food-processing industries.

Suggested Readings

4. Lasers: Fundamental and Applications, Graduate Text in Physics, K. Thyagarajan, Ajoy ghatak (2nd edition, Springer, 2002)
5. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000)
6. Fundamentals of molecular spectroscopy, C. N. Banwell ((McGraw Hill)

Details of Content of General Elective (GE) courses (to be offered to students of other departments as well in the form of Open electives)

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc
Course Code: PH-GEC5201
Course Name: Radiation Safety

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Radiation Safety GEC	4	3	1	0	Bachelor's degree in any discipline

Duration: 60 Hours(45L+15T)

Course Objectives

This course is aimed to introduce the student to practical aspects of nuclear radiation with an understanding of basic quantities and doses, the role of fundamental processes involved in the interaction of X- rays, gamma-rays, charged particles and neutrons with matter, the principles underlying the operation of nuclear detection/dosimetry instruments, areas of applications, awareness of the need and methods for safety protocols for radioactive material and environmental safety.

Contents

Unit I: (11 Hours)

Basics of Radiation: Origin of radiation, binding energy and Q-value, stable and unstable isotopes, radioactive decay (alpha, beta, neutron and electromagnetic transitions), mean life and half life, nuclear reactions, concept of cross sections and attenuation coefficients, Neutron flux, kinematics of nuclear reactions. Slowing down and moderation. Basic idea of different units of activity, radiation quantities: exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, quality factor, radiation and tissue weighting factors, KERMA, Annual Limit of Intake (ALI) and Derived Air Concentration (DAC). .

Unit II: (11 Hours)

Devices for radiation measurement and survey: Radiation interaction with matter. Introduction to types of radiation detectors: semiconductor, scintillator and gas detectors (Geiger-Muller counters, ionisation chamber and proportional counters) Principles of radiation counting statistics, dead time and calibration standards. Types of Radiation Dosimeters: thermoluminescence, radiographic films, calorimetry, semiconductor diodes; Relation between detection and dosimetry; exposure measurements with free air chamber. Interaction of ionising and non-ionising radiation at the cellular level. Application of Nuclear techniques: Medical science (e.g., MRI, PET, Projection Imaging Gamma Camera, Radiation therapy), Art &

Archaeology, Art, Crime detection, Oil & Mining, Water assessment, Industrial usage: Tracing, Gauging, Material modification, Sterilization, Food preservation

Unit III: (12 Hours)

Radiation Protection Standards: Classification of radioactive sources, Radiation dose to individuals from natural radioactivity in the environment and man-made sources, Basic concept of radiation protection standards: historical background, International Commission of Radiological Protection and its recommendations, the system of radiological protection, justification of practice, optimization of protection and individual limits, radiation and tissue weighting factors, committed equivalent dose, committed effective dose, concept of collective dose, potential exposures, dose and dose constraints, system of protection for invention-categories of exposures-Occupational, Public and Medical exposures, Permissible levels for neutron flux, factors governing internal exposure-Radionuclide concentration in air and water –ALI, DAC and contamination levels, effects of inhaled radionuclides on biological systems, impact on humans and society.

Unit IV: (11 Hours)

Regulations, Monitoring, & Radioactive Waste Management: Evaluation of external radiation hazard-effect of distance, time and shielding, shielding calculation, personnel and area monitoring-internal radiation hazards, radio toxicity of different radio nuclides and the classification of laboratories, control of contamination-bioassay and air monitoring, chemical protection, Radiation accidents and disaster monitoring, Sources & classification of Radioactive waste, permissible limits for disposal of waste, general method of disposal, storage management of radioactive waste in facilities. Responsibilities of operator, regulatory bodies, and government .

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.

- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

A knowledge of the principle of operation of various radiation detectors, understanding of radiation dose calculation and permissible doses for different levels of users, and radiation effects, an understanding of instrumentation in practical situations, awareness about the management of radioactive material, and adherence to safety protocols.

Suggested Reading:

1. Nuclear and Particle Physics, W. E. Burcham and M. Jobes (Pearson Education, 1995)
2. Radiation detection and measurement, G. F. Knoll (4th Ed., Wiley, 2010)
3. Thermoluminescence Dosimetry, McKinlay, A. F., Bristol, Adam Hilger (Medical Physics Hand book 5)
4. Fundamental Physics of Radiology, W. J. Meredith and J. B. Massey (John Wright and Sons, 1989)
5. An Introduction to Radiation Protection, A. Martin and S. A. Harbison (John Willey & Sons, 1981)
6. Medical Radiation Physics, W. R. Hendee (Medical Publishers Inc., 1981)
7. Nuclear Physics : Principles and applications, John Lilley (Wiley, 2001)
8. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (2nd Ed., Elsevier, 2014)
9. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (2nd Ed., Springer, 2013)
10. IAEA Publications : (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interim) (2010); (b) Safety Standards Series No. RS-G-1.5 (2002), RS-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007) (latest version).
11. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities. 12. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources.

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc

Course Code: PH-GEC5202

Course Name: Complex System & Networks

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Complex System & Networks GEC	4	3	1	0	Bachelor's degree in a branch of Science, and Mathematics as a subject in Classes XI, XII

Duration: 60 Hours(45L+15T)

Course Objectives

This course deals with the interdisciplinary subject of complex systems, that include, among others, living organisms, ecosystems and human societies. The course emphasizes a unifying theme – complex networks – that cuts across all these systems. It develops the mathematical tools of graph theory and dynamical systems to provide insight into the structure, dynamics and evolution of a variety of complex systems in the physical sciences, life sciences, social sciences and engineering.

Contents

Unit I: (7 Hours)

Overview: Examples of complex systems: organisms, brains, ecosystems, societies, the internet. Components of these systems: molecules, cells, species, agents, computers. Collective phenomena exhibited by these systems. Contrast with other collective phenomena in physics such as phase transitions. Adaptive nature of these systems.

Unit II: (10 Hours)

Graph theory and the network structure of complex systems: Complex networks of interaction as a unifying theme underlying complex systems. Undirected, directed and bipartite graphs, hypergraphs. Adjacency matrix of a graph. Graph theoretic measures of network structure. Random graph ensembles, small-world, scale-free, hierarchical and autocatalytic graphs. Network motifs. Nature of graphs that arise in various complex systems

Unit III: (14 Hours)

Dynamics of complex systems: Dynamics on a fixed network. Examples of continuous and discrete dynamical systems to be taken from various complex systems such as chemical networks, metabolic networks, ecological food webs, genetic regulatory circuits, neural networks, social and economic networks, epidemiological networks. Fixed point and limit cycle attractors of these systems. The influence of network structure on dynamics.

Unit IV:

(14 Hours)

Evolution of complex systems: How networks change over time. Preferential attachment model of scale free networks. The origin of life puzzle. Model of autocatalytic network evolution and self-organization of a complex network. Community assembly models in ecology. Evolution of biological and social networks. Crashes and recoveries in complex systems. Robustness and fragility of complex systems.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome:

Being able to appreciate that complex networks of interacting components underlie many complex systems studied under different disciplines. Learning the similarities and differences between complex systems from the perspective of network structure. Learning certain mathematical methods of graph theory and dynamical systems. Being able to apply these methods to characterize the structure of various complex systems and to model certain phenomena exhibited by them.

Suggested Reading:

1. Networks: An Introduction, M. E. J. Newman (Oxford University Press, 2010).
2. Origins of Order, Stuart Kauffman (Oxford University Press, 1993).
3. Handbook of Graphs and Networks: From the Genome to the Internet, S. Bornholdt and H.-G. Schuster (Wiley-VCH, 2003).
4. Dynamics of Complex Systems, Yaneer Bar-Yam (Perseus Books, 1997)

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc

Course Code: PH-GEC5203

Course Name: Introductory Astronomy

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Introductory Astronomy GEC	4	3	1	0	Bachelor's degree in any discipline

Duration: 60 Hours(45L+15T)

Course Objectives

Since this course is an open elective, with students from diverse backgrounds opting for it, the primary objective is to impart a basic knowledge about the oldest branch of physical science in a conceptual mode, relying less on mathematics and more on physical understanding. Since exciting developments have been taking place in astronomy of 20th and 21st centuries, with India playing crucial roles, the aim is to enable students to have a flavour of both historical and modern aspects so that they acquire a perspective of their place in the universe.

Contents

Unit I (7 Hours)

Antiquity of astronomy: Planets and stars in Egyptian and Babylonian civilizations; Possible reference to stars and planets in Indus Valley Civilization; stars and constellations in Rig Veda as well as in other vedic literature; reference to Halley's comet in a Babylonian clay tablet; Far Eastern astronomy - comets and Crab supernova; Reference to cosmic objects in mythologies, Classic literature and science fictions.

Early astronomical measurements: Measurement of Earth's radius by Eratosthenes; Lunar and solar motion studies by Hipparchus - equinoxes and solstices, lunar and solar eclipses; Aryabhatta I and his seminal contributions to astronomy - relative motion, spinning Earth, eclipses, etc.; Varahamihira, Brahmagupta and other siddhantic astronomers of India; symbiotic relation between mathematics and astronomy; evidence of the precession of equinoxes from vedic literature; Jai Singh and his Jantar Mantar.

Unit II (12 Hours)

Solar system: geocentric model - Ptolemy, Tycho Brahe and Samanta Chandrasekhar; retrograde motion of Mars and theory of epicycles; Copernicus and the heliocentric model; Kepler's laws of planetary motion - a formulation based on a set of mathematical laws for the first time in physical sciences; Galileo's pioneering work - length and time measurements,

telescope, lunar craters, moons of Jupiter, rings of Saturn, corroboration of Copernican model, Pisa tower and equivalence principle.

Laws of gravitation: motion of the Moon around the Earth, falling bodies, Newton's genius; Halley's comet and laws of gravity; importance of gravity as a force in astronomy; Physics of the Sun; Thermonuclear reactions; discovery of Neptune and Pluto; asteroid belt, meteors and comets; Tidal forces and the oceanic tides; precession of equinox and change of seasons; dating Rig veda using the precession of equinox; Distances - parallax method; standard candles - Cepheid variables and Henrietta Leavitt, Type Ia Supernovae; Spectroscopy - atomic spectra, emission and absorption lines, their widths and Doppler shifts.

Unit III

(18 Hours)

Stellar population and Hertzsprung-Russell diagram; Meghnad Saha, ionized elements, Saha equation and birth of astrophysics; Wilson-Bappu effect and stellar distances; Stellar structure and evolution- evolution of low mass stars and high mass stars; white dwarfs - Fowler, Chandrasekhar and Eddington; Chandrasekhar's mass limit; Baade and Zwicky - supernova and neutron stars; supernova explosion; pulsars.

Milky Way and other galaxies: Shapley-Curtis debate; measurement of Doppler shift in emission lines by Humason, Slipher and Hubble; Cepheid variable and distances of galaxies; Classification of galaxies - spirals, ellipticals, irregulars, dwarfs, lenticulars, etc.; Hubble's law and birth of cosmology as a scientific discipline; Big bang and steady state models; Hoyle-Narlikar cosmology; Radio source counts, evolution of radio-sources and setback to steady-state theory; angular resolution, radio interferometry and large baselines; detection of apparent superluminal motion; radio telescopes in India - Govind Swarup and collaborators.

Unit IV

(8 Hours)

The Universe: Penzias, Wilson and the cosmic microwave background; corroboration of thermal history in big bang cosmology as predicted by Gamow and his collaborators; Big bang model, singularity and Raychaudhuri equation; clusters of galaxies; Zwicky and the dark matter; observed large scale structure; Vera Rubin and the evidence of dark matter from galactic rotation curves; Type Ia supernovae and accelerating universe; the puzzle of dark energy; new astronomy - X-ray and gamma ray astronomy, gravitational waves, neutrino astronomy, 30 metre telescope and the square kilometre array; discovery of exoplanets.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.

- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome

A historical perspective of the development of Astronomy. Conceptual understanding of basic principles involved. A flavour of current developments in this field and India's role in them. Appreciation of laws of nature that are discovered on Earth but which explain successfully distant cosmic objects and the universe as a whole .

Suggested Reading

1. The Physical Universe, Frank Shu (University Science Books, 1982)
2. Cosmology: The Science of the Universe, Edward Harrison (Cambridge University Press, 2000)
3. From Black Clouds to Black Holes, J. V. Narlikar (World Scientific, 1985)
4. Archeoastronomy - Introduction to the Science of Stars and Stones, Giulio Magli (Springer, 2016)

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc

Course Code: PH-GEC5204

Course Name: Physics of Biological Systems

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics of Biological Systems GEC	4	3	1	0	Bachelor's degree in a branch of Science, and Biology as a subject in Classes XI, XII

Duration: 60 Hours(45L+15T)

Course Objectives

This open elective course will introduce students to selected biological phenomena from the point of view of physics, emphasizing quantitative regularities. It will enable students from non-biology backgrounds to gain an overview of living systems, and those from biology backgrounds to perform mathematical modelling of certain biological processes.

Contents

Unit I (10 Hours)

Length and time scales in biology: Types, sizes and roles of biomolecules - metabolites, proteins, RNA, and DNA. Ranges of cell sizes and interdivision time scales,. Ranges of organism sizes and lifetimes, Scaling laws in biology, Complexity of living systems, Timeline of life on Earth, Time scales in biological evolution. Experimental techniques.

Unit II (14 Hours)

Cellular dynamics: Dynamical systems, coupled ordinary differential equations, Phenomena and models of intracellular chemical dynamics. Reaction-diffusion systems, Ecological interactions: Predator-prey model. The brain: Dynamics of a single neuron, Neural networks, Learning, Memories as attractors of neural network dynamics.

Unit III (9 Hours)

Information in living systems: Probability, entropy and information, Applications of Information theory in genetics. Brownian motion of colloids.

Unit IV (12 Hours)

Random walk in $d=1,2,3$ and Self-avoidance, classification and conformations of polymers and related Scaling, structures of DNA, simulation methods and related experiments.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.

- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome

Gain knowledge of structures and processes in living systems at multiple length and time scales, including at the level of molecules, cells, multi-cellular organisms and ecosystems. Appreciate that life is a consequence of physical processes at the molecular level. Learn certain mathematical methods of dynamical systems, probability and information theory. Also, to learn a few techniques for numerical simulations of proteins or biopolymers. Be able to apply these methods to model certain biological phenomena

Suggested Reading

1. Physics in Molecular Biology, Kim Sneppen and Giovanni Zocchi (CUP 2005).
2. Biological Physics: Energy, Information, Life, Philip Nelson (W.H. Freeman & Co, NY, 2004).
3. Biophysics: Searching for Principles, William Bialek (Princeton University Press, 2012).
4. Physical Biology of the Cell (2nd Edition), Rob Phillips et al (Garland Science, Taylor & Francis Group, 2013).
5. An Introduction to Systems Biology, Uri Alon (Chapman and Hall/CRC, 2013).
6. Mathematical Biology: I. An Introduction, J.D. Murray (3rd Ed., Springer, 2004).

MASTER of SCIENCE in PHYSICS
Semester III & IV of 2 year MSc/ Semester I & II of 1 year MSc
Course Code: PH-GEC5205
Course Name: Physics Education

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics Education GEC	4	3	1	0	Bachelor's degree in a branch of Science, and Physics as a subject in Classes XI, XII

Duration: 60 Hours(45L+15T)

Course Objectives

This course will develop pedagogic knowledge for teaching-learning of physics informed by global best praxis. It will delineate procedural and content knowledge for meaningful laboratory work; and design of appropriate technology enhanced active learning environments.

Contents

Unit I (5 Hours)

Foundations of Teaching-Learning of Physics: Goals of physics teaching. Beliefs and Epistemological Expectations and how they impact teaching-learning of physics. Theoretical models of student learning. Structure of knowledge. Difference between novice learners and experts. Theories of cognition. Constructivist and social theories of learning. Guided Enquiry and Active Learning. Engendering cognitive change.

Unit II (12 Hours)

Effective Teaching-Learning Strategies: Models of Classroom. Traditional instructor centred environment vs Active engagement student centred environment. Physics Education Research (PER): What works and what does not work. Designing Lecture based effective instruction methods: Concept Tests; Peer Instruction; Interactive Lecture demonstrations; Just in Time Teaching; Interactive Tutorials; Cooperative Problem Solving. Modeling. Problem Solving. Enhancing learning through peer, group and collaborative work. Cognitive Apprenticeship. Research-based curricula: Developing hands-on activities. Developing Interactive worksheets/Tutorials.

Unit III (12 Hours)

Evaluating Conceptual Learning: Formative and Summative Evaluation. Designing examinations. Types of questions: MCQ, Representation-translation questions, ranking tasks, context-based reasoning problems, estimation problems, qualitative questions, essay questions. Domain knowledge content surveys and concept probes (Mechanics, Electricity and Magnetism, Vectors, Quantum Mechanics etc).

Unit IV

(16 Hours)

Learning in the Lab: Students' understanding of the nature of scientific investigation and its influence on lab work. Student's perception of concepts of statistics, errors of observation, reliability and validity of observations; graphical representation of data and impact on performance. Developing Procedural and Conceptual Knowledge (PACK) in the Laboratory. Learning to design open-ended experiments and verify hypotheses. Assessment of performance.

Technology Enhanced Learning Environments: Appropriate use of technology. Developing Demonstration experiments and hands-on activities for conceptual learning. Sensor based Data Acquisition Laboratories. Integrating Simulations, Visualization, Video, Modeling for conceptual learning. Designing Technology Enhanced Active Learning. Future of the classroom.

Tutorial Component: (15 hours)

- The course includes a tutorial segment that is closely integrated with the theoretical content covered in all the four units.
- Tutorial activities will primarily involve structured problem-solving exercises, assigned regularly by the course coordinator(s).
- These problems will require analytical approaches, encouraging students to apply the physical principles discussed in the lectures.
- Problem sets will be designed to reflect the conceptual depth of the course and will challenge students to develop a deeper understanding of the subject.
- Students are expected to attempt and solve these problems independently and present their solutions during the scheduled tutorial sessions.
- Wherever applicable, numerical methods may also be introduced, allowing students to use both analytical and computational techniques for solving physics problems.
- Regular in-class assessments will be conducted to monitor student progress and understanding.
- Assignments provided by the course coordinator(s) will be reviewed periodically to ensure consistent academic engagement.
- Marks for the tutorial component will be awarded in accordance with the university's evaluation guidelines.

Course Learning Outcome

Understanding the theoretical framework of how students learn; familiarity with a range of effective strategies for teaching-learning; evaluating and enhancing student's conceptual understanding of physics and problem solving abilities; developing effective learning in the lab and open-ended investigations; designing technology enhanced active learning environments;. Designing effective assessment and evaluation tools for student learning; developing innovative teaching-learning resources and curricula.

Suggested Reading

1. Teaching Introductory Physics, Arnold Arons (John Wiley and Sons Inc., 1997).
2. Teaching Physics with the Physics Suite, Edward F. Redish (John Wiley and Sons Inc., 2003).
3. Teaching and Learning in the Science Laboratory, Dimitris Psillos and Hans Niedderer (Editors) (Kluwer Academic Publishers, 2002).
4. Understanding Basic Mechanics, Frederick Reif (John Wiley and Sons Inc., 1995).
5. Peer Instruction, Eric Mazur (Prentice Hall, 1997).
6. Physics by Inquiry. Vol. I and II., Lillian C. Mc Dermott (John Wiley and Sons Inc., 1996).
7. Workshop Physics. The Physics Suite. Priscilla, W. Laws (John Wiley and Sons Inc., 2004)
8. Real Time Physics Active Learning Laboratories. The Physics Suite, David R. Sokoloff, Ronald K. Thornton, Priscilla W. Laws (John Wiley and Sons Inc., 2004)
9. Activity Based Tutorials. The Physics Suite, Michael C. Wittmann, Richard N. Steinberg, Edward F. Redish and the University of Maryland Physics Education Research Group (John Wiley and Sons Inc., 2004)
10. Tutorials in Introductory Physics, Lillian C. Mc Dermott, Peter S. Shaffer and the Physics Education Research Group (John Wiley and Sons Inc., 2003)
11. Modelling in Physics and Physics Education, Proceedings of the GIREP Conference 2006. Ed van den Berg, Ton Ellermeijer and Onne Slooten. GIREP 2006.
12. Five Easy Lessons: Strategies for Successful Physics Teaching, Randall D. Knight.