A.C.-24.07.2025
Appendix-09

UNIVERSITY OF DELHI

MASTER OF SCIENCE in PHYSICS

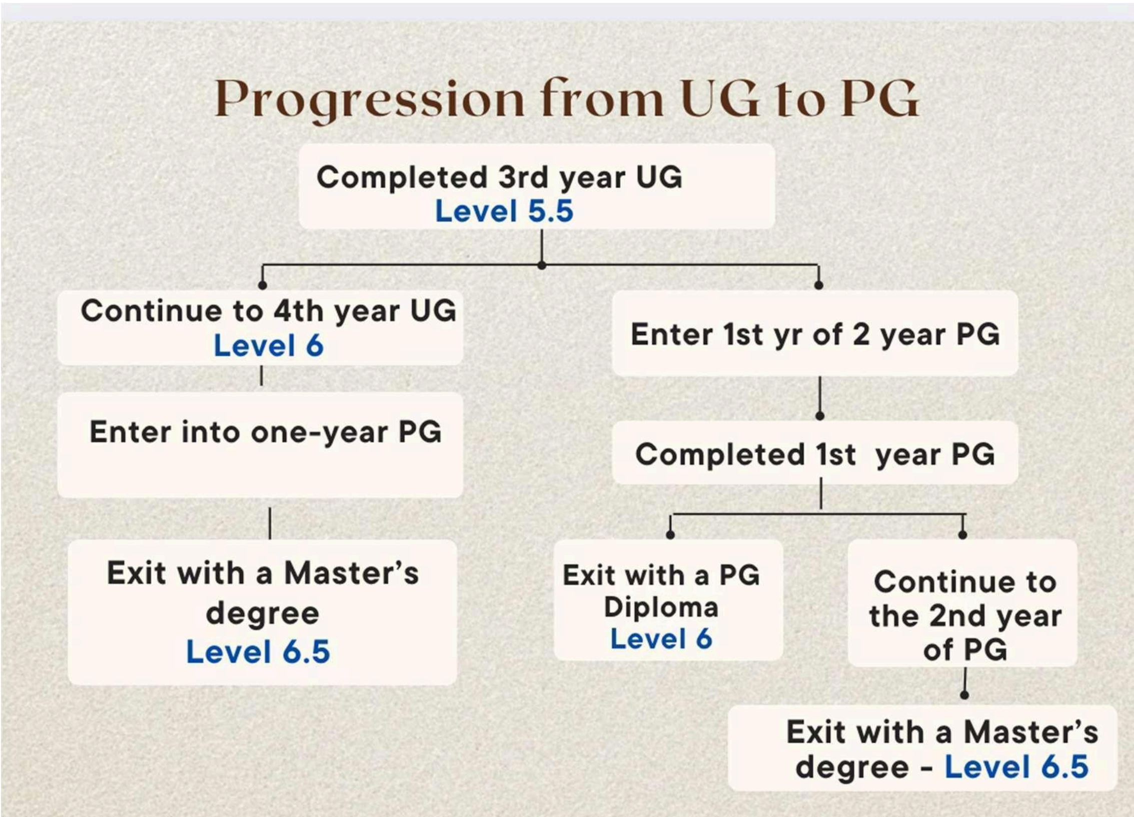
(Two Years Programme (2nd year) and One Year Programme-NEP)

(Coursework with Research)

(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
Completed 3rd year UG
Level 5.5
Continue to 4th year UG
Level 6
Enter 1st yr of 2 year PG
Enter into one-year PG
Completed 1st year PG
Exit with a Master's degree
Level 6.5
Exit with a PG Diploma
Level 6
Continue to the 2nd year of PG
Exit with a Master's degree - Level 6.5

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)
(Coursework with Research)

Course Credit Scheme for M.Sc. Physics

Semester	Core Courses			Elective Course			DIssertation	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 /GEC3 2DSEs or 1DSEs + 1 GEC	4	8	Credit: 6	22
IV	02 DSC9 DSC10	3+1+0	08	DSE7 DSE8 /GEC4 2DSEs or 1DSEs+1GEC	4	8	Credit: 6	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		Credits in each core course			
CORE COURSE:		**Lecture**	**Tutorial**	**Practical**	**Credits**
PH-DSC 5101: **Nuclear and Particle Physics**	18	3	1	0	4
PH-DSC5102 : **Statistical Physics**	21	3	1	0	4
Total credits in Core courses					8
Number of Elective / General Elective courses: 2		Credits in each elective course			
ELECTIVE COURSES: (Select 2 DSE courses or 1 DSE courses and 1 GE)		**Lecture**	**Tutorial**	**Practical**	**Credits**
EXPERIMENTAL COURSES					
Module A-I:					
PH-DSE5111:Physics at the Nanoscale – I (Theory)	23	3	1	0	4
PH-DSE5112:Nanomaterials Lab – I (Lab)	25	0	0	4	4
Module B-I:					
PH-DSE5113: Advanced Electronics - I (Theory)	28	3	1	0	4
PH-DSE5114:Advanced Electronics - I (Lab)	30	0	0	4	4
Module C-I:					
PH-DSE5115:Advanced Nuclear Physics – I (Theory)	34	3	1	0	4
PH-DSE5116:Advanced Nuclear Physics - I (Lab)	37	0	0	4	4

ELECTIVE COURSES:		Lecture	Tutorial	Practical	Credits
Module D-I:					
PH-DSE5117:Fundamentals of Spectroscopy (Theory)	40	3	1	0	4
PH-DSE5118:Lasers and Spectroscopy (Lab)	42	0	0	4	4
Module E-I:					
PH-DSE5119:Advanced Solid State Physics –I (Theory)	44	3	1	0	4
PH-DSE5120:Advanced Solid State Physics – I (Lab)	46	0	0	4	4
THEORY COURSES					
PH-DSE5131:General Theory of Relativity and Cosmology I	48	3	1	0	4
PH-DSE5132: Condensed Matter Physics I	51	3	1	0	4
PH-DSE5133: Plasma Physics I	53	3	1	0	4
PH-DSE5134: Particle Physics I	55	3	1	0	4
PH-DSE5135: Quantum Field Theory I	57	3	1	0	4
PH-DSE5136: Basics of Astronomy and Observational Techniques	59	3	1	0	4
PH-DSE5137: Radio Astronomy and Instrumentation	61	2	0	2	4
PH-DSE5138: Fluid Dynamics	64	3	1	0	4
PH-DSE5139: Nonlinear Dynamics	66	3	1	0	4
PH-DSE5140: Applied Physics	68	3	1	0	4
PH-DSE5141: Quantum Information and Computation	70	3	1	0	4
PH-DSE5142: Computational Material Science	73	3	0	1	4
PH-DSE5143: Quantum Optics	75	3	1	0	4

ELECTIVE COURSES:		Lecture	Tutorial	Practical	Credits
PH-DSE5144: Atmospheric Physics	77	3	1	0	4
PH-DSE5145: X-ray Spectroscopic Techniques	79	3	1	0	4
PH-DSE5146: Complex Systems	81	3	1	0	4
PH-DSE5147: Accelerator Physics	83	3	1	0	4
PH-DSE5148: Research Methodology in Physics	85	3	0	1	4
Total credits in Electives/General Electives					12
*PH-ARM5101: Advanced Research methodology in Physics	88	1	0	1	2
Mandatory for the students who have not studied 4 credit Research Methodology paper in UG programme under NEP					
DISSERTATION					
PH-DIS5101: **Dissertation**	102				6
Total credits in Dissertation Course					6
Total credits in Semester III					22
GENERAL ELECTIVE (GE)	Courses to be offered to other departments				
PH-GEC5101: Radiation Safety	104	3	1	0	4
PH-GEC5102: Complex System & Networks	107	3	1	0	4
PH-GEC5103: Introductory Astronomy	109	3	1	0	4
PH-GEC5104: Physics for Biological Systems	112	3	1	0	4
PH-GEC5105: Physics Education	114	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**	117	3	1	0	4
PH-DSC5202: **Advanced Classical Dynamics, Fields & Matter**	120	3	1	0	4
Total credits in Core courses					8
Number of Elective/General Elective courses: 2		Credits in each elective course			
ELECTIVE COURSES: (Select 2 DSE courses or 1 DSE courses and 1 GE)		**Theory**	**Practical**	**Tutorial**	**Credits**
EXPERIMENTAL COURSES					
Module A-II:					
PH-DSE5211: Physics at the Nanoscale – II (Theory)	123	3	1	0	4
PH-DSE5212: Nanomaterials – II (Lab)	125	0	0	4	4
Module B-II:					
PH-DSE5213: Advanced Electronics - II (Theory)	127	3	1	0	4
PH-DSE5214: Advanced Electronics- II (Lab)	129	0	0	4	4
Module C-II:					
PH-DSE5215:Advanced Nuclear Physics – II (Theory)	131	3	1	0	4
PH-DSE5216: Advanced Nuclear Physics - II (Lab)	134	0	0	4	4
Module D-II:					
PH-DSE5217: Advanced Laser Physics (Theory)	137	3	1	0	4
PH-DSE5218: Advanced Laser Physics (Lab)	139	0	0	4	4

ELECTIVE COURSES:		Theory	Practical	Tutorial	Credits
Module E-II:					
PH-DSE5219: Advanced Solid State Physics–II (Theory)	141	3	1	0	4
PH-DSE5220: Advanced Solid State Physics – II (Lab)	144	0	0	4	4
Special Lab courses:					
PH-DSE5221:Advanced Numerical Techniques	146	0	0	4	4
PH-DSE5222:Advanced Observational Astrophysics Lab	148	0	0	4	4
PH-DSE5223:Machine Learning for Physicists	151	2	0	2	4
THEORY COURSES					
PH-DSE5231: General Theory of Relativity and Cosmology II	153	3	1	0	4
PH-DSE5232: Condensed Matter Physics II	155	3	1	0	4
PH-DSE5233: Plasma Physics II	157	3	1	0	4
PH-DSE5234: Particle Physics II	159	3	1	0	4
PH-DSE5235: Quantum Field Theory II	161	3	1	0	4
PH-DSE5236: Nuclear Astrophysics	163	3	1	0	4
PH-DSE5237: Supersymmetric Quantum Mechanics	165	3	1	0	4
PH-DSE5238: Spintronics Fundamentals and Applications	167	3	1	0	4
PH-DSE5239: Molecular Electronics	169	3	1	0	4
PH-DSE5240: Astrophysics	171	3	1	0	4
PH-DSE5241: Soft Matter Physics	173	3	1	0	4
PH-DSE5242: Advanced Course on Quantum Computing	175	2	0	2	4
PH-DSE5243: String Theory	178	3	1	0	4

ELECTIVE COURSES:		Theory	Practical	Tutorial	Credits
PH-DSE5244: Superconductivity, Superfluidity & Critical Phenomena	180	3	1	0	4
PH-DSE5245: Accelerator Applications	182	3	1	0	4
PH-DSE5246: Metamaterials, Plasmonics and Photonics	184	3	1	0	4
PH-DSE5247: Nuclear Safety & Security	186	3	1	0	4
PH-DSE5248: Advanced Statistical Physics	189	3	1	0	4
PH-DSE5249: Biophysics	191	3	1	0	4
Total credits in Electives/General Elective courses					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.*					
*PH-ARM5201: Techniques of Research writing in Physics	193	1	0	1	2
**Mandatory for the students who have not studied 4 credit Research Methodology paper in UG programme under NEP*					
DISSERTATION					
PH-DIS5201: Dissertation	208				6
Total credits in Dissertation Course					6
Total credits in Semester IV					22
GENERAL ELECTIVE (GE) Courses to be offered to other departments	Courses to be offered to other departments				
PH-GEC5201: Radiation Safety	210	3	1	0	4
PH-GEC5202: Complex System & Networks	213	3	1	0	4
PH-GEC5203: Introductory Astronomy	215	3	1	0	4
PH-GEC5204: Physics for Biological Systems	218	3	1	0	4
PH-GEC5205: Physics Education	220	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**	18	3	1	0	4
PH-DSC5102 : **Statistical Physics**	21	3	1	0	4
Total credits in Core courses					8
Number of Elective/General Elective courses: 2		Credits in each elective course			
ELECTIVE COURSES: (Select 2 DSE courses or 1 DSE courses and 1 GE)		**Lecture**	**Tutorial**	**Practical**	**Credits**
EXPERIMENTAL COURSES					
Module A-I:					
PH-DSE5111:Physics at the Nanoscale – I (Theory)	23	3	1	0	4
PH-DSE5112:Nanomaterials Lab – I (Lab)	25	0	0	4	4
Module B-I:					
PH-DSE5113: Advanced Electronics - I (Theory)	28	3	1	0	4
PH-DSE5114:Advanced Electronics - I (Lab)	30	0	0	4	4
Module C-I:					
PH-DSE5115:Advanced Nuclear Physics – I (Theory)	34	3	1	0	4
PH-DSE5116:Advanced Nuclear Physics - I (Lab)	37	0	0	4	4
Module D-I:					
PH-DSE5117:Fundamentals of Spectroscopy (Theory)	40	3	1	0	4

ELECTIVE COURSES:		Lecture	Tutorial	Practical	Credits
PH-DSE5118:Lasers and Spectroscopy (Lab)	42	0	0	4	4
Module E-I:					
PH-DSE5119:Advanced Solid State Physics –I (Theory)	44	3	1	0	4
PH-DSE5120:Advanced Solid State Physics – I (Lab)	46	0	0	4	4
THEORY COURSES					
PH-DSE5131:General Theory of Relativity and Cosmology I	48	3	1	0	4
PH-DSE5132: Condensed Matter Physics I	51	3	1	0	4
PH-DSE5133: Plasma Physics I	53	3	1	0	4
PH-DSE5134: Particle Physics I	55	3	1	0	4
PH-DSE5135: Quantum Field Theory I	57	3	1	0	4
PH-DSE5136: Basics of Astronomy and Observational Techniques	59	3	1	0	4
PH-DSE5137: Radio Astronomy and Instrumentation	61	2	0	2	4
PH-DSE5138: Fluid Dynamics	64	3	1	0	4
PH-DSE5139: Nonlinear Dynamics	66	3	1	0	4
PH-DSE5140: Applied Physics	68	3	1	0	4
PH-DSE5141: Quantum Information and Computation	70	3	1	0	4
PH-DSE5142: Computational Material Science	73	3	0	1	4
PH-DSE5143: Quantum Optics	75	3	1	0	4
PH-DSE5144: Atmospheric Physics	77	3	1	0	4
PH-DSE5145: X-ray Spectroscopic Techniques	79	3	1	0	4
PH-DSE5146: Complex Systems	81	3	1	0	4
PH-DSE5147: Accelerator Physics	83	3	1	0	4
PH-DSE5161: Quantum Mechanics I	90	3	1	0	4

ELECTIVE COURSES		Lecture	Tutorial	Practical	Credits
PH-DSE5162: Electronics	93	3	1	0	4
PH-DSE5163:Foundational Laboratory in Experimental Physics	96	0	0	4	4
PH-DSE5164:Experimental Laboratory in Material and Optical Physics	99	0	0	4	4
PH-DSE5148: Research Methodology in Physics		3	0	1	4
Total credits in Electives/General Electives					12
*PH-ARM5101: Advanced Research methodology in Physics	88	1	0	1	2
**Mandatory for the students who have not studied 4 credit Research Methodology paper in UG programme under NEP*					
DISSERTATION					
PH-DIS5101: Dissertation	102				6
Total credits in Dissertation Course					6
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 co-requisite.*
- *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**	117	3	1	0	4

PH-DSC5202: **Advanced Classical Dynamics, Fields & Matter**	120	3	1	0	4
Total credits in Core courses					8
Number of Elective/General Elective courses: 2		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)	123	3	1	0	4
PH-DSE5212: Nanomaterials – II (Lab)	125	0	0	4	4
Module B-II:					
PH-DSE5213: Advanced Electronics - II (Theory)	127	3	1	0	4
PH-DSE5214: Advanced Electronics- II (Lab)	129	0	0	4	4
Module C-II:					
PH-DSE5215:Advanced Nuclear Physics – II (Theory)	131	3	1	0	4
PH-DSE5216: Advanced Nuclear Physics - II (Lab)	134	0	0	4	4
Module D-II:					
PH-DSE5217: Advanced Laser Physics (Theory)	137	3	1	0	4
PH-DSE5218: Advanced Laser Physics (Lab)	139	0	0	4	4
ELECTIVE COURSES:		**Theory**	**Practical**	**Tutorial**	**Credits**
Module E-II:					
PH-DSE5219: Advanced Solid State Physics–II (Theory)	141	3	1	0	4

PH-DSE5220: Advanced Solid State Physics – II (Lab)	144	0	0	4	4
Special Lab courses:					
PH-DSE5221:Advanced Numerical Techniques	146	0	0	4	4
PH-DSE5222:Advanced Observational Astrophysics Lab	148	0	0	4	4
PH-DSE5223:Machine Learning for Physicists	151	2	0	2	4
THEORY COURSES					
PH-DSE5231: General Theory of Relativity and Cosmology II	153	3	1	0	4
PH-DSE5232: Condensed Matter Physics II	155	3	1	0	4
PH-DSE5233: Plasma Physics II	157	3	1	0	4
PH-DSE5234: Particle Physics II	159	3	1	0	4
PH-DSE5235: Quantum Field Theory II	161	3	1	0	4
PH-DSE5236: Nuclear Astrophysics	163	3	1	0	4
PH-DSE5237: Supersymmetric Quantum Mechanics	165	3	1	0	4
PH-DSE5238: Spintronics Fundamentals and Applications	167	3	1	0	4
PH-DSE5239: Molecular Electronics	169	3	1	0	4
PH-DSE5240: Astrophysics	171	3	1	0	4
ELECTIVE COURSES:		**Theory**	**Practical**	**Tutorial**	**Credits**
PH-DSE5241: Soft Matter Physics	173	3	1	0	4
PH-DSE5242: Advanced Course on Quantum Computing	175	2	0	2	4

PH-DSE5243: String Theory	178	3	1	0	4
PH-DSE5244: Superconductivity, Superfluidity & Critical Phenomena	180	3	1	0	4
PH-DSE5245: Accelerator Applications	182	3	1	0	4
PH-DSE5246: Metamaterials, Plasmonics and Photonics	184	3	1	0	4
PH-DSE5247: Nuclear Safety & Security	186	3	1	0	4
PH-DSE5248: Advanced Statistical Physics	189	3	1	0	4
PH-DSE5249: Biophysics	191	3	1	0	4
PH-DSE5261: Quantum Mechanics II	196	3	1	0	4
PH-DSE5262: Solid State Physics	199	3	1	0	4
PH-DSE5266: Foundational Laboratory in Experimental Physics	202	0	0	4	4
PH-DSE5267: Experimental Laboratory in Material and Optical Physics	205	0	0	4	4
Total credits in Elective / General Elective courses					12
*PH-ARM5201: Techniques of Research writing in Physics	193	1	0	1	2
**Mandatory for the students who have not studied 4 credit Research Methodology paper in UG programme under NEP*					
DISSERTATION					
PH-DIS5201: Dissertation	208				6
Total credits in dissertation Course					6
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, 1968)
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 configration 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 555Multivibrator 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, Wisskoff-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, BaF_2 $CeBr_3$ and $LaBr_3$ 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 (DSEre 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 (2^{nd} 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 (Ist 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. Aschroft & N. David Mermin (Harcourt Publishers, 1976)
2. Solid State Physics, Gerald Burns (AcademicPress, 1985)
3. Solid State Physics, Wlater A. Harrison (Dover Publications, 1980)
4. Solid State Physics: An introduction to Principles of Materials Science, Harald Ibach andHans 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. Lovessey (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 liquidsSpringer 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-Tc materials, Michel Cyrot and Davor Pavuna, (World Scientific, 1992) 1.

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 Fransisco 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-relativisttic 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→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) × 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 UniversityPress, 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 Vaaisaalaa 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 (4^{th} 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 (6^{th} 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 III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-ARM5101
Course Name: Advanced Research methodology in Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Research Methodology in Physics ARM	2	1	0	1	Research Methodology in Physics

Duration: (15L+30P) 45 Hours

Course Objectives

The objective of this course is to develop a deeper understanding of how physical models are formulated, tested, and evaluated when multiple explanations of the same data are possible. Emphasis is placed on identification of measurable quantities, determination of model parameters from experimental observations, comparison between competing physical descriptions, and interpretation of empirical relations connecting physical variables. The course develops the ability to judge whether conclusions drawn from theoretical calculations or experimental measurements are reliable within stated assumptions and approximations.

Unit I: Physical Quantities, Model Parameters, and Inference (15 Hours)

Physical observables and measurable quantities, SI units defined in terms of fundamental constants, dimensional consistency of physical relations, parameters as measurable characteristics of physical systems, identification of dominant variables, role of symmetry and conservation laws in simplifying models, limiting cases and consistency checks, forward and inverse problems in physics, sensitivity of physical predictions to parameter variation, extraction of physical parameters from indirect measurements, parameter correlations and degeneracy, uncertainty propagation through models, reliability and interpretation of parameter estimation, comparison between alternative physical models describing the same data, examples from oscillations, diffusion, and transport processes.

Unit II: Experimental Evidence, Scaling Relations, and Model Validation (30 Hours)

Consistency between theoretical predictions and experimental observations, role of independent measurements in testing physical models, identification of systematic deviations between model and data, distinguishing measurement uncertainty from model inadequacy, internal consistency checks across different physical observables, comparison between competing explanations of the same observations, dimensional analysis and scaling relations observed in experiments, power-law behaviour in physical systems, dimensionless quantities as indicators of dominant physical effects, identification of relevant physical scales from experimental data, controlled approximations in physical models, phenomenological relations between observables, domain of validity of empirical laws, examples from spectroscopy, diffusion, oscillations, transport, and continuum approximations.

Course Learning Outcomes

Students will learn how measurable physical quantities and model parameters are identified in theoretical and experimental descriptions of physical systems. The study of parameter sensitivity and inverse problems will help students understand how physical predictions depend on underlying assumptions and how experimental data constrain model parameters. The idea of model comparison and validation will enable students to assess consistency between theoretical expectations and observations. Dimensional analysis and scaling relations will help students interpret empirical laws in terms of dominant physical variables, while understanding the limits of validity of approximations will develop the ability to judge reliability of physical models in different regimes.

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 et al., Numerical Recipes, Cambridge University Press.
4. L. D. Landau and E. M. Lifshitz, Course of Theoretical Physics, selected volumes.
5. E. Fermi, Notes on Thermodynamics and Statistics, University of Chicago Press.

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 (2^{nd} Ed., Wiley Interscience Publications, John Wiley & Sons).
7. Communication Systems, Simon Haykins (5^{th} Ed., Wiley, 2009).
8. Digital Signal Processing, J.G. Proakis and D.G. Manolakis (4^{th} Ed., Pearson, 2007).
9. Solid State Electronic Devices, B.G. Streetman (7^{th} Ed., Pearson, 2015).
10. Digital Design, M. Mano (5^{th} Ed., Pearson, 2013).
11. Digital Principles and Applications, A.P. Malvino and D.P. Leach (8^{th} 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 60Co 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 pi-mu-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 Tc superconductors.
- Determination of transition temperature in liquid crystalline materials.
- Crystal structure determination by x-ray diffraction powder photograph method.

<u>Waves and Optics</u>

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 Febry 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/1-3488984 .

MASTER of SCIENCE in PHYSICS

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

Course Code: PH-DIS5101

Course Name: DISSERTATION/ACADEMIC PROJECTS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Dissertation / Academic Projects	6				

Total: … Hours

Course Objectives

The dissertation aims to provide students with an opportunity to undertake independent research on a topic of current interest in physics. It enables them to apply the theoretical, computational, and experimental skills acquired during the programme to investigate a research problem in a systematic manner.

Course Learning Outcomes

Outcomes expected of *Dissertation writing track / Academic Projects* in the 2nd Year of PG Programmes (as per the regulation of the University of Delhi)

The following four outcomes must be achieved by the end of III Semester:

i. Research Problem identification
ii. Review of literature
iii. Research design formulation
iv. Commencement of experimentation, fieldwork, or similar tasks

Notes:

1. The Dissertation/Academic Project chosen should be an original work and not a repetition of work done in the 4th Year of the UG programme. It may be an extension though of the work done in the 4th Year of UG programme.
2. All academic projects should be application based research and not exploratory or descriptive research.
3. The **Coursework + Research** track will normally be available only to the **top 20% of students** in the two-year M.Sc. programme and the **top 20% of students** admitted to the one-year M.Sc. programme.
4. The exact cutoff for eligibility may vary from year to year based on academic performance and other relevant considerations.
5. The allocation of Dissertation/Project work is subject to the availability of faculty supervisors.
6. For experimental projects, allocation is further subject to the availability of research

facilities, laboratory space, and scientific instrumentation in the Department.

7. The Departmental Course Assignment Committee shall review the situation annually and may modify the eligibility criteria, selection process, and number of available Dissertation/Project positions as deemed appropriate.
8. Selection for the Dissertation/Project component will be made on a case-by-case basis in accordance with the prevailing guidelines approved by the Department.
9. Students of the two-year M.Sc. programme opting for a Project or Dissertation must have **no Essential Repeat (ER)** in any course at the time of selection.
10. At the end of the semester, the progress of the dissertation work will be evaluated by a committee constituted by the Experimental Research Committee, based on the learning outcomes and evaluation criteria specified by the University.

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

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. Jochain (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 (5^{th} 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, Lame'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:

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:

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:

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:

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.

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.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, 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. Schafer (2nd Ed., Pearson, 2006)
5. Electronic Communication systems, W. Tomasi (5th Ed., Peason, 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.)

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Duration: 120 Hours (8P/Week)

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 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-Winger 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-elatic 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 - Ewning 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-Wast 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)

- Kerr effect.
- 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

5. Lasers: Fundamental and Applications, Graduate Text in Physics, K. Thyagarajan, Ajoy ghatak (2^{nd} edition, Springer, 2002)
6. Polarization of light, Ajoy Ghatak and Arun Kumar (Mc GrawHill Education, 2012)
7. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000)
8. Teaching laser physics by experiments, (Am. J. Phys., 2011, http://doi.org/1-3488984)
9. Infrared Spectroscopy, Fundamentals and Applications, Barbara Stuart, (Wiley & Sons, 2004)
10. Modern Raman Spectroscopy-a practical approach, E. Smith and G. Dent (John Wiley & Sons, 2004)
11. 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 -1 (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)

2. 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)
3. 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).
4. Measure Hall coefficient, dc conductivity and mobility of a semiconductor at different temperatures (77 K to room temperature).
5. Resistivity measurements using four probe technique
6. Resistivity of semiconducting materials using Van-der Pauw method

Unit-II: Semiconducting Devices (28 Hours)

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

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

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

8. 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

a Optical Properties of Photonic Crystals, K. Sakoda (Springer, 2001)

b The Rietveld method, R.A.Young (IUCR-Oxford University Press, 1995)

c Fundamentals of Crystallography, C.Giacovazzo (IUCR-Oxford University Press, 2002)

d Characterization of nanophase materials, Zhon Ling Wang (Wiley-VCH Verlag GmbH, 2000)

e Physical Properties of Semiconductors, C. M. Wolfe, J.R.N.Holonyak and G.E.Stillman (Prentice Hall International Inc., London, 1989).

f 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 95 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 (35 Hours)

A. Observational Astronomy with Telescope : (25 Hours)

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 equipments .

Suggested Readings

1. Astrophysical Techniques, C.R. Kitchin (CRC press, 1995)
2. Observational Astrophysics, R. C. Smith (Cambridge Univ. Press, 2000)
3. TelescopeC.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 relativistics 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, Lauglin 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, Wlater 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-Tayler 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 Alfven 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. Schimdt (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

<table>
<tr><th rowspan="2">Course Title and Code</th><th rowspan="2">Credits</th><th colspan="3">Credit distribution of the course</th><th rowspan="2">Pre-requisite of the course</th></tr>
<tr><th>Lecture</th><th>Tutorial</th><th>Practical</th></tr>
<tr><td>Nuclear Astrophysics

DSE</td><td>4</td><td>3</td><td>1</td><td>0</td><td>Quantum Mechanics -I & II, Statistical Physics, Classical Mechanics, Electrodynamics, Mathematical Physics, Nuclear & Particle Physics</td></tr>
</table>

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, MoS_2, 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)
Nanoelectronics & 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 & Quant um 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 Tc Superconductivity.

Unit III: Superfluid ^{3}He (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 (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).

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

3. Statistical Mechanics (2nd Edition), Kerson Huang, *(John Wiley & Sons, 1987)*.
4. Statistical Mechanics (3rd Edition), R. K. Pathria and Paul D. Beale, *(Elsevier, 2011)*.
5. Statistical Mechanics, Shang-Keng Ma, *(World Scientific Publishing, 1985)*.
6. Statistical Physics of Particles, Mehran Kardar, *(Cambridge University Press, 2007)*.
7. Statistical Mechanics: Entropy, Order Parameters, and Complexity, James P. Sethna, *(Oxford University Press, 2006)*.
8. Statistical Mechanics, Donald A. McQuarrie, *(University Science Books, 2000)*.
9. Principles of Condensed Matter Physics, P. M. Chaikin and T. C. Lubensky, *(Cambridge University Press, 1995)*.
10. Lectures on Phase Transitions and the Renormalization Group, Nigel Goldenfeld, *(CRC Press/Addison-Wesley, 1992)*.
11. Statistical Physics of Fields, Mehran Kardar, *(Cambridge University Press, 2007)*.
12. 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.

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MASTER of SCIENCE in PHYSICS

Semester IV of 2 year MSc/Semester II of 1 year MSc
Course Code: PH-ARM5201
Course Name: Techniques of Research writing in Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Techniques of Research writing in Physics ARM	2	1	0	1	Research Methodology in Physics, Advanced Research Methodology in Physics, Tools for Research in Physics

Duration: (15L+30P) 45 Hours

Course Objectives

The objective of this course is to develop the ability to communicate theoretical, computational, and experimental research in physics in a structured scientific format. Emphasis is placed on clear formulation of research problems, transparent presentation of assumptions, reproducible description of methods, logical presentation of results, and identification of limits of validity of conclusions.

The course develops the ability to convert research outcomes into structured documents such as thesis chapters, journal articles, technical reports, and conference communications. Attention is given to clarity of definitions, consistency of notation, presentation of equations and figures, description of experimental procedures, and appropriate citation of prior work.

The course also introduces principles of ethical scientific communication including attribution of ideas, avoidance of plagiarism, proper citation practices, and responsible use of computational and AI-assisted tools.

Unit I: Structure of Scientific Writing in Theoretical and Experimental Physics

(15 Hours)

Formulation of research questions in terms of measurable quantities, distinction between hypothesis, model, approximation, and theory, logical organization of scientific arguments.

Standard structure of scientific papers: abstract, introduction, theoretical framework, experimental or computational methodology, results, discussion, conclusion.

Connection between theoretical predictions and experimentally measurable quantities, role of assumptions and approximations in physical reasoning, identification of domain of validity of models.

Writing mathematical expressions as statements of physical relations, defining symbols and parameters clearly, dimensional consistency, explanation of limiting cases.

Description of experimental methods including apparatus, control parameters, calibration procedures, and measurement uncertainties at descriptive level.
Distinction between derivation, empirical observation, interpretation, and speculation in scientific writing.
Examples from nuclear and particle physics, statistical physics, atomic and molecular physics, and condensed matter.

Unit II: Presentation of Results, Reproducibility, and Academic Integrity (30 Hours)

- Presentation of theoretical results, experimental data, and computational outputs using tables, graphs, and diagrams.
- Writing figure captions, describing trends in data, comparison between theoretical predictions and observations, identification of uncertainties and variability in measurements.
- Documentation of experimental and computational procedures in reproducible form, description of parameter values and assumptions used in analysis.
- Basic structure of thesis chapters and journal manuscripts, preparation of abstracts, posters, and short technical reports.
- Citation practices in physics literature, referencing journal articles, books, datasets, and software tools, distinction between commonly known results and original contributions.
- Avoidance of plagiarism, similarity index limits, academic integrity, acknowledgement of sources, ethical use of AI-assisted tools.
- Preparation of a short structured document based on the student's MSc research work, using writing and bibliography software (LaTeX, bibTeX) in various journal formats.

Course Learning Outcomes

Students will learn how theoretical models, experimental procedures, and quantitative results are communicated in physics through structured scientific documents. Concepts of logical organization, clear definition of variables, and transparent presentation of assumptions will help students communicate research findings effectively. Understanding of graphical representation of data and explanation of physical conclusions will enable students to present results in a form suitable for thesis writing and publication. Knowledge of citation practices and academic integrity will help students credit prior work and highlight their contributions in proper manner.

Suggested Readings

1. R. A. Day and B. Gastel, How to Write and Publish a Scientific Paper, Cambridge University Press.
2. M. Alley, The Craft of Scientific Writing, Springer.
3. L. Lamport, LaTeX: A Document Preparation System, Addison-Wesley.

4. American Physical Society, Physical Review Style and Notation Guide.
5. IOP Publishing, Author Guidelines for Journal Articles.

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. Exposer 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, WiedemannFranz 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 (Ist 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).

MASTER of SCIENCE in PHYSICS

Semester II of 1 year MSc

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.

<u>Nuclear Physics</u>

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 60Co 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 pi-mu-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 Tc superconductors.
- Determination of transition temperature in liquid crystalline materials.
- Crystal structure determination by x-ray diffraction powder photograph method.

<u>Waves and Optics</u>

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 Febry 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/1-3488984 .

MASTER of SCIENCE in PHYSICS
Semester III of 2 year MSc/ Semester I of 1 year MSc
Course Code: PH-DIS5201
Course Name: DISSERTATION/ACADEMIC PROJECT

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Dissertation/Academic Project	6	…	…	…	…

Total: … Hours

Course Objectives

The dissertation/Academic Project aims to provide students with an opportunity to undertake independent research on a topic of current interest in physics. It enables them to apply the theoretical, computational, and experimental skills acquired during the programme to investigate a research problem in a systematic manner.

Course Learning Outcomes

Outcomes expected of Dissertation writing track / Academic projects in the 2nd Year of PG Programmes (as per the regulation of the University of Delhi)

The following three outcomes must be achieved by the end of IV Semester:

i. Completion of experimentation/ fieldwork
ii. Submission of dissertation/Project report
iii. Research output in the form of any one of the following –
   - Prototype or product development/ patent.
   - Any other scholastic work as recommended by the BRS / DRC or/and approved by the Research Council (if applicable). The recommendation of the DRC shall be based on an evaluation of the student's dissertation work through an appropriate examination/review process by a committee.
   - Publication in reputed Journals such as Scopus indexed journals or other similar quality journals or in a National Conference.
   - Book or Book Chapter in a publication by a reputed publisher.

<u>Notes:</u>

1. The Dissertation/Academic Project chosen should be an original work and not a repetition of work done in the 4th Year of the UG programme. It may be an extension though of the work done in the 4th Year of UG programme.
2. All academic projects should be application based research and not exploratory or descriptive research.
3. If a student opts to fulfil the dissertation/Academic Project requirement through publication in a reputed journal, a copy of the acceptance letter from the journal must

be submitted on or before the last date of the End-of-Semester Examination. In the case of a national conference publication, the student must submit both the paper acceptance letter and a certificate confirming the presentation of the paper at the conference.

4. At the end of the semester, the progress of the dissertation work will be evaluated by a committee constituted by the Experimental Research Committee, based on the learning outcomes and evaluation criteria specified by the University.
5. The **Coursework + Research** track will normally be available only to the **top 20% of students** in the two-year M.Sc. programme and the **top 20% of students** admitted to the one-year M.Sc. programme.
6. The exact cutoff for eligibility may vary from year to year based on academic performance and other relevant considerations.
7. The allocation of Dissertation/Project work is subject to the availability of faculty supervisors.
8. For experimental projects, allocation is further subject to the availability of research facilities, laboratory space, and scientific instrumentation in the Department.
9. The Departmental Course Assignment Committee shall review the situation annually and may modify the eligibility criteria, selection process, and number of available Dissertation/Project positions as deemed appropriate.
10. Selection for the Dissertation/Project component will be made on a case-by-case basis in accordance with the prevailing guidelines approved by the Department.
11. Students of the two-year M.Sc. programme opting for a Project or Dissertation must have **no Essential Repeat (ER)** in any course at the time of selection.

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 (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-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.
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- ➢ 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.