தமிழ்நாடு மத்திய பல்கலைக்கழகம்

तमिलनाडु केन्द्रीय विश्वविद्यालय

CENTRAL UNIVERSITY OF TAMIL NADU

(Established by an Act of Parliament, 2009)

Department of Physics

(DST-FIST Sponsored)

Exploring the fundamental laws of nature to understand the universe and create a better tomorrow.

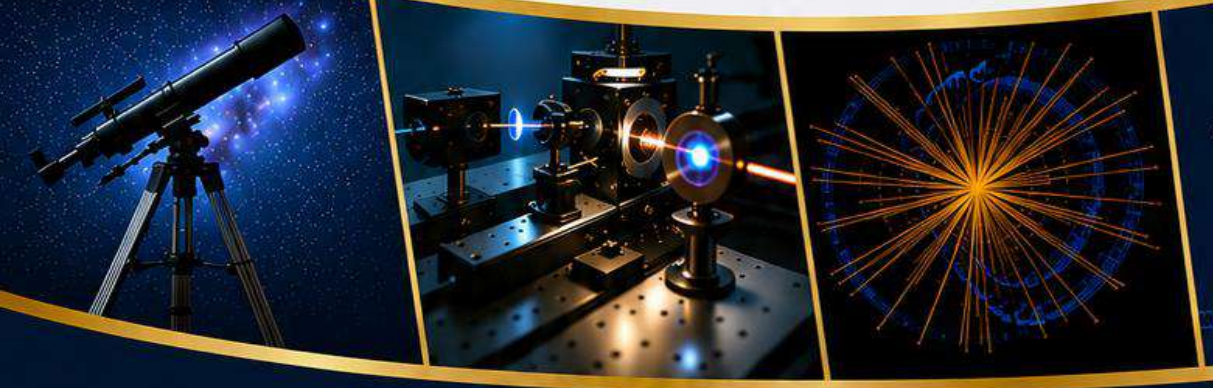
School of Basic and Applied Sciences

Syllabus

B.Sc Honours

&

B.Sc Honours with Research



(2025 – 2026 onwards)

Department of Physics

School of Basic and Applied Sciences

Syllabus

B.Sc. Honours
&
B.Sc. Honours with Research

2025-2026 onwards

Table of Contents:

1. PROGRAM OUTLINE

A. Preamble:

1. **Started**: 2010.
2. **Programmes offered**: B.S. honours, Integrated M.Sc. M.Sc., and Ph.D in physics
3. **Vision and Thrust areas of the Department in brief**:
   The department of Physics of CUTN envisages itself to be a centre of excellence in basic and applied aspects of Physics, both in teaching and research, in 22 years.

4. **Unique feature of the department**:
   The department is established with well-equipped teaching and research laboratories, at par with international standards. All the classrooms are equipped with audio visual aids and a few with smart classrooms with interactive/communicative teaching aids for effective teaching and learning. In order to kindle students' creative learning, E-magazine, prevega (outreach program) Spark and other extra- curricular/co- curricular activities are inculcated through our perturbations club. The performance of all the students is being monitored constantly through Gurukula mentoring and a group of students are assigned to each faculty member for getting guidance for their academic/career development.

B. Title: The title of the program is Bachelor of Science in Physics (Honours / Honours with Research). The Rules and Regulations of the Central University of Tamil Nadu apply to this program.

C. Objectives of the Program:

On completion of the program, the students will be able to:

- Understand the fundamental laws of Physics and its advancement so far.
- Develop the insight into the nature, scope, and objective of Physics.
- Develop logical and rational thinking.
- Develop the art of innovation, making strategies, and solving scientific problems.
- Develop the scientific spirit.
- Develop skills to meet present industry requirements.

D. Duration

The duration of the BSc honors program shall be four academic years. Each

academic year consists of two semesters.

E. Eligibility for admission

As per notification by the Central University of Tamil Nadu.

F. Medium of instruction

Medium of instruction shall be English.

G. Methods of transaction

A list of suggestive methods of curriculum transaction are as follows:

- Lectures - cum- discussion.
- Lecture - cum - demonstration.
- Assignments and tutorials
- Seminars and Group Discussion
- Individual projects
- Project reviews
- Using library & ICT resources
- Internships

H. Attendance:

As per university guidelines

I. Course outline

The course is designed as per NEP-2020 guidelines to provide teaching at par with top institutes both at national and international level. Moreover, it will train them to take various national and international level examinations to enter into the field of research, to become professional physicists, excel in various interdisciplinary fields, and service sectors other than Physics. This syllabus is an attempt to balance all these requirements. The course is divided as follows.

Semester wise credit distribution is given in the following table:

PROFORMA OF COURSE STRUCTURE:

Table – 1

First Year						
SEMESTER I						
Course Code	**Course Title**	**Course Type**	**Credits**	**Hours / week**	**Marks**	
					Int	**Ext**
PHY5011	Foundations of Physics*	CC	3	3	40	60
PHY5012	Foundations of Physics Laboratory*	CCP	2	4	100	
MAT501#	Calculus*	Minor	3	3	40	60
MAT501#	Basic Computing Laboratory*	Minor	2	4	100	
PHYOE#	Open Elective	OE	3	3	40	60
	English	AECC	3	3	40	60
	Cyber Security	SEC	2	2	40	60
	Environmental Science	VAC	3	3	40	60
Total			**21**	**25**		
*For Physics and Mathematics students.						
SEMESTER II						
Course Code	**Course Title**	**Course Type**	**Credits**	**Hours / week**	**Marks**	
					Int	**Ext**
CHE502#	General Chemistry**	Minor	3	3	40	60
CHE502#	General Chemistry Practical **	Minor	2	4	100	
BTY501#	Basic of Biology **	Minor	3	3	40	60
BTY501#	Biology Practical laboratory *	Minor	2	4	100	
PHYOE#	Open Elective	OE	3	3	40	60
TAM502#/ HIN502#	Tamil / Hindi	AECC	3	3	40	60
GLY502#	Disaster Risk Reduction	SEC	2	2	40	60
LAW501#	Constitutional Values	VAC	3	3	40	60
Total			**21**	**25**		

	Cumulative Total		**42**			
PHY5021	Foundations of Physics[+]	Minor	3	3	40	60
PHY5022	Foundations of Physics Laboratory[+]	Minor	2	4	100	
For students exiting after one year (Certificate)						
	Skill Development of the Youths and their Livelihood (NPTEL)	VOC	4	4	100	
	Cumulative Total		**46**			

**For Physics and Mathematics students.
[+]For Chemistry and Biotechnology students.

Second Year

SEMESTER III

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY5031	Mechanics and Relativity[++]	CC	3	3	40	60
PHY5032	Mechanics Laboratory[++]	CCP	2	4	100	
CHE503#	General Physical Chemistry	Minor	3	3	40	60
MAT503#	Differential Equations and Integral Transforms	Minor	3	3	40	60
PHYOE#	Open Elective	OE	3	2	40	60
TAM503#/ HIN503#	Tamil / Hindi	AECC	3	3	40	60
PHYSE01	Machine Shop	SEC	2	2	100	
PES504#	Yoga and Fitness	VAC	2	2	40	60
	Total		**21**	**22**		
	Cumulative Total		**63**			
PHY5033	General Physics***	Minor	3	3	40	60

[++]For Physics and Mathematics students.
***For Chemistry and Mathematics students.

SEMESTER IV

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY5041	Heat and Thermodynamics	CC	3	3	40	60
PHY5042	Electricity and Magnetism	CC	3	3	40	60
PHY5043	Numerical Methods and Computer	CC	3	3	40	60

	Programming					
PHY5044	Heat and ThermodynamicsLaboratory	CCP	2	4	100	
PHY5045	Electricity and Magnetism Laboratory	CCP	2	4	100	
PHY5046	Computer Programming Laboratory	CCP	2	4	100	
ENG504#	English	AECC	3	3	40	60
PHYSE#	Skill Enhancement Course(Department)	SEC	3	3		
	Extension Activity	EXT	1*	---	---	
Total			**21**	**27**		
Cumulative Total			**84**			
*Students have to enroll in any one of the following extension activities (NCC/NSS/Red Ribbon) in the first semester and attend the enrolled activity across all four semesters. The course will be evaluated in the fourth semester.						
For students exiting after two years (Diploma)						
	Skill Development of the Youths and their Livelihood (NPTEL)	VOC	4	4	100	
		Total	**88**			
Third Year						
SEMESTER V						
Course Code	**Course Title**	**Course Type**	**Credits**	**Hours / week**	**Marks**	
					Int	**Ext**
PHY5051	Mathematical Methods in Physics	CC	4	4	40	60
PHY5052	Classical Mechanics	CC	4	4	40	60
PHY5053	Quantum Physics and its Applications	CC	4	4	40	60
PHY5054	Solid State Physics	CC	4	4	40	60
PHY5055	Solid State Physics Laboratory	CCP	2	4	100	
PHY5056	Mathematical Methods Practical	CCP	2	4	100	
PHYON##	MOOC-1 (NPTEL)	DSE	3	3	40	60
Total			**23**	**25**		
Cumulative Total			**107**			
SEMESTER VI						
Course Code	**Course Title**	**Course**	**Credits**	**Hours /**	**Marks**	

		Type		week	Int	Ext
PHY5061	Statistical Physics	CC	4	4	40	60
PHY5062	Atomic and Nuclear Physics	CC	4	4	40	60
PHY5063	Electronics	CC	4	4	40	60
PHY5064	Atomic and NuclearPhysicsLaboratory	CCP	2	4	100	
PHY5065	ElectronicsLaboratory	CCP	2	4	100	
PHYEC##	Department Specific Elective (Either Department or MOOCS)	DSE	3	3	40	60
PHYEC##	Department Specific Elective (Either Department or MOOCS)	DSE	3	3	40	60
PHYIN01	Internship	INT	2	----	100	
Total			**24**	**26**		
Cumulative Total			**131**			
• **Students can exit after three years with a B.Sc. Physics Degree (with 131 credits)** • **Students who wish to continue for a fourth year will receive either a B.Sc. Honours/ Honours with Research Degree based on their total CGPA as follows:** For B.Sc. Honours with Research degree, the student shall score more than 7.5 CGPA.						
Total credits (after 3 years)			**131**			

FOURTH YEAR

SEMESTER – VII

S. No	Course Code	Course Title	Type	Credit	Hours / Week		Marks	
					L	P	Int	Ext
1	PHY5071	Mathematical Physics I	CC	4	4	-	40	60
2	PHY5072	Quantum Mechanics I	CC	4	4	-	40	60
3	PHY5073	Electromagnetic Theory	CC	4	4	-	40	60
4	PHY5074	Molecular Physics and Spectroscopy	CC	4	4	-	40	60
5	PHY5075	Research and Publication Ethics	CC	2	2	-	40	60
6	PHYEC20	Spectroscopy Laboratory	DSE	2	-	4	100	
7	PHYEC##	Department Specific Elective (Either Department or MOOCS)	DSE	3	3	-	40	60
		Total		**23**	**21**			
		Cumulative Total		**154**				

L: Lecture; P: Practical

SEMESTER – VIII

S.No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext

					L	P		
For B.Sc. Honours Degree								
1	PHY5081	Mathematical Physics II	CC	3	3	-	40	60
2	PHY5082	Quantum Mechanics II	CC	4	3	-	40	60
3	PHY5083	Condensed Matter Physics	CC	3	3	-	40	60
4	PHY5084	Nuclear and Particle Physics	CC	3	3	-	40	60
5	PHY5085	Research Project	PROJ	6	-	16	100	
			Total	**19**	**12**	**16**		
			OVERALL TOTAL	**173**				
For B.Sc. Honours with Research Degree								
1	PHY5081	Mathematical Physics II	CC	3	3	-	40	60
2	PHY5082	Quantum Mechanics II	CC	4	4		40	60
3	PHY5086	Research Project	PROJ	12	-	24	100	
			Total	**19**	**7**	**28**		
			OVERALL TOTAL	**173**				

CC: Core Course; CCP: Core Course Practical; Minor: Allied Courses; DSE: Discipline Specific Elective; OE: Open Elective; AEC: Ability Enhancement Compulsory Course; SEC: Skill Enhancement Course; VAC: Value Added Course; EXT: Extension Activity; VOC: Vocational Course; INT: Internship; PROJ: Research Project; L: Lecture; P: Practical **(Apart from the list of experiments provided in each practical courses, the additional experiments may be added based on the availability of equipment's).**

K. EVALUATION:

The performance of each student enrolled will be assessed at the end of each semester. Evaluation of the student will be done as per the Grading System adopted by the Central University of Tamil Nadu. The final result in each course will be determined based on (a) continuous assessment, and (b) performance in the Term End Examination which will be in the ratio of 40:60 (40 Continuous Assessment and 60 Term End Exam) in case of a theory paper. In the case of Practical, the result will be determined on the basis of continuous evaluation only. The passing minimum in the course shall be intimated time to time as per the guidelines of Central University of Tamil Nadu.

2. VISION, MISSION, AND OBE PATTERN

A. Vision statement of the department:

The Department of Physics of CUTN envisages itself to be a center of excellence in basic and applied aspects of Physics, both in teaching and research, in next 20 years.

B. Mission statement of the department:

M-1	To establish a world class Department of Physics while being sensitive to the location of the University and the demographics of the student input.
M-2	To establish a world class research laboratory with cutting edge technology in multi and trans disciplinary areas of Physics and to train students to develop the high level of global competence in core/ Applied areas of Physics.
M-3	To collaborate with Institutes of eminence and Industries for enhanced learning experience through ICT integrated teaching-learning process.

C. Program Outcomes

On the successful completion of the program, the student will be able to

PO-1	Develop and establish advance knowledge and apply theories and principles of Physics/Applied Physics in the domain of industry, research and development.
PO-2	Successfully acquiring jobs after pursuing research in advanced laboratories around the globe and build perform as professional teachers in Physics and other science disciplines.
PO-3	Provide professional services to industry, research organizations and institutes in India and overseas.
PO-4	Develop, create and apply appropriate techniques, resources and relevant IT toolsto find complex scientific solutions related to academic and research activities with clear understanding of its advantages and limitations.
PO-5	Provide value based and ethical leadership in the professional and social life.

D. Specific Outcomes (PSO)

PSO-1	Apply the knowledge gained in fundamental and applied Physics in solving scientific problems at varied complexity, analyze the same to formulate/ develop substantiated solutions.
PSO-2	Apply the research-based knowledge and advanced method to design newexperiments, analyze resulting data and interpret the same to provide valid conclusions.
PSO-3	Gain broad understanding of ethical and professional skill in scientific applications in the context of local, global, economic, environmental and societal realities and to develop sustainable practical solutions for academic and research problems within professional and ethical boundaries.
PSO-4	Educate scientifically the new development in Science and Technology and make them critical thinkers and innovators.
PSO-5	Engage in independent and lifelong learning in the broadest context of technological change and pursue his/her career either in higher studies or in various sectors.

E. Graduate Attributes

(a) Disciplinary/ interdisciplinary knowledge
(b) Computational and ICT skills/ digital literacy.
(c) Communication skills.
(d) Ethics/ moral awareness.
(e) Problems solving/ Analytical/ reflective thinking.
(f) Critical thinking
(g) Cooperation/ teamwork.

(h) Self-directed learning.
(i) Research related skills

F. PSO to Mission Statement Mapping:

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5
M-1	3	2	2	3	3
M-2	2	3	3	3	2
M-3	1	3	2	3	1

G. PO to PSO Mapping:

	PO-1	PO-2	PO-3	PO-4	PO-5
PSO-1	3	2	3	3	1
PSO-2	3	3	3	3	1
PSO-3	2	1	3	2	3
PSO-4	3	3	3	3	1
PSO-5	2	2	3	1	3

SEMESTER – I

Course Code : PHY5011
Course Title : Foundation of Physics
Course Type : Theory (Core)
Credits : 03 (45 Hours)

Foundations of Physics

Unit 1
Mathematical Toolkits
Functions of single and multiple variables; ordinary and partial differentiation. Scalars and vectors; product of two vectors; Simple ordinary differential equations and its solutions. Coordinate systems: polar, spherical polar, and cylindrical, unit vectors; graphs and plotting; maxima and minima.

Unit 2
Dimensional Analysis, Approximations, and errors
Dimensional analysis. Taylor series. Approximation and estimation, scaling, The factorial function and its uses; Stirling's approximation. Least-count errors; random errors; ways of reducing errors; systemic errors; propagation of errors; sensitivity of errors to measurements; Least-squares fit of a straight line to data.

Unit 3
Force and Energy
Fundamental forces in nature, phenomenological forces (contact force, tension, normal force, friction), viscosity, Hook's law and simple harmonic motion, different types of energy, work energy theorem, potential energy, potential energy model to predict force, energy diagrams, bound states and binding energy, conservation laws, energy Conservation and the Ideal Gas Law.

Unit 4
Elementary Fluid Mechanics
Definition of fluid, pressure in fluid, laminar and turbulent flow, viscous forces and viscosity, Reynolds number, description of laminar flow- velocity profile in thin channel and cylindrical tube (flow of blood in veins), flow conductance &resistance , square micro fluidics.

Unit 5
Elementary Probability Theory
Rules of probability, Discrete and continuous random variables, Discrete and continuous distributions (Counting bacterial colony, radioactive decay, Threshold of human vision etc.. to be taken as an example): Binomial, Poisson, exponential, and Gaussian distribution; mean and variance, central limit theorem (statement only), parameter estimation.

References:

1. Mathematical methods in Physical sciences, Mary L Boas, Wiley, 3ed (2023)
2. An introduction to error analysis, J. R. Taylor, University Science Book (1997)
3. An Introduction to mechanics, D. Kleppner, R. Kolenkow, CUP, 2ed (2014)
4. Mechanics: Berkeley Physics Course Vol 1, C. Kittel, et. al, McGraw Hill Education; 2nd edition (2017)
5. Introductory Physics for life sciences Vol 2, D.V.Guerra, CRC Press, 1 ed (2023)
6. https://oyc.yale.edu/physics/phys-200
7. https://www.feynmanlectures.caltech.edu/

Course Outcomes		Level
CO-1	Apply mathematical tools to model and solve problems involving functions, differentiation, and coordinate systems.	**Apply**
CO-2	Analyze and estimate physical quantities using dimensional analysis, Taylor series, and error propagation methods.	**Analyze**
CO-3	Demonstrate understanding of different types of forces and energies and apply conservation principles to physical systems.	**Understand / Apply**
CO-4	Apply principles of fluid mechanics to model laminar flow and assess flow characteristics in biological and physical contexts.	**Apply / Analyze**
CO-5	Evaluate and interpret probabilistic data using elementary probability theory and probability distributions.	**Evaluate**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	2	2	3	1
CO-3	3	3	2	2	1
CO-4	3	2	3	3	1
CO-5	3	3	2	3	2

Course Code : PHY5012
Course Title : Foundation of PhysicsLaboratory
Course Type : Practical (Core)
Credits : 02 (60 Hours)

List of Experiments

1. Least-count of Vernier calipers, screw gauge, travelling microscope, stopwatches;
2. Representation of experimental data (graph, histogram, etc…), mean and standard deviation.
3. Estimates & actual measurement of length, mass, time units of physical objects/processes around us. e.g: height of the lab table, thickness of practical notebook etc.
4. Conservation of energy.
5. Study of random error in finding the time period of oscillation of simple pendulum.
6. Idea of distribution using Galton's board

7. Verification of Stoke's law using liquid column
8. Verification of Hook's law using spring-mass system
9. Measurement of surface tension using capillary rise method.
10. Estimation of density of objects using Archimedes' principle

SEMESTER – II

(Same as Semester I for other branches)

Course Code : PHY5021
Course Title : Foundation of Physics
Course Type : Theory (Minor)
Credits : 03(45 Hours)

Course Code : PH5022
Course Title : Foundation of PhysicsLaboratory
Course Type : Practical (Minor)
Credits : 02(60 Hours)

SEMESTER – III

Course Code : PHY5031
Course Title : Mechanics and Relativity
Course Type : Theory (Core)
Credits :03 (45 Hours)

Mechanics and Relativity

Unit-I

Fundamentals of Dynamics: Reference frames, Inertial frames, Galilean transformations, Galilean invariance, Review of Newton's Laws of Motion. Components of velocity and acceleration in – Cartesian system, Plane, Spherical Polar, and Cylindrical coordinate systems, Solution of Newton's equation and its graphical representation (eg. Linear motion, Projectile motion, etc.,)

Unit-2

Dynamics of a System of Particles: Principle of conservation of momentum, energy, Determination of Centre of Mass of discrete and continuous objects having cylindrical and spherical symmetry (1-D, 2-D and 3-D). Conservative and non-conservative forces. Force as gradient of potential energy, Potential energy diagram, Work energy theorem, Impulse and Linear momentum, Elastic and inelastic collision, direct and oblique collision of two smooth surfaces.

Unit-3

Simple Harmonic Motion: Differential equation of SHM and its solution, Linearity and Superposition Principle. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Pendulums, Simple and Compound pendulum, Resonance, sharpness of resonance; power dissipation and Quality Factor. Superposition of two collinear oscillations having equal frequencies and different frequencies (Beats). Superposition of two perpendicular Harmonic oscillations, Lissajous figures.

Unit-4

Rotary Motion: Uniformly rotating frame, Centripetal acceleration due to rotation, banking of curves, Coriolis force with examples, Rotational motion, Rolling, Moment of inertia, Calculation of moment inertia of systems of different geometrical shapes, parallel and perpendicular axis theorems, Radius of gyration, Gravitation- Laws of gravitation. Kepler's laws of planetary motion, Gravitational potential energy. Inertial and gravitational mass Gravitational potential and field due to spherical shell and solid sphere.

Unit 5

Special Theory of Relativity: Michelson-Morley Experiment and its outcome, Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Transformation of velocity, mass, energy and momentum, four-vector, invariance under Lorentz transformation and velocity addition equations in terms of hyperbolic functions**.**

Reference Books:

1. Feynman Lectures Vol. I, R.P. Feynman, R.B. Leighton and M. Sands, Pearson Education, The New Millenium Edition (2021).
2. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, Cambridge University Press, 2nd edition (2014).

3. Introduction to classical mechanics, 3rd edition, David Morin, Cambridge University Press (2008).
4. Mechanics, P. Durai Pandian, Laxmi Durai Pandian, MuthamizhJayapragasam, S.Chand& Co, 6th revised edition (2005).
5. Mechanics, D. S. Mathur & P. S. Hemne, Revised Edition, S.Chand& Co (2000).
6. Dynamics, Narayanamurthi. M.&Nagarathnam. N, The National Publishing, Chennai (2008).
7. https://onlinecourses.nptel.ac.in/noc24_me148/preview NPTEL course on Mechanics by Prof Anjani Kumar Tiwari, IIT-Roorkee.
8. https://youtube.com/playlist?list=PLyQSN7X0ro203puVhQsmCj9qhlFQ-As8e&si=UaBRZHsw2g1RVksU Lectures on Mechanics by Prof Walter Lewin, MIT.
9. https://youtube.com/playlist?list=PLvyl1YgaAepLZpteZ7rs0SQ87_MBIIJ6x&si=SXDgblQ5T2vXnO2f Lectures on mechanics by Prof HC Verma, IIT-Kanpur.

Course Outcomes		Level
CO-1	Revision of Newton's laws, explain fundamental concepts of dynamics such as reference frames and Galilean transformations, including their applications in various coordinates.	**Understand, Remember**
CO-2	Apply laws of motion and conservation principles to systems of particles and solve problems involving collisions and center of mass.	**Apply**
CO-3	Analyze simple harmonic motion, damped and forced oscillations, and interpret resonance and energy dissipation phenomena.	**Analyze**
CO-4	Calculate moment of inertia and apply concepts of rotational dynamics, Coriolis force, and gravitation to physical systems.	**Apply**
CO-5	Evaluate the postulates of special relativity and solve problems using Lorentz transformations and relativistic mechanics.	**Understand, Evaluate**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	1	2	3	1
CO-2	1	3	3	1	2
CO-3	1	1	3	1	2
CO-4	2	1	2	1	3
CO-5	3	2	3	1	2

Course Code : PHY5032
Course Title : Mechanics Laboratory
Course Type : Practical (Core)
Credits : 02 (60 Hours)

List of Experiments

1. Calculation of Moment of Inertia Using Torsional pendulum
2. Verification of Centripetal force
3. Verification of conservation of momentum and energy using collision experiment.
4. Finding time period and acceleration due to gravity using simple pendulum and compound pendulum
5. Determination of wavelength of the sound using resonance of an air column and water column
6. To determine Young's modulus - cantilever bending
7. To determine Young's modulus - Koeing's method
8. Determination of viscosity by Poiseullie's flow method.
9. Determination of viscosity by Stokes' method.
10. Verification of principle of projectile motion (determination of range, time of flight, etc.)
11. Michelson Interferometer.
12. Virtual/Simulation experiment for relativity.

Course Code : PHY5033
Course Title : General Physics
Course Type : Theory (Minor)
Credits : 03 (45 Hours)

General Physics (Minor Course for other branches)

Prerequisite: Mathematics at the level of Higher Secondary

Unit 1

Thermal Physics: Thermodynamic Equilibrium, Concept of Temperature, Constant Volume Gas Thermometer, Concept of Work and Heat, State Functions, Laws of Thermodynamics, Internal Energy, Entropy, Thermodynamics processes, Isothermal, Adiabatic, Isobaric, and Isochoric processes, General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes. Conversion of Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine and efficiency

Unit 2

Waves and Optics: simple harmonic motion (SHM) – composition of two SHMs in a straight line and at right angles. Introduction to transverse and longitudinal waves, waves in stretched strings, Doppler effect and its applications, Superposition of coherent and incoherent waves, conditions for interference, Young's double-slit experiment, Double beam interference from thin film, Newton's rings, – air wedge – determination of diameter of a thin wire by air wedge, diffraction of light versus sound – normal incidence.

Unit 3

Atomic Physics: Atomic structure, Bohr model of Hydrogen atom, Atomic mass, reduced mass, Rydberg constant and wave number, correspondence principle. Somerfield's atom model and explanation of fine structure of H line in Balmer series of hydrogen atom and its limitations. Spectral line width and intensities Stark effect, Normal Zeeman effect, Stern-Gerlach experiment, Concept of spin, Pauli's exclusion principle.

Unit 4

Nuclear Physics: Nuclear constituents, mass, size and density, mass defect, binding energy, isobar, isotope and isotone, nuclear models (brief introduction to liquid drop and shell model), radioactivity: Alpha and Beta decay, properties of Alpha, Beta, and Gamma rays, Determination of E/M of Alpha particles, nuclear detector: Law of radioactive disintegration, Half-life period and carbon dating.

Unit 5

Solid State Physics: Amorphous and Crystalline Materials, Lattice and Basis, Unit Cell, Miller Indices, Types of Lattices, SC, BCC, FCC structure, nearest neighbor, density and atomic packing fraction, coordination number, spacing between lattice planes, diffraction of X-rays by Crystals, Laue and Bragg's Law, Semiconductors, Band Gap, P and N type semiconductors, p-n junction.

Reference Books:

1. Modern Physics, R. Murugeshan and KiruthigaSivaprasath, S. Chand and Co., 18th Edition (2022).
2. Allied Physics, K. Thangaraj and D. Jayaraman, Popular Book Depot(2004).
3. Textbook of Optics, Brijlal and N. Subramanyam, S. Chand and Co., 25th Edition (2020).
4. Modern Physics, S. Ramamoorthy, National Publishing & Co., (1962).
5. Concepts of Modern Physics, A. Beiser, Tata McGraw Hill Publication, 6th Edition (2006).

6. Fundamentals of Physics, Resnick, Halliday and Walker, John Wiley and Sons (Asia) Pvt. Ltd., 11th Edition (2018).
7. Introductory Nuclear Physics, Kenneth S. Krane, Wiley India Pvt. Ltd, (2008).
8. Concepts of Nuclear Physics, Bernard L. Cohen, Tata McGraw Hill, (1998).
9. Introduction to the Physics of Nuclei & Particles, R. A. Dunlap, Thomson Asia (2004).
10. Introduction to Elementary Particle Physics, D. Griffiths, Harper and Row (1987).
11. Elements of Solid State Physics, J. P. Shrivastava, PHI, 2nd Edition (2006).
12. Problems and Solutions in Solid State Physics, S. O. Pillai, New Age International Publishers (1994).
13. Solid State Physics, Rita John, Tata McGraw Hill Publications (2014).
14. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
15. https://archive.nptel.ac.in/courses/115/104/115104043/?utm_source=chatgpt.comNPTEL course on Nuclear Physics byProf. H. C. Verma, IIT Kanpur

Course Outcomes		Level
CO-1	To know the concepts in thermodynamics and apply it to the simple problems involving ideal gases	Understand, Analyze, Apply
CO-2	To get the ideas of wave theory of light, and understand the concepts of interference, diffraction, and polarization of light waves.	Understand, skill
CO-3	To understand the atomic structure of matter and know the different models of atoms in the development of atomic physics.	Understand, Analyze
CO-4	Learn about nuclear physics and radioactivity of nuclear elements	Understand, Analyze, Apply
CO-5	Get the ideas of crystal structure and basic crystallography	Understand, skill

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	1	2	1
CO-2	3	3	1	2	1
CO-3	3	3	1	2	1
CO-4	3	3	1	1	1
CO-5	3	3	1	1	1

SEMESTER – IV

Course Code : PHY5041
Course Title : Heat and Thermodynamics
Course Type : Theory (Core)
Credits : 03 (45 Hours)

Heat and Thermodynamics

Unit 1

Zeroth & First Law Of Thermodynamics: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics and Concept of Temperature, Constant Volume Gas Thermometer, Concept of Work and Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law and various processes, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient

Unit 2

Second Law of Thermodynamics: Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine and efficiency. Refrigerator and coefficient of performance, 2^{nd} Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

Unit 3

Entropy: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero

Unit 4

Thermodynamic Potentials and Maxwell's Relations: Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. First and second order Phase Transitions with examples, Clausius Clapeyron equations. Joule-Kelvin effect – porous plug experiment – Joule-Thomson effect, liquefaction of gas by Linde's Process – adiabatic demagnetization. Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of C_P-C_V, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases

Unit 5

Kinetic Theory of Gases: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance. Concepts of conduction, convection and radiation.

Reference Books:

1. Heat and Thermodynamics, M. W. Zemansky and R. H. Dittman , Mc-Graw Hill, 7^{th} Ed. (1997).
2. Fundamentals of Statistical and Thermal Physics, F. Reif,, Mc-Graw Hill (1965).
3. Thermodynamics and Introduction to Thermostatistics,H. B. Callen, John Wiley & Sons. 2nd Ed. (1985).
4. Thermodynamics kinetic theory and Statistical Thermodynamics,F. W. Sears and G. LSalinger, Narosa Publishing House (1998).

5. Statistical Mechanics, K. Huang, John Wiley and Sons,2nd Ed. (2008).
6. Statistical Mechanics, B.K. Agarwal and Melvin Eisner, John Wiley and Sons,(1988).
7. An introduction to Thermal Physics, D. V. Schroeder, Oxford Univ. Press (2021).
8. A Treatise on Heat, MeghnadSaha, B.N. Srivastava, Indian Press, 5th Edition (1965).
9. Thermal Physics, S. Garg, R. Bansal, C. Ghosh, Tata McGraw-Hill, 2nd Edition (2001).
10. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, Springer, 1st Ed. (2009).
11. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
12. https://onlinecourses.nptel.ac.in/noc24_ph17/previewNPTEL course on Thermal
13. Physics by Prof. Debamalya Banerjee, IIT Kharagpur
14. https://ocw.mit.edu/courses/3-020-thermodynamics-of-materials-spring-2021/
15. Thermodynamics. S.R. Kale,https://onlinecourses.nptel.ac.in/noc25_me78/preview.
16. https://www.physics.ox.ac.uk/system/files/file_attachments/basic_thermo.pdf

Course Outcomes		Level
CO-1	Understand concept of laws of thermodynamics	**Understand**
CO-2	Understand the concept of entropy and its importance in thermodynamics system.	**Understand**
CO-3	Understand the concept of thermos dynamic potentials and its importance	**Understand/ Analyze**
CO-4	Analyze the different thermodynamics effects	**Analyze**
CO-5	Thermodynamics concepts in theory of gases	**Analyze**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	1	1	1	2	1
CO-2	3	1	1	2	1
CO-3	2	2	1	2	1
CO-4	2	2	1	2	1
CO-5	2	2	1	2	1

Course Code :PHY5042
Course Title :Electricity and Magnetism
Course Type : Theory (Core)
Credits : 03 (45 Hours)

Electricity and Magnetism

Unit 1

Electrostatics: Inverse square law, Electric field and intensity, Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. Conservative nature of Electrostatic Field. Electrostatic Potential. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole.

Unit 2

Electrostatic Energy of System of Charges: Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Parallel-plate capacitor. Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric.

Unit 3

Magnetostatics: Magnetic force between current elements and definition of Magnetic Field B Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its applications. Torque on a current loop in a uniform Magnetic Field. Magnetization and Magnetic Susceptibility, Scalar Potential and Vector potential

Unit 4

ACCircuts and Network Theorems: AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit. Peak, average and RMS values of ac current and voltage. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem.

Unit 5

Maxwell's Equations: Introduction to Maxwell's Equations and its importance in Free space and medium.

Reference Books:

1. Introduction to Electrodynamics, D.J. Griffiths, Cambridge University, 5th edition (2023).
2. Fundamentals of Physics, Halliday D, Resnick R and Walker J, Wiley, , Extended 12th edition (2022).

3. Electricity and Magnetism, Purcell EM, Morin DJ, Cambridge University, 3rd edition (2013).
4. Electricity and Magnetism, N.S.Khare and S.S.Srivastava, AtmaRam&Sons, New Delhi, 10th edition (1983).
5. Electricity and Magnetism, R. Murugeshan, S. Chand, 10th edition (2017).
6. https://onlinecourses.nptel.ac.in/noc21_ph05 NPTEL course on Electromagnetism by Prof Nirmal Ganguly, IISER Bhopal
7. https://youtube.com/playlist?list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&si=O3UKWoYfrHv8q_UP Lectures by Prof. Walter Lewin, MIT
8. HyperPhysics Concepts

Course Outcomes		Level
CO-1	Recall & explain the fundamental laws of electrostatics and apply them to compute electric field, potential, force and torque for symmetric charge distributions and electric dipoles.	**Remember/Apply**
CO-2	Compute electrostatic energy and capacitance for isolated and composite systems and analyze how polarization, susceptibility and dielectric constant of materials modify these results	**Understand**
CO-3	Recall basic magnetostatics, determine magnetic fields produced by steady currents using Biot-Savart and Ampère's laws, and evaluate magnetic dipole moments, torques and magnetization parameters in current loops and materials.	**Remember/Apply**
CO-4	Analyse sinusoidal (AC) circuits with complex impedance; calculate resonance, power dissipation, quality factor and bandwidth in series / parallel LCR networks; and verification of circuit theorems.	**Analyze**
CO-5	Formulate Maxwell's equations, derive the electromagnetic-wave equation in free space and material media, and interpret plane-wave solutions.	**Understand**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	3	3	1
CO-2	3	1	3	3	2
CO-3	3	3	3	3	2

CO-4	3	3	3	3	2
CO-5	3	3	2	3	1

Course Code : PHY5043
Course Title : Numerical Methods and Computer programming
Course Type : Theory (Core)
Credits : 03 (45 Hours)

Numerical Methods and Computer Programing

Unit-1

Programming Language*: Introduction to basic computer architecture, Unix System, and languages, variable types, various types operators, function, conditional statements (if-else, for loop, do while), array, Basic i/o: file manipulation (reading and writing).

Approximations and round off errors: Binary and decimal arithmetic, floating point numbers, single and double precision arithmetic, significant digits, true/absolute and truncation errors, general error formulae. Taylor Series – Taylor polynomial approximation and error formula.

Unit-2

Determination of roots of polynomials and transcendental equations: Bisection methods, Newton-Raphson method, Secant method and Bairstow's method.
Solutions of simultaneous linear algebraic equations: Gauss Elimination and Gauss-Siedel iteration methods.

Unit-3

Interpolation: Direct method, Newton's divided difference method, Lagrange method. Least squares approximation, fitting data to a straight line, fitting data to linear combinations of functions.

Unit-4Numerical integration: Midpoint rule, trapezoidal method, Simpson's (1/3 and 3/8) method, Gauss quadrature method.

Unit-5

Numerical differentiation: Backward, Forward and Central difference relations and their uses in Numerical differentiation and integration, Application of difference relations in the solution of partial differential equations. Numerical solution of ordinary differential equations by Euler, Modified Euler method, Runge-Kutta methods (RK2 and RK4).

*****This part should be covered in parallel to the Numerical methods (Unit 1 – 5), so that student can apply the numerical techniques in the laboratory sessions.

Recommended Books:

1. An Introduction to Numerical Analysis, Kendall E. Atkinson, Wiley, 2nd Editio (2008).

2. Computer Oriented Numerical Methods, V. Rajaraman, PHI, 4th Edition (2019).
3. Numerical Methods in Science and Engineering, M.K. Venkatraman, National Publishing Company, Madras, 5th Edition, (1996)
4. Numerical methods,Balaguruswami, TMH, 1st Edition, (2010).
5. Schaum's Outline of Programming with C++, John R Hubbard, McGraw-Hill, 2nd Edition (2000).
6. Numerical Recipes in C++: The Art of Scientific Computing, W.H. Press et al, Cambridge University Press, 2nd Edition (2002).
7. Introduction to computation and programming using Python, John Guttag, MIT Press, 2nd Edition (2016).
8. E-content: https://math.libretexts.org/Workbench/Numerical_Methods_with_Applications_(Kaw)/1%3A_Introduction/1.01%3A_Introduction_to_Numerical_Methods
9. Numerical mathematical analysis, J.B. Scarborough, Oxford & IBH, 6th Edition (2017). Also see the e-book here: https://www.scribd.com/document/729271645/Scarborough-J-B-Numerical-Mathematical-Analysis-1930-1-1

Course Outcomes		Level
CO-1	Taylor series expansion, Root finding methods, numerical methods to solve linear and differential equation, curve fitting and plotting	Understand
CO-2	Root finding methods to get approximated roots of various order polynomials and transcendental equations, Gauss elimination method for solving SLE and finding determinant and inverse of matrix, Euler and Runge-Kutta method for finding solutions for ODE and for IVP frequently used in Physics.	Apply
CO-3	Analyze how considering higher order terms reduces approximation error in Taylor polynomial and numerical differentiation.	Analyze
CO-4	Apply the numerical methods though computer program	Apply
CO-5	Solve numerical problems related to finding roots of polynomial and transcendental equations, SLE and ODE IVP.	Evaluate

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	3	1
CO-2	3	3	3	3	1
CO-3	3	3	3	3	1
CO-4	3	3	3	3	1
CO-5	3	3	3	3	1

Course Code : PHY5044
Course Title : Heat and Thermodynamics Laboratory
Course Type : Practical (Core)
Credits : 02

List of Experiments

1. Thermometry - Measuring temperature using different thermometers such as (a) alcohol (b) mercury (c) IR (contact less) (d) digital (e) min-max (f) dry-wet (for humidity).
2. Verification of Newton's law of cooling.
3. Determination of thermal conductivity of a good conductor by Searle's method.
4. Determination of thermal conductivity of a bad conductor by Lee's Disc method.
5. Determination of Specific heat by method of mixtures.
6. Verification of Stefan-Boltzmann law.
7. Determination of Mechanical equivalent of heat using Joule’s experiment.
8. Verification of Seeback effect using thermocouple.
9. Determination of Latent heat of steam/ice.
10. Verification of Boyle's law.
11. Determination of Emissivity of a surface using a spherical calorimeter.

Course Code : PHY5045
Course Title : Electricity and Magnetism Laboratory
Course Type :Practical (Core)
Credits : 02

List of Experiments

1. Study of Resonance in LCR Circuits to find out resonance frequency and quality factor.
2. Study of Charging and discharging of Capacitor.
3. Comparison of Capacitance using Ballistic Galvanometer
4. Measurement of Inductance using Ballistic Galvanometer
5. Determination of unknown capacitance of a capacitor using De Sauty’s bridge
6. Measurement of inductance of a coil using Owen’s Bridge
7. Determination of specific resistance of the given material.
8. Verification of Kirchoff’s laws.
9. Verification of maximum power transfer theorem
10. Determination of low resistance using Kelvin double bridge method.
11. Determination of earth magnetic field.

Reference Books:

1. Virtual labs, https://www.vlab.co.in/
2. Brijlal and Subramaniam, “Electricity and Magnetism
3. Jacob Millman and Christos C Halkias, “Electronic Devices and Circuits”, Tata McGraw Hill Edition, 1991

Course Outcomes		Level
CO-1	Students can understand the fundamentals of electricity and magnetism	**Fundamental**
CO-2	Students can easily understand those experiments	**Understanding**
CO-3	Students can utilize the instrumental facility to do the experiments	**Utilizing**
CO-4	Students can do this practical experiments with various options to get	**Developments**
CO-5	Students can develop their self-knowledge to think for the innovative Ideas	**Higher study**

Mapping of Program Outcomes with Course Outcomes

Map course outcomes (CO) for each course with program outcomes (PO) and program specific outcomes (PSO) in the 3-point scale of STRONG (3), MEDIUM (2) and LOW (1).

Course Outcomes	Program Outcomes				
	Po-1	**Po-2**	**Po-3**	**Po-4**	**Po-5**
CO-1	3	3	2	3	1
CO-2	2	3	3	3	1
CO-3	3	3	3	3	1
CO-4	2	3	3	3	2
CO-5	3	3	1	3	2

Course Code : PHY5046
Course Title : Computer programing Laboratory
Course Type : Practical (Core)
Credits : 02

List of experiments:

1. Simple programs with basic arithmetic operations and conditional statements.
2. Find out the factorial of a given integer.
3. Find out the approximate value of sin(x), cos(x) using Taylor polynomial method.
4. Determination of root of a polynomial by Bisection method, Secant method and Newton-Raphson method.
5. Solution of linear simultaneous equations by Gauss-Elimination method.
6. Solution of ordinary differential equations: Euler's I & II method, Runge-Kutta (RK2 & RK4) method.
7. Numerical Integration-1: Midpoint method & Trapezoidal method.
8. Numerical Integration-2: Simpson's method, Gauss Quadrature method.
9. Interpolation: Newton's divided difference method and Lagrange method.
10. Basic program to read a data file and file manipulation (e.g. Grading of students using the data file of their marks secured in various subject).

Recommended Books:

1. An Introduction to Numerical Analysi, Kendall E. Atkinson, 2008, 2nd Edition Wiley.
2. Computer Oriented Numerical Methods, V. Rajaraman, 2019, 4th Edition, PHI
3. Numerical Methods in Science and Engineering, M.K. Venkatraman, 1996, 5th Edition, National Publishing Company, Madras.
4. Numerical methods by Balaguruswami, 2010, 1stEdition, TMH.
5. Schaum's Outline of Programming with C++, John R Hubbard, 2000, 2nd Edition, McGraw-Hill.
6. Numerical Recipes in C++: The Art of Scientific Computing, W.H. Press et al, 2002, 2nd Edition, Cambridge University Press.
7. Introduction to computation and programming using Python, John Guttag, 2016, 2nd Edition, MIT Press.
8. E-content for C++ programming: https://indico.cern.ch/event/782305/contributions/3256009/attachments/1793528/2922655/C_ESIPAP.pdf
9. E-content for numerical methods (Python): https://pythonnumericalmethods.studentorg.berkeley.edu/notebooks/Index.html

Course Outcomes		Level
CO-1	Program structure, use of variables, conditional statements, function, various operators, one and multi-dimensional array.	Understand
CO-2	Student will develop algorithm to solve various numerical techniques to find out the root of equations, solutions for ODE in IVP, numerical integration and interpolation of a given data.	Apply
CO-3	Analyze the flow of the program, nested for loop, function overload, manipulation of mulit-dimensional array	Analyze
CO-4	Apply the numerical methods though computer program to solve SLE, matrix inversion.	Apply
CO-5	Skill to learn programing language (C++/Pyhton), designing algorithm and to solve numerical problems using computer programs.	Skill

Course Outcomes	**Program Outcomes**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	3	1
CO-2	3	3	3	3	1
CO-3	3	3	3	3	1
CO-4	3	3	3	3	1
CO-5	3	3	3	3	1

SEMESTER - V

Course Code : PHY5051
Course Title : Mathematical Methods in Physics
Course Type : Theory (Core)
Credits : 04 (60 Hours)

Mathematical methods in Physics

Unit 1

Partial Differentiation: Functions of more than one variable, partial derivatives, notations. Power series in two variables, total differentials, approximations using differential. Differentiation of a function of function (chain rule), Implicit differentiation, constrained maximization and Lagrange multipliers, change of variables, differentiation of Integrals (Leibniz's rule).

Unit 2

Vector Analysis: Recap of Vectors and scalars, scalar product, vector product, triple product, gradient, divergence and curl. Invariances, vector differentiation, del and Laplacian operators, Gauss' divergence theorem, Green's and Stokes theorems and their applications. Curvilinear coordinates: polar, spherical polar and cylindrical, and basis line element, area element, volume element, Jacobian.

Unit 3

Differential Equations: Ordinary differential equations: exact equations, integrating factors, Bernoulli's equation; Second-order equations with constant coefficients, general solutions, complementary function, particular integral, Wronskian, rules for D operators, Euler equation, power series solutions, Frobenius Method.

Partial differential equations: First order PDE and solution using variable separable method, Linear second-order partial differential equations, classification of PDEs, Laplace's equation, the wave equation, Poisson's equation, Diffusion equation.

Unit 4

Matrix Algebra: Definition of a matrix, addition and multiplication of matrices, the commutator, transpose of a matrix, symmetric and skew-symmetric matrices, Hermitian and anti-Hermitian matrix, orthogonal matrix, unitary matrix, trace of a matrix, rotation matrices, the inverse of a matrix, systems of linear equations, eigen-values and eigenvectors, Cayley-Hamilton theorem, diagonalization of a matrix, powers of a matrix, functions of matrices.

Unit 5

Special Functions: Gamma function, Legendre, Hermite, Laguerre function Generating function, Recurrence relations and their differential equations Orthogonality of eigenfunctions Bessel's function of first kind, Spherical Bessel function, Associated Legendre function, Spherical harmonics.

References:

1. Mathematical methods in Physical sciences, Mary L Boas, Wiley, 3ed (2023)
2. Mathematical Methods for Physicists – G. B. Arfken, Hans J. Weber, Academic Press, 7th Edition, 2012.
3. Mathematical Methods for Physics and Engineering – K. F. Riley, M. P. Hobson, S. J. Bence, Cambridge University Press, 3rd Edition, 2006.
4. Mathematical Physics – V. Balakrishnan, Ane Books, 1st Edition, 2007.
5. Advanced engineering mathematics, E. Kreyszig, John Wiley & Sons, 10ed (2011)
6. https://archive.nptel.ac.in/courses/115/105/115105097/
7. https://archive.nptel.ac.in/courses/111/106/111106148/

Course Outcomes		Level
CO-1	Apply techniques of partial differentiation including total differentials, chain rule, implicit differentiation, and Lagrange multipliers.	**Apply / Analyze**
CO-2	Evaluate and manipulate vector fields using gradient, divergence, and curl; and apply Gauss, Green, and Stokes theorems in physical contexts.	**Analyze / Apply**
CO-3	Solve ordinary and partial differential equations using analytical methods such as separation of variables, Frobenius method, and classification of PDEs.	**Apply / Analyze**
CO-4	Perform algebraic operations on matrices and solve linear systems; determine eigenvalues/eigenvectors and diagonalize matrices.	**Understand / Apply**
CO-5	Derive and use properties of special functions such as Bessel, Legendre, Hermite, and Gamma functions in solving physical problems.	**Apply / Analyze**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	3	3	3	1
CO-3	3	3	2	3	1
CO-4	3	2	2	3	1
CO-5	3	3	2	3	1

Course Code : PHY5052
Course Title : Classical Mechanics
Course Type : Theory (Core)
Credits : 04 (60 Hours)

Classical Mechanics

Unit 1

Lagrangian Dynamics: System of particles-Constraints and degrees of freedom, Generalized Coordinates, Concept of virtual work, D'Alembert Principle, Lagrange equation from D'Alembert principle, Application of Lagrange equations of motion -Free particle motion in 2D and 3D - plane polar coordinates and spherical polar coordinates, Atwood's machine – Bead sliding in a rotating wire, Simple pendulum, Compound pendulum

Unit 2

Hamiltonian Dynamics: Hamiltonian function, Legendre transformation, Hamilton's canonical equation of motion, Physical significance, Phase space, Application of Hamilton's equation of motion – Linear harmonic oscillator, Simple pendulum, Pendulum suspended from a massless spring, Pendulum with a moving point of support, Compound pendulum, Motion of a particle in a central force field, Cyclic co-ordinates and conservation theorem, Calculus of Variation-Hamiltonian's Variation principle.

Unit 3

Central Force Problem: Central force and motion in a plane, Reduction of a two-body central force to equivalent one body problem, Equation of motion and first integral, Differential equation for an orbit, Equivalent one-dimensional problems with effective potential, Classification of orbits for some specific potential. Integral power law potential, Virial theorem, Keplers Problems: Scattering in a central force field-transformation of Scattering to Laboratory co-ordinates

Unit 4: Kinematics of Rigid Body: Independent co-ordinate of a rigid body, Orthogonal transformation, Formal properties of transformation matrix, Euler angles, Euler's theorem, Finite rotation, Infinitesimal rotations (contact transformation). Angular momentum, Moment of inertia tensor, Kinetic energy of motion of a rigid body about a point; Euler's equation of motion-Torque free motion of a rigid body-heavy Symmetrical top.

Unit 5

Canonical Transformation and Hamilton-Jacobi Theory: Canonical transformation, Generating functions, Conditions for canonical transformation, Poisson's brackets, Langrange brackets, Invariance of Poission bracket under canonical transformation, Angular momentum Poission bracket relation. Hamilton Jacobi equation for Hamilton's principal function, Harmonic oscillator problem by Hamilton Jacobi method, Small oscillations-Normal co-ordinates-Normal frequencies of vibrations -Vibrations of linear triatomic molecule

Reference Books:

1. Classical Mechanics, H. Goldstein, Narosa Publishing House, 3rd Edition (2001).
2. Classical Mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill Education, 1st Edition (1991).
3. Classical Mechanics, J. C. Upadhyaya, Himalaya Publishing House, 1st Edition (2006).
4. Classical Mechanics, P. V. Panat, Narosa Publishing House, 1st Edition (2000).
5. Classical Mechanics, S. L. Gupta, V. Kumar, and H. V. Sharma, Pragati Prakashan, 1st Edition (2009).
6. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

7. https://archive.nptel.ac.in/courses/122/106/122106027/NPTEL course on Classical Physics by Prof. V. Balakrishnan, IIT Madras.
8. https://onlinecourses.nptel.ac.in/noc22_ph28/preview?utm_source=chatgpt.com NPTEL course on Introduction to Classical Mechanics by Prof. Anurag Tripathi, IIT Hyderbad

Course Outcomes		Level
CO-1	To gain deeper understanding of the basic classical mechanics principles such as constraints, generalised coordinates, D'Alemberts principle, Lagrangian and Hamiltonian formulations.	**Remember**
CO-2	To be able to formulate and solve the problems on canonical transformations, Poisson brackets and Harmonic oscillators.	**Understand**
CO-3	To understand the theory of small oscillations which is important in several areas of physics e.g., motion of masses connected by springs –vibrations of linear triatomic molecule and coupled mechanical oscillators.	**Apply**
CO-4	To understand the motion of rigid body and essential features of a problem (like motion under central force, rigid body dynamics, periodic motions), use them to set up and solve the appropriate mathematical equations.	**Analyze**
CO-5	To solve the Central Force Problem and understanding the concept of special theory of relativity.	**Skill**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	**Program Outcomes**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	0	3	3
CO-2	3	1	3	3	3
CO-3	3	3	3	3	2
CO-4	2	1	3	2	3
CO-5	0	3	3	3	2

Course Code : PHY5053
Course Title : Quantum Physics and its Applications
Course Type : Theory (Core)
Credits : 04 (60 Hours)

Quantum Physics and its Applications

Unit 1

Classical to Quantum Mechanics: Difficulties of classical physics and origin of quantum theory, black body radiation, Compton effect, Double slit experiment with light, de Broglie waves, phase velocity and group velocity, Davisson and Germer's experiment, uncertainty principle – consequences.

Unit 2

Time Dependent Schrodinger Equation: Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum, Ehrenfest theorem. Wave Function of a Free Particle.

Unit 3

Time Independent Schrodinger Equation: Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle.

Unit 4

Solving Schrodinger Equation for Simple Problems: Continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problems: (i) free particle: continuous state, (ii) step potential (Energy less than step height and energy more than step height), (iii) Finite Square well potential (scattering & bound state solutions)(iv) Infinite square well potential (asymmetric & symmetric), (v) barrier penetration problem – quantum mechanical tunneling, (vi) linear harmonic oscillator

Unit 5:

Application to Atomic Physics: Orbital angular momentum: eigenvalue and eigenfunctions, spherical harmonics, space quantization, energy quantization, radial wavefunction, centrifugal barrier, quantum numbers, hydrogen spectrum, vector atom model, magnetic moment, Stern-Gerlach experiment, concept of spin, spin orbit interaction, fine structures of hydrogen spectrum.

Reference Books:

1. Introduction to Quantum Mechanics, D. J. Griffiths and D. F. Schroeter, Cambridge University Press, 3rd Edition (2018).
2. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, R. Eisberg and R. Resnick (John Wiley & Sons).
2. Quantum Mechanics: Concepts and Applications, NouredineZettili, John Wiley & Sons, 2nd Edition (2009).
3. A Textbook of Quantum Mechanics, P. M. Mathews and K. Venkatesan, Tata McGraw-Hill, 2nd Edition (2010).

4. Quantum Mechanics (Vol. 1), Claude Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Wiley-VCH, 2nd Edition (2006).
5. Quantum Mechanics (Vol. 2), Claude Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Wiley-VCH, 2nd Edition (2006).
6. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
7. https://nptel.ac.in/courses/115106066NPTEL course on Quantum Mechanics-An Introduction byProf. S. Lakshmi Bala, IIT Madras.
8. https://onlinecourses.nptel.ac.in/noc24_ph15/previewNPTEL course on Quantum Mechanics by Prof. P. Ramadevi, IIT Bombay.

Course Outcomes		Level
CO-1	Explain the failure of classical physics and the origin of quantum concepts like black body radiation, photoelectric effect, and uncertainty principle.	**Understand / Analyze**
CO-2	Formulate and interpret the time-dependent Schrödinger equation and its implications on the evolution of quantum states.	**Apply / Analyze**
CO-3	Solve the time-independent Schrödinger equation for stationary states and apply the uncertainty principle in wave packet analysis.	**Apply / Analyze / Evaluate**
CO-4	Apply boundary conditions to solve quantum mechanical problems like particle in a box, step potential, and harmonic oscillator.	**Apply / Analyze**
CO-5	Analyze many-electron systems, atomic spectra, and fine structure using principles of quantum mechanics and angular momentum theory.	**Understand / Analyze**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	2	1
CO-2	3	3	2	3	1
CO-3	3	3	2	3	1
CO-4	3	3	2	3	1
CO-5	3	3	3	3	1

Course Code : PHY5054
Course Title : Solid State Physics
Course Type : Theory (Core)
Credits : 04 (60 Hours)

Solid State Physics

Unit 1

Bonding in Solids: Inter-atomic potentialsand bonding in solids; Types of bonds in crystals - Ionic, covalent, Metallic, van der Waal's and Hydrogen Bonding - Bond energy of sodium chloride molecule - variation of interatomic force with interatomic spacing - cohesive energy of ionic solids - application to sodium chloride crystal - evaluation of Madelung constant for sodium chloride.

Unit 2

Crystal Structure & Crystal Diffraction: Amorphous and Crystalline Materials. Lattice; Basis (atoms, molecules, electric and magnetic dipoles etc) – Primitive and unit cell-seven classes of crystal-Bravais Lattice -Structure of crystals: Simple cubic, Face centered cubic, Body centered cubic and Hexagonal close packed structure. Miller Indices, Wigner -Seitz cell - Reciprocal lattice - application to diffraction - Brillouin Zones. diffraction methods for structure determination. Bragg's Law. Atomic and Geometrical Factor; Structure factor. Radial distribution function; Laue method, powder method and rotating crystal method

Unit 3

Lattice Dynamics: Elastic properties - Quantization of elastic waves,; - Theory of elastic vibrations in mono and diatomic lattices - phonons – vibrations and thermal properties of solids - Dispersion relations - Phonon momentum and inelastic scattering by phonons. - lattice specific heat – Dulong and Petit's law - Vibrational modes - Einstein model - Density of modes in one and three dimensions - Debye Model of heat capacity - Anharmonic Effects - Explanation for Thermal expansion, Conductivity and resistivity – Umklapp process.

Unit 4

Magnetic Properties of Solids: Magnetization – Dia-, Para-, antiferro, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of diamagnetism, Temperature dependence of Magnetization - Curie's law, Weiss's Theory of Ferromagnetism - Curie-Weiss law for susceptibility- Ferromagnetic Domains - Bloch wall - domains and magnetic anisotropy; B-H Curve- Hysteresis and Energy Loss.

Unit 5

Dielectric Properties of Materials: Relation among E, D &P Polarizability - frequency and temperature effects on polarization-dielectric loss. Local Electric Field. Clausius-Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion, Langevin-Debye equation. Dielectrics in a.c. fields

Reference Books:

1. Introduction to Solid State Physics, Charles Kittle, Wiley Publication (2019).

2. .Solid State Physics by S.O.Pillai, New Age International (P) Ltd.,(2002).

3. Solid State Physics by A. J.Dekker, Macmillan India(1985).

4. Solid State Physics by HC Gupta, Vikas Publishing House Pvt. Ltd., New Delhi (2001).

5. Solid State Physics, Rita John, Tata McGraw Hill Publications (2014).

Course Outcomes		Level
CO-1	To get knowledge about various aspects of chemical bonding and understand the formation of solids with various crystal structures and symmetries.	UnderstandAnalyse,
CO-2	Apply the knowledge to resolve the crystal structure of solids through XRD and structural characterization tools.	Remember, Evaluate, Analyse, Skill
CO-3	Understand the concept of phonons and their role on specific heat of solids. Apply the knowledge to analyze the phonon dispersion relation for simple solids. Gain insight into the origin of thermal conductivity, thermal expansion though phonon scattering processes.	Understand, Apply
CO-4	Gain knowledge about the origin of magnetism, ordering of magnetism, and various theory involved in understanding magnetism in solids.	Understand/Analyze/ Apply
CO-5	Understand the concept of electronic polarization and its role on piezoelectricity and ferroelectricity.	Acquire, Understand, Apply

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	2	1
CO-2	2	2	2	2	1
CO-3	3	3	2	2	1
CO-4	2	3	2	2	1
CO-5	3	2	2	2	1

Course Code : PHY5055
Course Title : Solid State Physics Laboratory
Course Type : Practical (Core)
Credits : 02 (60 Hours)

List of experiments:

1. Study of behaviour of para-, dia- and ferromagnetic materials in presence of external magnetic field.
2. Calculation of lattice parameters of unit cell of given system using XRD data.
3. Determination of the Magnetic susceptibility of Solids.
4. To determine the coupling coefficient of a Piezoelectric crystal.
5. B-H curve
6. Study of the frequency dependence of Dielectric Constant of a dielectric Material.
7. Study of P-E Hysteresis loop of a Ferroelectric Crystal.
8. Phase transition of dielectric materials.
9. Determine band gap from temperature dependent resistivity of a semiconductor (Ge) crystal using two-probe method
10. To determine the Hall coefficient of a semiconductor sample
11. To measure the transition temperature of a high temperature superconductor.
12. Estimation of surface plasmon resonance frequency.

Course Code : PHY5056
Course Title : Mathematical Methods Practical
Course Type : Practical (Core)
Credits : 02 (60 Hours)

The following experiments can be performed using any open source programming languages.

1. Solution of First order differential equation:
- Radioactive decay
- Current in RC, LC circuits with DC source
- Newton‟s law of cooling
- Classical equations of motion

2. Solution of Second order Differential Equation:
- Harmonic oscillator (no friction)
- Damped Harmonic oscillator
  - o Overdamped
  - o Critical damped
  - o Oscillatory
- Forced Harmonic oscillator
  - o Transient and
  - o Steady state solution

3. Solution of Partial Differential Equation

- Wave equation
- Heat equation
- Poisson equation
- Laplace equation
- Schrodinger Equation

4. Calculate eigenvalues and eigenvectors of a given matrix. Verify linear independence.

Reference Books:

1. Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2. Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3. Schaum's Outline of Programming with C++, J. Hubbard, 2000, McGraw-Hill Education.
4. C++ How to Program, Paul J. Deitel and Harvey Deitel, Pearson (2016).
5. Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
6. Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
7. An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
8. Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
9. Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).

SEMESTER –VI

Course Code : PHY5061
Course Title : Statistical Physics
Course Type : Theory (Core)
Credits : 04 (60 hours)

Statistical Physics

Uniit I

Introduction to Statistical Methods: Elementary statistical concepts and examples; Sample space, Probability theorems, method of countingsPermutation, Combinations; Multiplication and division rules for counting; random variables, discrete and continuous distribution, moments, fluctuations

Unit II

Classical Statistics: Objective of statistical Physics ; microstates and macrostates; Different types of Thermodynamics system and its macrostates with examples. Concept of Probability and ensembles; Probability density; Concept of Phase – Space; Gamma point ; Phase- Space trajectory and its degree of freedom. Phase-Space density and its time evolution; Liouville theorem; Stationary state; Conditions for equilibrium

Unit III

Microcanonical Ensemble: Macrostate of microcanonical ensemble;Postulate of Equal a-priori probabilities; Number of Microstates and its counting for ideal gases; Micro- Macro relation: Boltzmann Entropy; Difference between Statistical entrpy and Thermodynamics entropy. Statistical averages: Simple average and Weighted average; moments and fluctuations; Phase – space of representaion of microcanonical ensemble; Time average; microcanonical ensemble average in Phase-Space. Ergodic Hypothesis (statement only). Statistical definition of temperature and pressure.

Unit IV

Canonical and Grand Canonical Ensemble: Macrostate of canonical and Grand canonical ensemble and its Probability distribution. Boltzman Weight; Gibbs Statistical entropy; Canonical and Grand canonical partition function; Calculation of thermodynamic quantities, energy and density fluctuations. Proper and improper counting; extensive property of statistical entropy, Gibbs Paradox; Sakkur- Tedrode equation; Various thermodynamic potentials and their connection with partition functions. Calculation of thermodynamic quantities for ideal monatomic gases.

Unit V

Origin of Quantum Statistics: Black Body Radiation; Wien's Distribution Law; Rayleigh-Jeans Law; Stefan-Boltzmann Law; Planck's Quantum Postulates. Planck's Law of Blackbody Radiation; Experimental Verification; Quantum Statistics: Bose-Einstein statistics and Fermi-Dirac statistics. Probability distribution of Bosons and Fermions; Bose Einstein condensation (qualitative); Examples illustrating counting procedures for MB, BE and FD statistics. Comparison between the three statistics. Conditions under which the quantum mechanical distribution functions reduce to the classical MB distribution.

Books recommended:

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann, Oxford University Press, 2nd Ed., (1996).

2. Introductory Statistical Mechanics,R. Bowley and M. Sanchez, Oxford University Press,

2nd Ed.,(1999).

3. Fundamentals of Statistical and Thermal Physics, F. Reif,, Mc-Graw Hill (1965).

4. Thermodynamics and Introduction to Thermostatistics,H. B. Callen, John Wiley & Sons. 2nd Ed. (1985).

5. Thermodynamics kinetic theory and Statistical Thermodynamics,F. W. Sears and G. L Salinger, Narosa Publishing House (1998).

6. Statistical Mechanics, K. Huang, John Wiley and Sons,2nd Ed. (2008).

7. Statistical Mechanics, B.K. Agarwal and Melvin Eisner, John Wiley and Sons,(1988).

8. Statistical Physics, Berkeley Physics Course, F. Reif,, Tata McGraw-Hill (2008).

E-content Readings:

1. Lecture Series on Classical Physics: (Lecture1) Introduction and Probability, V. Balakrishnan, (2009). https://www.youtube.com/watch?v=Q6Gw08pwhws

2 Lecture Series on Classical Physics: (Lecture25) Connection between Statistical Mechanics and Thermodynamics, V. Balakrishnan, (2009). https://www.youtube.com/watch?v=-0S0ScEOH5w

3. Lectures on Statistcal Physics, David Tong, http://www.damtp.cam.ac.uk/user/tong/statphys.html(2012).

Course Outcomes		Level
CO-1	Understand concept of counting and Probability	**Understand**
CO-2	Understand concept of ensemble counting and Probability	**Understand**
CO-3	Applying the ensemble concepts to isolated, closed and open thermodynamics system.	**Apply**
CO-4	Remember the conceptof Quantum statistical distribution.	**Remember**
CO-5	Analyze the different statistical distribution	**Analyze**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	1	2	1	2	1
CO-2	1	2	1	2	1
CO-3	2	2	1	2	1
CO-4	2	2	1	2	1
CO-5	3	2	1	2	1

Course Code : PHY5062
Course Title : Atomic and Nuclear Physics
Course Type : Theory (Core)
Credits : 04 (60 Hours)

Atomic and Nuclear Physics

Unit-1

Positive Rays and Photoelectric Effect: e/m of an electron by Dunnington's method – electron theory and applications – important sources of electrons- Practical appliances of electron beams – Sources and properties of positive rays – e/m of positive rays by Thomson's parabola method – Mass spectrographs.

Photoelectric emission – Leonard's experiment – Richardson and Compton experiment –laws of photoelectric emission – Einstein's photoelectric equation –experimental verification by Millikan's method –photoelectric cell– photo emissive cell –photovoltaic cell – photo conducting cell – applications of photoelectric cells –photomultiplier.

Unit-2

Atomic Structure andSplitting of Spectral Lines: Sommerfield's relativistic atom model – vector atom model – various quantum numbers – Spectrum of helium and alkali atom- isotopic shift, width of spectrum lines- L-S and J-J coupling – fine and hyperfine structures- Zeeman, Paschen-Bach and Stark effects- electric dipole transitions and selection rules.

Excitation, ionisation and critical potentials – Davis and Goucher's method – optical spectra – spectral notation and selection rules – fine structure of sodium D-line – Zeeman effect – experimental arrangement and classical theory of normal Zeeman effect – Larmor's theorem – quantum theory of normal Zeeman effect –anomalous Zeeman effect –explanation of splitting of D_1 and D_2lines of sodium – Paschen Back effect - Stark effect.

Unit-3

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, isobar, isotope and isotones, mass spectrometer (Bainbridge spectrometer)

Unit-4

Nuclear Model: Liquid drop model and semi empirical mass formula, evidence for nuclear shell structure, nuclear magic numbers, spin and parity of nuclei, concept of nuclear force. **Radioactivit**y: Laws of radioactivity and Carbon Dating, basics of α-decay processes and Greiger-Nuttall Law, β-decay and neutrino hypothesis, gamma decays: kinematics, internal conversion. **Nuclear reactions**: Conservation Laws, Q-value, type of reaction. Basics of Fission and Fusion reaction, nuclear reactors.

Unit-5

Basic idea about nuclear physics detectors: cloud chamber, bubble chamber and GM counter, Scintillator detector. Linear accelerator, cyclotron and synchrotron.

Basic idea about fundamental particles and forces, quark model (elementary ideas)

Recommended Books:

1. Atomic Physics by J.B. Rajam, S. Chand & Company Ltd., New Delhi, 7th Edition (2007).

2. Fundamentals of Molecular Spectroscopy, Colin N. Banwell and Elaine M. McCash, McGraw-Hill Education Pvt. Ltd, Fourth Edition (2018)
3. Concept of Modern Physics, Arthur Beiser, McGraw Hill, 6th Edition (2009).
5. Brijlal and N. Subrahmanyam, Atomic & Nuclear Physics,S. Chand & Co, Reprint Edition (2006).
6. Introductory Nuclear Physics by Kenneth S. Krane, Wiley India Pvt. Ltd, ,Repreint Edition (2008).
7. Introduction to Nuclear and Particle Physics, Ashok Das and Thomas Ferbel, World Scientific, 2nd Edition (2003).
8. Nuclear Physics: Theory and Experiment, R.R. Roy and B.P. Nigam, New Age International (P) Ltd, 3rd Edition (2023)
9. Nuclear Physics: An Introduction, S.B. Patel,New Age International (P) Ltd, 3rd Edition (2021)
10. Concepts of nuclear physics, Bernard L. Cohen, Tata McgrawHil, Reprint Edition (1974)
11. Techniques for Nuclear and Particle Physics Experiments, W. R. Leo,Springer-VerlagBerlin Heidelberg, 2nd Edition (1994)
12. E-content: https://ibphysics.org/topic7/
13. NPTEL Course: https://archive.nptel.ac.in/courses/115/105/115105100/

Course Outcomes		Level
CO-1	Various classical atomic models and the origin of vector atom models, basic concept of couplings, and demonstrate the splitting of spectral lines under the influence of weak, strong magnetic, and electric fields. Basic idea of Liquid-drop model, Shell model, basic principles of fission and fusion reaction, interaction of radiation with matter, basic working principles of nuclear reactors, accelerators and radiation detectors, basic nature of fundamental forces.	Understand
CO-2	Find out the stability of nucleus using liquid drop models, Shell model to find nuclear spin, principle of fission used for nuclear reactors, energy generation in stars due to fusion reaction.	Apply
CO-3	Splitting of spectral lines under the influence of electric and magnetic fields. Differentiate the fine structure and hyperfine structures. Single particle Shell model of nuclei	Analyze
CO-4	Binding energy of nucleus, matter-particle interaction mechanism to characterise the GM counter, laws of radioactivity, energy resolution of the scintillator detector, identifying an unknown radiative source.	Apply
CO-5	Spin and parity of nuclei, half-life and age of a radioactive sample, Q-value of a nuclear reaction.	Evaluate

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	1	3	3	1
CO-3	3	2	1	2	1
CO-4	3	2	2	3	1
CO-5	3	2	2	2	1

Course Code : PHY5063
Course Title : Electronics
Course Type : Theory (Core)
Credits : 04 (60 Hours)

Electronics

Unit-1

Diodes and Transistors: P-N junction diode and its V-*I* Characteristic of a Diode; Diode applications (LED, Solar cells); Junction Transistors: Basic Bipolar Junction Transistor (BJT) structure -Operation, Characteristics, and Parameters; Transistor biasing-Base Resistor Method, Collector feedback resistor method; voltage divider method; Junction Field Effect Transistor (JFET): Characteristics and Parameters;Metal-oxide-semiconductor field-effect transistor (MOSFET): Characteristics and Parameters

Unit-2

Transistors Applications: Amplifiers- Single stage transistor amplifier, dc and ac equivalent circuits; load line analysis; operating point, voltage gain; classification of amplifiers; Multistage Amplifiers: RC coupled Transistor amplifiers; Transformer coupled Amplifiers; Direct coupled Amplifiers; Feedback Amplifiers

Oscillators: Tank Circuit; Colpits, Hartley and Phase-shift Oscillator

Unit-3

Operational amplifiers and their applications: Op-Amp: Construction of inverting and non-inverting op-amp; concept of virtual ground; impedance; common mode and differential mode of signals, open loop and closed loop gain; OP-Amp with negative feedback-inverting amplifier and non-inverting amplifiers, voltage followers

Applications: Summing Amplifier, Average Amplifier, Integrator and Differentiator, comparator

Unit-4

Logic Gates and Sequential Circuits: Basic logic gates(OR, AND, NOT) -universal logic gates (NAND and NOR); S-R Flip-flop , J-K Flip-flop, T and D type flipflops, master-slave flip-flop, truth tables; Registers: Types – Serial In-Serial Out, Serial In-Parallel Out, Parallel In-Serial Out, and Parallel In-Parallel Out, and Application. Counters: Asynchronous and Synchronous counters. Comparators.

Unit-5

A/D and D/A converters Microprocessor and microcontroller basics:D/A converters: Weighted-resistor D/A converter – R-2R ladder D/A converter – Specifications. A/D converters: Flash A/D converter – Successive Approximation method

Introduction to Microprocessor and Microcontroller Architectures; assembly language programming using 8085 for addition and subtraction

Recommended Books:

1. Electronic devices and circuit theory, R. Boylestad and L. Nashelsky, Prentice Hall , Seventh edition (1998)
2. Principles of electronics, V.K. Metha and Rohit Metha, S. Chand and Company, Eleventh Edition (2008)
3. Microelectronics: Circuit analysis and design, Donald A. Neamen, Mc Graw Hill, Fourth edition (2010)
4. Digital fundamentals, Thomas L. Floyd, Pearson eleventh edition (2015)

5. Digital electronics: Principles, Devices and Applications,Anil K. Maini, JohnWeily and Sons (2007)
6. Microprocessor Architecture, programming, and applications with 8085, Ramesh S. Gaonkar, Prentice Hall ,Fifth edition (2002)
7. https://archive.nptel.ac.in/courses/108/106/108106188/
8. https://onlinecourses.nptel.ac.in/noc22_ee55/preview
9. https://onlinecourses.nptel.ac.in/noc22_ee12/preview

Course Outcomes After the success of the completion of the course, the students' ability to		Level
CO1	Working principle of diodes, transistor and amplifier	Understand
CO2	Construction of electronic circuits using OP-AMPS for mathematical operations	Skill
CO3	Gain knowledge about logic gates and their implementation in construction of adders and substractors.	Apply
CO4	Able to understand Register, counters & A/D convertors and use them in electronic circuits	Understand &Apply
CO5	Assembly language programming on 8085 microprocessor.	Apply

Mapping of Program Outcomes with Course Outcomes

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	2	1
CO-2	3	3	2	3	1
CO-3	3	3	2	2	1
CO-4	2	3	3	3	1
CO-5	3	2	2	3	1

Course Code :PHY5064
Course Title : Atomic and Nuclear Physics Laboratory
Course Type : Practical (Core)
Credits : 02(60 Hours)

List of experiments:

1) Investigating electron energy levels in atoms using Photoelectric effect.
2) Estimation of e/m using Milikan's oil drop experiment.
3) Study of photoconductivity of a photodiode.
4) Study of fine-structures in sodium.
5) Study the spectrum of atomic hydrogen.
6) Characterization of GM counter and study of nuclear counting statistics.
7) Study of nuclear counting statistics.
8) Verification of Inverse Square law for gamma rays.
9) Determination of absorption co-efficient of Al using GM counter.
10) Estimation of the efficiency of GM tube for (a) Beta source (b) Gamma source.
11) Study of energy resolution characteristics of the scintillation detector.
12) Calibration of the Gamma ray spectrometer.
13) Determine the energy of unknown gamma radiation.

Course Code : PHY5065
Course Title : Electronics Laboratory
Course Type : Practical (Core)
Credits : 02(60 Hours)

List of experiments:

1. A study of Transistor Characteristics (a) CB, (b) CE and (c) CC.
2. Studies on BJT CE amplifier.
3. Study of determination of frequency of oscillations using Hartley Oscillator.
4. Construction of inverting and non-inverting amplifier.
5. Study of summing and average amplifier.
6. Study of Integrator and differentiator using OPAMP.
7. Verification of OR, AND, NOT, XOR, NOR, and NAND gates operations.
8. Construction of Op-Amp- 4 bit Digital to Analog converter (Binary Weighted and R/2R ladder type).
9. Study of R-S, clocked R-S and D-Flip flop using NAND gates.
10. Study of Half adder / Half subtractor using basic logic gate ICs.
11. Construction of seven segment display.
12. Verification of arithmetic operations (addition, and subtraction) with Microprocessor 8085.

SEMESTER - VII

Course Code : PHY5071
Course Title : Mathematical Physics -I
Course Type : Theory (Core)
Credits : 04(60 Hours)

Unit 1

Function of Real Variables: Features of a function, sketching functions, interpreting graph of functions using the concepts of calculus. Functions represented by integrals -, Gaussian integral in 1, 2 and 3 dimensions, step function θ, Dirac delta function – Defining relation, sequences of function tending to δ-function, relation between θ and δ function, properties of Dirac delta function, derivative of δ-function.

Unit 2

Linear Vector Spaces: Linear Vector Spaces and its dual, Linear Dependence and Independence of vectors, Basis and Dimensions, Infinite dimensional vector space- Hilbert space, subspace, space of square integrable functions, Orthogonal Vectors, Orthogonal Basis, Gram-Schmidt process of generating an Orthonormal Basis, Change of basis, singular value decomposition. Linear Transformations. Representation of Linear Transformations by Matrices. Inner Product. Similarity transformation.

Unit 3

Curvilinear Coordinates: Orthogonal coordinate systems, Gradient, Curl, Divergence and Laplacian in orthogonal coordinate systems, Spherical, Polar and Cylindrical co-ordinates, Poisson's and Laplace Equations. Coordinates Transformation in N- dimensional Space

Unit 4

Fourier Series, Transform and Application: Fourier series, orthogonality of functions, Dirichlet conditions. Application: Summing of Infinite Series. Fourier integral theorem, Fourier transform, Parseval's identity, convolution theorem, transform of derivates, Fourier transforms of simple function occurring in physical application.

Unit 5

Laplace Transform and Its Application: Laplace Transform (LT) of Elementary functions. Properties of LTs, Change of Scale, Shifting. LTs of Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Periodic Functions. Convolution Theorem. Inverse LT. Evaluation of inverse Laplace transform using counter integration. Application of Laplace Transforms to 2nd order Differential Equations, Coupled differential equations of 1st order.

Reference Books:

1. Mathematical methods in Physical sciences, Mary L Boas, Wiley, 3ed (2023)
2. Mathematical Methods for Physicists – G. B. Arfken, Hans J. Weber, Academic Press, 7th Edition, 2012.
3. Mathematical Methods for Physics and Engineering– K. F. Riley, M. P. Hobson, S. J. Bence, Cambridge University Press, 3rd Edition, 2006.
4. Mathematical Physics – V. Balakrishnan, Ane Books, 1st Edition, 2007.
5. Advanced engineering mathematics, E. Kreyszig, John Wiley & Sons, 10ed (2011)
6. https://archive.nptel.ac.in/courses/115/105/115105097/
7. https://archive.nptel.ac.in/courses/111/106/111106148/
8. https://www.youtube.com/playlist?list=PLbMVogVj5nJRhl_6TUGChpnt2Lg0AZvZu

Course Outcomes		Level
CO-1	Interpret and analyze real-valued functions and their representations using calculus, Gaussian integrals, and Dirac delta functions.	**Understand / Analyze**
CO-2	Explain and apply the principles of linear vector spaces, Hilbert spaces, orthogonality, and linear transformations in physical and mathematical contexts.	**Apply / Analyze**
CO-3	Derive and use vector differential operators in curvilinear coordinates and apply them to solve Poisson and Laplace equations.	**Apply / Analyze**
CO-4	Develop and use Fourier series and transforms to analyze periodic and aperiodic physical systems, including summing infinite series.	**Apply / Evaluate**
CO-5	Apply Laplace transform techniques to solve ordinary and coupled differential equations and model physical systems.	**Apply / Evaluate**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	2	1
CO-2	3	3	2	3	1
CO-3	3	3	2	3	1
CO-4	3	3	2	3	1
CO-5	3	3	2	3	1

Course Code : PHY5072
Course Title : Quantum Mechanics I
Course Type : Theory (Core)
Credits : 04(60 Hours)

Quantum Mechanics -I

Unit 1

General Formalism: Historical background, Stern-Gerlach experiment leading to concept of vector space, Ket and bra notation for vector space, Inner product, Norm of a vector, Orthonormality and linear independence, Basis and dimension, Outer product, Projection operator, Completeness (closure property), Hilbert space, Operator, Hermitian operator, Eigen value and eigen function, Representation theory, Change of basis, Unitary operator, Matrix elements, Unitary transformation, Diagonalization, Coordinate and momentum representation.

Unit 2

Measurements in Quantum Mechanics: Expectation values, Compatible and incompatible observable, Base kets as simultaneous eigen kets of maximal set of commuting observables, Examples, Heisenberg uncertainty principle, Gaussian wave packet, Schrödinger picture, Heisenberg picture and interaction picture, density matrix, pure and mixed states, evolution. Invariance Principle and Conservation Laws: Symmetry and conservation laws, Displacement in space- conservation of linear momentum, Displacement in time –conservation of energy, Rotations in space- conservation of angular momentum, Space- inversion parity.

Unit 3

Solution of Schrodinger Equation: One dimensional simple harmonic oscillator: Eigen function and Eigen value by solving Schrödinger equation and also by operator method, Creation and annihilation operators. Two beads on a wire and a particle in a two-dimensional box. Two dimensional harmonic oscillators. Linear combination of atomic orbitals (LCAO) approximation. Periodic lattice, Bragg reflection.

Unit 4

Angular Momentum: Angular Momentum: Orbital Angular Momentum, Spherical harmonics, Operators Orbital angular momentum operators L , Lx, Ly and Lz, Spin angular momentum and total angular momentum, Commutation relations, Ladder operators, Matrix representation of Operators Jx, Jy, Jz, and J , Pauli spin matrices, Addition of two angular momentums, Clebsch-Gorden coefficients. Selection Rules and simple applications.

Unit 5

Three Dimensional Problems: Free particle in Cartesian coordinates, free particle in spherical polar coordinates, radial wave functions, radial momentum, particle in a three-dimensional box, degeneracy, density of states, charged particle in magnetic field, Fermi energy and Landau levels, Two-particle problem, effective potential, angular momentum barrier, Solution of Schrödinger equation for Hydrogen atom-energy levels and stationary state wave functions

Reference Books:

1. Introduction to Quantum Mechanics, D. J. Griffiths and D. F. Schroeter, Cambridge University Press, 3rd Edition (2018).
2. Introductory Quantum Mechanics, R. L. Liboff, Pearson Education, 4th Edition (2003).
3. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Pearson Education, 2nd Edition (2010).
4. Quantum Mechanics: Concepts and Applications, NouredineZettili, John Wiley & Sons, 2nd Edition (2009).

5. A Textbook of Quantum Mechanics, P. M. Mathews and K. Venkatesan, Tata McGraw-Hill, 2nd Edition (2010).
6. Quantum Mechanics, A. K. Ghatak and S. Lokanathan, Macmillan India, 5th Edition (2004).
7. Quantum Mechanics, J. L. Powell and B. Crasemann, Oxford University Press, 2nd Edition (1995).
8. Quantum Mechanics (Vol. 1), Claude Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Wiley-VCH, 2nd Edition (2006).
9. Quantum Mechanics (Vol. 2), Claude Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Wiley-VCH, 2nd Edition (2006).
10. Quantum Mechanics, G. Aruldhas, Prentice-Hall of India Pvt. Ltd., 2nd Edition (2002).
11. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Robert Eisberg and Robert Resnick, Wiley India Pvt. Ltd., 2nd Edition (2006).
12. Basic Quantum Mechanics, J. M. Cassels, Cambridge University Press, 1st Edition (1963).
13. Quantum Mechanics, S. P. Singh, Prentice-Hall of India, 1st Edition (1999).
14. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
15. https://nptel.ac.in/courses/115106066NPTEL course on Quantum Mech, An Introduction byProf. S. Lakshmi Bala, IIT Madras.
16. https://onlinecourses.nptel.ac.in/noc24_ph15/previewNPTEL course on Quantum Mechanics by Prof. P. Ramadevi, IIT Bombay.

Course Outcomes		Level
CO-1	Understand and apply the mathematical framework of quantum mechanics including vector spaces, operators, and representations.	Understand, Apply
CO-2	Analyze the principles of quantum measurements and their implications, including density matrices and pictures of evolution.	Analyze, Understand
CO-3	Solve the Schrödinger equation for standard quantum systems using analytical and operator methods.	Apply, Analyze
CO-4	Demonstrate a thorough understanding of angular momentum in quantum mechanics and perform angular momentum algebra.	Understand, Apply, Analyze
CO-5	Analyze and interpret solutions to three-dimensional quantum systems including the hydrogen atom and particles in potential wells.	Analyze, Evaluate

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	3	2	2	1
CO-3	3	2	2	3	1
CO-4	3	3	2	2	1
CO-5	3	2	3	3	1

Course Code : PHY5073
Course Title : Electromagnetic Theory
Course Type : Theory (Core)
Credits : 04(60 Hours)

Electromagnetic Theory

Unit 1

Laplace Equation: Boundary value problems and Laplace equation –uniqueness theorem – Solution of Laplace equation in Cartesian and spherical polar coordinates – Examples of solutions for boundary value problems. Dielectric sphere in a uniform field – Molecular polarizability and electrical susceptibility – Electrostatic energy in the presence of dielectric – Multipole expansion. Method of images, Point charge in the presence of grounded conducting sphere and charge insulated conducting sphere, Point charge near a conducting sphere at fixed potential, conducting sphere in uniform electric field by method of images.

Unit 2

Electric and Magnetic Fields in Matter: Electric fields in matter – induced electric dipoles, Polarization of a medium, field due to polarized object – concept of bound and surface charges, field of an uniformly polarized sphere, Gauss's law in the presence of dielectrics, linear dielectrics, dielectric constant, energy stored in dielectric.
Magnetic field in matter- magnetic dipoles, origin of diamagnetism, field due to magnetized object – concept of bound and surface currents, field of an uniformly magnetized sphere, Ampere's law in magnetized materials, linear magnetic media.

Unit 3

Electrodynamics: Faraday's laws of Induction - Maxwell's displacement current, Maxwell Equations, Vector and scalar potentials, Gauge transformations, Lorentz gauge, Coulomb gauge, Green's functions for wave Equation, Energy and momentum of the field, Poynting theorem and conservation of energy and momentum for a system of charged particles and electromagnetic fields, Poynting theorem in linear dispersive media with losses, Poynting theorem for harmonic field.

Unit 4

Radiation: Radiating Systems, Radiation by Moving Charges: Retarded time and retarded potential, radiation of a localized oscillating source, Electric dipole fields and radiation, Magnetic dipole radiation, Multipole expansion of the electromagnetic fields, Retarded potential and fields of an current carrying wire, Lienard–Wiechert potentials and fields for a moving point charge, power radiated by an accelerated point charge – Larmor formula, Radiation reaction and its physical explanation, Abraham Lorentz formula, Radiation damping

Unit 5

Electromagnetic Waves: Plane waves in non-conducting media - Linear and circular polarization, reflection and refraction at a plane interface-normal and oblique incidence – Absorption and dispersion - Waves in a conducting medium, Reflection at a conducting surface, the frequency dependence of permittivity- Waveguides, Propagation of waves in a rectangular wave guide. Coaxial Transmission Line.

Reference Books:

1. Classical Electrodynamics, J.D. Jackson, John Wiley & Sons, 2nd Edition (1985).
2. Introduction to Electrodynamics, David J. Griffiths, Pearson Education, 3rd Edition (2003).

3. Classical Electricity and Magnetism, Wolfgang K.H. Panofsky and Melba Phillips, Addison-Wesley, 2nd Edition (1962).
4. The Classical Theory of Fields, L.D. Landau and E.M. Lifshitz, Pergamon Press, 4th Ed. (1975).
5. Electrodynamics of Continuous Media, L.D. Landau and E.M. Lifshitz, Pergamon Press, 2nd Ed. (1984).
6. Classical Electrodynamics, Hans C. Ohanian, Infinity Science Press, 2nd Ed. (2007).
7.http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
8. https://archive.nptel.ac.in/courses/115/106/115106122/NPTEL course on Electromagnetism byDr. Nirmal Ganguli, IISER Bhopal.

Course Outcomes		Level
CO-1	Solve Laplace equation for different problems in Electromagnetic Theory	Apply
CO-2	Understand the effects of electric and magnetic fields applied to matter	Understand
CO-3	Understand the concept of scalar & vector potentials, Poynting theorem for electromagnetic fields	Understand
CO-4	Analyze the origin of radiation emission from accelerated charges & currents	Analyze
CO-5	Understand the concepts of reflection, refraction, absorption, and dispersion of light electromagnetic waves.	Understand

Mapping of Program Outcomes with Course Outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	3	3	1	2	1
CO2	3	3	1	2	1
CO3	3	3	1	2	1
CO4	3	3	1	1	1
CO5	3	3	1	1	1

Course Code : PHY5074
Course Title : Molecular Physics and Spectroscopy
Course Type : Theory (Core)
Credits : 04 (60 Hours)

Molecular Physics and Spectroscopy

Unit-1

Atomic Spectroscopy: Types of spectra, spectrum of Hydrogen atom, spectral lines, different series in alkali spectra, spin orbit interaction, ground state terms, Selection Rules , Spectral Lines, Line broadening mechanism, Voight profile

Unit-2

Microwave Rotational Spectroscopy: The rigid rotor, centrifugal distortion, interaction of radiation with rotating molecules, rotational spectra and bond length, isotopic substitution, intensities of spectral lines, linear molecules, spherical tops, symmetric tops, the stark effect in molecules

Unit-3

Infra-Red and Raman Spectroscopy: Salient features of vibrational rotational spectra, vibrating diatomic molecules as a harmonic oscillator, potential energy function for a chemical bond, Morse potential, breakdown of Born-Oppenheimer approximation, vibrating rotator, mechanism of infrared radiation absorption, selection rules

Raman Effect: Classical theory of the Raman effect, pure rotational Raman spectra, vibrational Raman spectra, polarization of Raman lines, rule of mutual exclusion, structural determination from Raman and infra-red spectra, group frequencies

Unit-4

UV-Visible Spectroscopy: Vibrational coarse structure, Franck-Condon principle, dissociation energy, electronic structure of diatomic molecules, electronic angular momentum in diatomic molecules, selection rules, rotational fine structure of electronic-vibrational transitions, photoelectron spectroscopy

Unit-5

NMR and ESR Techniques: Theory of NMR, Relaxation effect, Theory of dipolar interaction and chemical shifts, Indirect spin-spin interactions, Experimental set up of NMR, Applications of NMR to quantitative measurements (Idea only), Quantum mechanical treatment of ESR, Nuclear interaction and hyperfine structure, Relaxation effects, ESR spectrometer, Applications of ESR method

Recommended Books:

1. Fundamentals of Molecular Spectroscopy, C. N. Banwell, McGraw Hill Book Company.
2. Atomic and Molecular Spectroscopy, Rita Kakkar, Cambridge University Press.
3. Atoms, Molecules and Photons, W. Demtröder, Springer.

Course Code : PHYEC20
Course Title : SpectroscopyLaboratory
Course Type : Practical (DSE)
Credits : 02 (60 Hours)

List of Experiments

1. Zeeman effect experiment
2. Electron spin resonance experiment.
3. Photo-electric effect.
4. Determination of Planck's constant.
5. Demonstration of quantization of energy level using Frank-Hertz experiment.
6. Determination of e/m ratio.
7. Study of UV-VIS spectroscopy.
8. IR-spectroscopy experiment (FTIR).
9. Analysis of Raman spectra.
10. Study of D_1 and D_2 line of sodium.

Course Code: PHY5075
Course Title: Research Methodology and Publication Ethics
Credits: 02 (30 Hours)

Research and Publication Ethics

Course structure: (As prescribed uniformly by the HRDC/UGC)

Overview

- This course has total 6 units focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands-on-sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research metrics (citations, h-index, Impact Factor, etc.) and plagiarism tools will be introduced in this course.

Pedagogy:

- Class room teaching, guest lectures, group discussions, and practical sessions.

Evaluation

- Continuous assessment will be done through tutorials, assignments, quizzes, and group discussions. Weightage will be given for active participation. Final written examination will be conducted at the end of the course.
- The course comprises of six modules listed in table below. Each module has 4-5 topics:

Modules	Unit title	Teaching Hours
	Theory	
RPE01	Philosophy and Ethics	4
RPE02	Scientific Conduct	4
RPE03	Publication Ethics	7
	Practice	
RPE04	Open Access Publishing	4
RPE05	Publication Misconduct	4
RPE06	Data bases and Research Metrics	7
	Total	30

THEORY

- RPE01: PHILOSOPHY AND ETHICS (3hrs.)

  1. Introduction to philosophy: definition, nature and scope, concept, branches
  2. Ethics: definition, moral philosophy, nature of moral judgments and reactions

- RPE02: SCIENTIFIC CONDUCT (5hrs.)

  1. Ethics with respect to science and research

2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication, and Plagiarism(FFP)
4. Redundantpublications:duplicateandoverlappingpublications,salamislicing
5. Selective reporting and misrepresentation of data

- RPE03:PUBLICATION ETHICS (7hrs.)

1. Publication ethics: definition, introduction and importance
2. Best practices/standards setting initiatives and guidelines: COPE, WAME,etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

PRACTICE

- RPE04: OPEN ACCESS PUBLISHING (4hrs.)

1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggested, etc

- RPE05: PUBLICATION MISCONDUCT (4hrs.)

A. Group Discussions (2hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2hrs.)

Use of plagiarism software like Tumitin, Urkund and other open source software tools

- RPE06: DATA BASES AND RESEARCH METRICS (7hrs.)

  A. Data bases (4hrs.)

     1. Indexing databases
     2. Citation databases: Web of Science, Scopus, etc.

  B. Research Metrics (3hrs.)

     1. Impact Factor of journal as per Journal Citation Report, SNIP, SIR, IPP, CiteScore
     2. Metrics: h-index, gindex, i10index, altmetrics

Semester - VIII

Course Code : PHY5081
Course Title : Mathematical Physics -II
Course Type : Theory (Core)
Credits : 03(45 Hours)

Mathematical Physics -II

Unit 1

Complex Analysis: Complex Numbers and their Graphical Representation. Euler's formula, De-Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Equations. Examples of analytic functions. Sequence and series of functions, convergence tests, absolute and uniform convergence, Taylor and Laurent series, analytic continuation.

Unit 2

Singularities:poles, removable singularity, essential singularity, branch points, branch cut. Integration of a function of a complex, variable. Cauchy's Integral formula. Simply and multiply connected region. Residues and Residue Theorem. Application of Contour Integration in solving Integrals.

Unit-3

Tensors: Transformation of coordinates, Einstein Summation convention, Contravariant, covariant and mixed tensor, tensors of rank greater than 2, Algebra of Tensors: Sum, Difference and Product of Two Tensors. Contraction, Quotient Law of Tensors, Symmetric and Anti-symmetric Tensors, Kronecker and Alternating Tensors Jacobian, Pseudo tensors, Fundamental operations with tensors, line element and metric tensor, tensor form of gradient, divergence, and curl, Covariant derivative, Christoffel's symbol, relative and absolute tensors.

Unit 4

Probability & Statistics: Independent and dependent events, Conditional Probability. Bayes' Theorem, Independent random variables, Probability distribution functions, special distributions: Binomial, Poisson and Normal, moment generating functions,
Experiment, sample and population, sample statistics – moments and moment generating functions, covariance and correlation, maximum likelihood estimator, method of least squares, Hypothesis testing.

Unit 5

Group Theory: Definition of group symmetry elements, homomorphisms; isomorphism; Subgroups and cyclic groups; Abelian groups, Reducible and irreducible representation –Character table. O(3), SU(2) groups.

Reference Books:

1. Mathematical methods in Physical sciences, Mary L Boas, Wiley, 3ed (2023)
2. Mathematical Methods for Physicists – G. B. Arfken, Hans J. Weber, Academic Press, 7th Edition, 2012.
3. Mathematical Methods for Physics and Engineering– K. F. Riley, M. P. Hobson, S. J. Bence, Cambridge University Press, 3rd Edition, 2006.
4. Mathematical Physics – V. Balakrishnan, Ane Books, 1st Edition, 2007.
5. Advanced engineering mathematics, E. Kreyszig, John Wiley & Sons, 10ed (2011)
6. https://archive.nptel.ac.in/courses/115/105/115105097/
7. https://archive.nptel.ac.in/courses/111/106/111106148/
8. https://www.youtube.com/playlist?list=PLbMVogVj5nJRhl_6TUGChpnt2Lg0AZvZu

Course Outcomes		Level
CO-1	Understand and apply the fundamental concepts of complex analysis including analyticity, Cauchy-Riemann equations, and series expansions.	**Understand, Apply**
CO-2	Analyze complex functions using contour integration and residue theorem to evaluate real integrals.	**Analyze, Apply**
CO-3	Understand and use tensor algebra and calculus including transformation rules, metric tensors, and covariant derivatives.	**Understand, Apply**
CO-4	Apply statistical methods and probability theory for data interpretation, including distributions, estimation, and hypothesis testing.	**Apply, Analyze, Evaluate**
CO-5	Understand the structure and representation of groups and use character tables in solving physical problems with symmetry.	**Understand, Apply, Analyze**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	1	2	3	1
CO-3	3	2	3	3	2
CO-4	3	2	3	3	2
CO-5	3	2	2	3	3

Course Code : PHY5082
Course Title : Quantum Mechanics -II
Course Type : Theory (Core)
Credits : 04(60 Hours)

Quantum Mechanics -II

Unit 1

Approximation Methods in Quantum Mechanics: Time independent perturbation theory, first order and second order corrections, degenerate perturbation theory, two-fold degeneracy, good states, variation principle, WKB approximation.

Unit 2

Applications of approximation methods: Stark effect in Hydrogen, spin-orbit coupling, Zeeman effect, Paschen-Back effect, ground state of Helium, Classical region, tunnelling.

Unit 3

Time Dependent Perturbation Theory: Constant perturbation, Transition to continuum, Fermi's golden rule, Harmonic perturbation, Radiative transitions; Adiabatic approximation, Sudden approximation. Semi-Classical Theory of Radiation: Einstein coefficients, Atom field interaction, Interaction energy, Dipole matrix elements, Stimulated emission rate, Spontaneous emission rate, Selection rules

Unit 4

Identical Particles: Principle of indistinguishability, Symmetry of wave functions, Spin and statistics, Pauli's exclusion principle, Construction of wave function of two electrons in L-S and j-j coupling, Allowed states, Ortho and para helium; Exchange force; Scattering of identical particles, Cases of spin half and spin zero particles.

Unit 5

Scattering: The scattering experiments, Relationship of cross-section and wave function, Scattering amplitude; Partial wave analysis: Expansion of a plane wave in terms of partial waves, Scattering by central potential, Zero energy scattering; Scattering by a square well potential, Effective range, Resonant scattering, Optical theorem, Born approximation, Integral equation for scattering, Born's first approximation, Spherically symmetric potential, Criterion for validity of Born approximation, Scattering of electrons by atoms, Rutherford scattering.

Reference Books:

1. Introduction to Quantum Mechanics, D. J. Griffiths and D. F. Schroeter, Cambridge University Press, 3rd Edition (2018).
2. Introductory Quantum Mechanics, R. L. Liboff, Pearson Education, 4th Edition (2003).
3. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Pearson Education, 2nd Edition (2010).
4. Quantum Mechanics: Concepts and Applications, NouredineZettili, John Wiley & Sons, 2nd Edition (2009).
5. A Textbook of Quantum Mechanics, P. M. Mathews and K. Venkatesan, Tata McGraw-Hill, 2nd Edition (2010).
6. Quantum Mechanics, A. K. Ghatak and S. Lokanathan, Macmillan India, 5th Edition (2004).
7. Quantum Mechanics, J. L. Powell and B. Crasemann, Oxford University Press, 2nd Edition (1995).
8. Quantum Mechanics (Vol. 1), Claude Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Wiley-VCH, 2nd Edition (2006).
9. Quantum Mechanics (Vol. 2), Claude Cohen-Tannoudji, Bernard Diu, and Franck Laloë,

Wiley-VCH, 2nd Edition (2006).
10. Quantum Mechanics, G. Aruldhas, Prentice-Hall of India Pvt. Ltd., 2nd Edition (2002).
11. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Robert Eisberg and Robert Resnick, Wiley India Pvt. Ltd., 2nd Edition (2006).
12. Basic Quantum Mechanics, J. M. Cassels, Cambridge University Press, 1st Edition (1963).
13. Quantum Mechanics, S. P. Singh, Prentice-Hall of India, 1st Edition (1999).
14. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
15. https://nptel.ac.in/courses/115106066NPTEL course on Quantum Mech, An Introduction byProf. S. Lakshmi Bala, IIT Madras.
16. https://onlinecourses.nptel.ac.in/noc24_ph15/previewNPTEL course on Quantum Mechanics by Prof. P. Ramadevi, IIT Bombay.

Course Outcomes		Level
CO-1	Understand and apply approximation methods such as perturbation theory (non-degenerate, degenerate), variation method, and WKB approximation.	**Understand, Apply, Analyze**
CO-2	Analyze physical systems such as Stark effect, Zeeman effect, Paschen-Back effect, and spin-orbit coupling using approximation methods.	**Apply, Analyze**
CO-3	Apply time-dependent perturbation theory to calculate transition probabilities; understand radiative transitions and derive Einstein coefficients.	**Apply, Analyze, Evaluate**
CO-4	Explain the quantum mechanics of identical particles, construct multi-particle wave functions under L-S and j-j coupling, and interpret exchange effects.	**Understand, Analyze**
CO-5	Apply quantum scattering theory including partial wave analysis and Born approximation to physical problems such as electron-atom and Rutherford scattering.	**Apply, Analyze, Evaluate**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	3	1
CO-2	3	3	2	3	1
CO-3	3	3	2	3	1
CO-4	3	3	2	2	2
CO-5	3	3	3	3	1

Course Code : PHY5083
Course Title : Condensed Matter Physics
Course Type : Theory (Core)
Credits : 03 (45 Hours)

Condensed Matter Physics

Unit 1

Theory of Electrons: Free electron theory and electronic specific heat; Response and relaxation phenomena. Drude model of electrical and thermal conductivity - Wiedemann – Franz law.. Hall effect magnetoresistance –and thermoelectric power. Fermi-Dirac distribution – Bloch theorem - Electrons in periodic lattice –Heat capacity of the electron gas – Ohm's law, Matthiessen's rule – nearly free electron - the origin and magnitude of energy gap – Bloch functions - Bloch theorem - Motion of an electron in a periodic potential – Kronig – Penney model - Approximate solution near a zone boundary – Limitations of K-P model – tight binding models band theory of solids: metals, semiconductors and insulators; conductivity, mobility and effective mass - Fermi surfaces: Reduced and periodic zone schemes of construction- de Haas – van Alphen effect - Cyclotron resonance.

Unit 2

Crystal Imperfections and Ordered Phases of Matter: Defects in Crystal: Point defects, Colour centers, F-centers, Line defects and planer defects – dislocations- Role of dislocations in crystal growth. Concentrations of Vacancy, Frenkel and Schottky imperfections - Burgers Vector – Presence of dislocation – surface imperfections- Ordered phases of matter: Translational and orientation order - Kinds of liquid crystalline order - Quasi crystals .

Unit 3

Theory of Ferroelectrics and Piezo Electrics: Ferroelectricity – Classifications of Ferroelectric crystals - Dipole theory of ferroelectricity – Landau Theory of the phase transition – First and second order transition, Long range order, Short range order and Bragg William model.– Theory of the ferroelectric displacive transitions: Polarization catastrophe, Soft optical phonon, Thermodynamics of ferroelectric transition, –Ferroelectric domains – Ferroelectric domain wall motion -Antiferroelectricity – Piezoelectric and pyroelectric material - Phenomenological Approach to Piezoelectric Effects - Piezoelectric Parameters and Their Measurements.

Unit 4

OPTICAL PROPERTIES OF SOLIDS: Optical constants, dispersion relation of optical constants from Maxwell's equations, Direct and indirect transitions Absorption in insulators, impurity and interband transitions Resume of macroscopic theory -- generalized susceptibility, Kramer's-Kronig relation, optical properties of metals - intra- and inter-band transitions; Conductivity and dielectric function of collision electron gas, Basic Theories and models of luminescence, phosphorescence, thermo-luminescence, electroluminescence and photo-conductivity, photoelectric effect- Moss-Burstein effect-Polorans – Excitons. Brillouin scattering - Raman effect.

Unit 5

Superconductivity: General Properties of Superconductors -Experimental Results - Critical Temperature - effect of magnetic field -Meissner effect - effect of current - thermal properties - entropy - specific heat -energy gap - isotope effect - London equations – Coherence length- Penetration Depth ; Type–I and Type–II Superconductors - Explanation for the Occurrence of Super Conductivity - BCS theory

Reference Books:

1. Charles Kittel, Introduction to Solid State Physics, 7th Edition, Wiley India Pvt. Ltd. , New Delhi, 2004.
2. J.P. Shrivastava: *Elements of Solid State Physics, 2nd edition,* PHI, New Delhi, 2006.
3. J. Dekker, Electrical Engineering Materials, Prentice Hall of India, 1975.
4. L.V. Azaroff*: Introduction to Solids,* TMH edition, 1996.
5. S.O. Pillai, Problems and Solutions in Solid State Physics, New Age international Publishers, New Delhi, 1994.
6. Rita John, Solid State Physics, Tata Mc Graw Hill Publications, 2014.
7. A.K. Bain, P. Chand, Ferroelectrics, Wiley, 2017.
8. M. A. Wahab, Solid State Physics – Structure and Properties of Materials. Narosa, New Delhi, 1999.
9. J.D. Patterson, B.C. Bailey Solid-State Physics: Introduction to the Theory, Springer Publications, 2007.
10. M. Ali Omar, Elementary Solid State Physics – Principles and Applications, Pearson, 1999.
11. Ajay Kumar Saxena, Solid state physics, , MacMillan Publishers(2006)
12. J.S.Blackmore Solid state physics, , second edition-Cambridge university press (1974)
13. Solid State Physics : H. Ibach and H. Luth (Springer, Berlin).
14. A Quantum Approach to Solids : P.L. Taylor (Prentice-Hall, Englewood Cliffs).
15. Intermediate Quantum Theory of Solids : A.O.E. Animalu (East- West Press, New Delhi).

Course Outcomes		**Level**
CO-1	Understand the electron dynamics in metals through simple concepts and apply it to understand electronic and thermal conductivity in solids. Gain knowledge about wave functions and apply the electronic heat capacity, Hall effect etc.	Understand/analyse Apply
CO-2	Study the role of various defect in solids and understand their stability and their influence on physical properties. Also analyse various ordering phenomena in condensed matter.	Understand/Analyze
CO-3	Understand the concept of electronic polarization and its role on piezoelectricity and ferroelectricity	Understand/analyse Apply
CO-4	Understand the original optical properties in solids and their difference in the insulators and metals. Apply the concept to study various optoelectronic properties.	Understand/analyse Apply
CO-5	Analyze the role of electron phonon coupling on superconductivity and understand various aspects of superconductivity including high Tc superconductors.	Understand/analyse Apply

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	2	2	2	1
CO-3	3	3	2	2	1
CO-4	3	3	1	3	1
CO-5	3	2	2	2	1

Course Code : PHY5084
Course Title : Nuclear and Particle Physics
Course Type : Theory (Core)
Credits : 03(45 Hours)

Nuclear and Particle Physics

Unit 1

Nuclear Models: Liquid drop model, Shell model and prediction of nuclear spin, moments, collective model

Nuclear Force: The Deuteron problem: Magnetic and electric quadrupole moments of Deuteron, Square well solution and Tensor force, nucleon-nucleon scattering, meson theory of nuclear force.

Unit 2

Radioactivity: Alpha decay and Gamow theory, angular momentum and parity in alpha decay. β-decay: Fermi theory of beta decay, parity violation in β-decay, angular momentum and parity selection rules, neutrino physics. Gamma decay: energetics of gamma decay, angular momentum and parity selection rules, angular distribution and polarization measurements, internal conversion and isomerism.

Unit 3

Nuclear Reactions: Conservation Laws, kinematics of reactions, Q-value, scattering and reaction cross section, optical model, compound nucleus reaction, direct and resonance reactions. Fission reaction and its characteristics, Fusion reaction and its characteristics, fusion reaction in star, Nucleosynthesis.

Unit 4

Interaction of radiation with matter: Energy loss due to ionization, Cherenkov radiation. Gamma ray interaction through matter
Detectors: gas detectors-ionization chamber, G-M counter, Scintillation counter, photo multiplier tube (PMT), semiconductor detectors, neutron detector.
Accelerators: linear accelerators, cyclotron, synchrotron, hadron colliders (principle, construction, with advantage and disadvantage)

Unit 5

Particle physics: Brief reminder ofClassifications of elementary particles and fundamental process, Isospin quantum numbers, Strangeness and hyper charge, Hadrons, Baryons, Leptons, Invariance principles and symmetries, Invariance under charge-parity(CP), time(T) and CPT, CP violation in neutral K-meson decay, Tau- Theta puzzle, Feynman diagrams, Quark model, Gell-Mann-Nishijma formula, Gell-Mann Okuba Mass formula.

Recommended Books:

1. Introductory Nuclear Physics, Kenneth S. Krane, Wiley India Pvt. Ltd, repreint Edition (2008).
2. Introduction to Nuclear and Particle Physics, Ashok Das and Thomas Ferbel, World Scientific, 2nd Edition (2003).
3. Nuclear Physics: Theory and Experiment, R.R. Roy and B.P. Nigam, New Age International (P) Ltd , 3rd Edition (2023).

4. Nuclear Physics: An Introduction, S.B. Patel, New Age International (P) Ltd, 3rd Edition (2021).
5. Concepts of nuclear physics, Bernard L. Cohen, Tata Mcgraw Hill, Reprint Edition (1974).
6. Techniques for Nuclear and Particle Physics Experiments, W. R. Leo, Springer-VerlagBerlin Heidelberg, 2nd Edition (1994)
7. Introduction to the physics of nuclei & particles, R.A. Dunlap, Thomson Asia, 1st Edition (2004).
8. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons., 2nd edition (2008).
9. Introduction to High Energy Physics, D.H. Perkins,Cambridge Univ. Press, 4th Edition (2000).
10. Quarks and Leptons, F. Halzen and A.D. Martin,Wiley India, New Delhi, 1st Edition (2008).
11. Radiation detection and measurement, G.F. Knoll, John Wiley & Sons, 4thEdition(2010).
12. E-content: https://ocw.mit.edu/courses/8-701-introduction-to-nuclear-and-particle-physics-fall-2020/
13. NPTEL Course link: https://nptel.ac.in/courses/115104043
14. NPTEL Course link: https://archive.nptel.ac.in/courses/115/103/115103101/

Course Outcomes		Level
CO-1	Collective models, various nuclear reactions, four fundamental forces and their properties, classification of elementary particles, symmetry and different quantum numbers, Gell-Mann Okuba mass formula.	Remember
CO-2	Shell model, Quantum mechanical treatment of nucleon system, scattering, Alpha decay, beta decay, interaction of radiation with matter, fission and fusion reaction	Understand
CO-3	Shell model to find nuclear spin, magnetic moment and electrical quadrupole moments of various nuclei. Apply quantum mechanics to solve alpha-decay and beta-decay process, also to understand nuclear reactions. Theory of interaction of radiation with matter to understand the working principle of radiation detectors. Conservation of various quantum numbers to understand three fundamental forces.	Apply
CO-4	Liquid drop models to understand stability of nuclei against beta decay and fission reaction. Deuteron problem is helpful to solve quantum mechanical systems, and finding out scattering cross sections, solving kinematic problems related to particle decay using invariant mass methods.	Apply
CO-5	Scattering cross section of nuclear reaction, half-life and mean life of radioactive sources, Gamow factor, feasibility of elementary particle reaction based on quantum number conservation.	Evaluate

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	1	3	3	1
CO-3	3	2	1	2	1
CO-4	3	2	2	3	1
CO-5	3	2	2	3	1

List of Discipline Specific Elective (DSE) Courses

Table - 2

COURSE CODE	COURSE TITLE
PHYEC01	Quantum Optics
PHYEC02	Quantum Computation and Quantum Information
PHYEC03	Semiconductor Physics & Devices
PHYEC04	Vacuum science and thin film physics
PHYEC05	Introduction to Monte-Carlo techniques
PHYEC06	Microwave Physics
PHYEC07	Soft Condensed Matter Physics
PHYEC08	Optics
PHYEC09	Experimental Methods in Physics
PHYEC10	An Introduction to Machine Learning for physicists
PHYEC11	Mathematics and Astronomy in India
PHYEC12	Astronomy and Astrophysics
PHYEC13	Applied dynamics
PHYEC14	Computational Condensed Matter Physics
PHYEC15	Nanomaterials And Nanotechnology
PHYEC16	Properties of Materials
PHYEC17	Nonlinear Dynamics
PHYEC18	Advanced Particle Physics
PHYEC19	Research Methodology for Scientific Research
PHYEC20	Spectroscopy Laboratory
	Other course to be offered depending on demand and reported to Board of Studies

List of Multidisciplinary/Open Elective course:

COURSE CODE	COURSE TITLE
PHYOE01	Gender Concerns in STEM Studies
PHYOE02	Physics of arts
PHYOE03	Introduction to Astronomy and astrophysics
PHYOE04	Solar Energy and its Applications
PHYOE05	Physics and Meditation
	Depends on Students interest additional Courses to be added and reported to Board of Studies

List of Skill Enhancement Courses (SEC):

COURSE CODE	COURSE TITLE
PHYSE01	Machine shop
PHYSE02	Latex typesetting for beginners
PHYSE03	Introduction to Python Programming and Graph Plotting
PHYSE04	Optical Instrumentation
PHYSE05	Renewable Energy Technologies
PHYSE06	Computational Modelling of Materials
	Additional Courses can be included and reported to Board of Studies

Discipline Specific Electives

Course Title: Quantum Optics
Course Type: Theory (DSE)

Quantum Optics

Unit 1:
FIELD QUANTIZATION: Quantization of electromagnetic field in a cavity, electromagnetic fields in free space - box normalization, electromagnetic field as a harmonic oscillator, fock states of field, vacuum state – fluctuations of field in vacuum, effects of vacuum fluctuations, Lamb shift, Casmir effect – derivation of energy shifts, quadrature operators, coherent and squeezed states of field, photon number statistics.

Unit 2:
COHERENC OF ELECTROMAGNETIC FIELDS: Classical theory of coherence, definition of first and second order coherence, quantum theory of coherence – effects of first order coherence – Young's double slit experiment, Hanbury Brown Twiss experiment (HBT) – Classical treatment – effects of second order coherence, quantum treatment of HBT experiment – calculation of second order coherence, Interference of light emitted from two atoms.

Unit 3:
BEAM SPLITTERS & INTERFEOMETERS :Quantum theory of Beam splitter – transformation of fields, relation between input and output fields, Beam splitter transformations on number state and coherent state inputs, MachZehnder interferometer, interaction free measurements, quantum treatment of Michelson interferometer – measurement of photon statistics, Detection of squeezed light – Homodyne measurement scheme, Interferometry with coherent light, phase measurement using entangled light sources and squeezed light. Quantum interferometric lithography

Unit 4:
ATOM FIELD INTERACTION: Interaction of an atom with a classical field – Rabi oscillations, interaction of an atom with a quantized single mode field – Jaynes-Cummings model, single mode field in thermal state – effects on population distribution, dressed states of atom-field interaction, Jaynes-Cummings model with large detuning – dispersive atom-field interaction, Schmidt decomposition and von Neumann entropy for the Jaynes-Cummings model, Atom's interaction with a multimode vacuum field – Weiskopf Wigner theory of spontaneous emission.

Unit 5:
QUANTUM COMPUTATION :Quantum bits, single qubit gates, phase gates, generation of single qubit states, Multiple qubits – Controlled Not gate, Swap gate, Toffoli gate, Bell states, No-Cloning theorem, Quantum Teleportation, Deutsch's Algorithm, Deutsch-Jozsa Algorithm, Quantum Fourier transform. Search Algorithms, Quantum key distribution.

Reference Books:

1. Introductory Quantum Optics, Christopher Gerry and Peter Knight, Cambridge University Press, First Edition (2005).
2. Quantum Optics: An Introduction, Mark Fox, Oxford University Press, First Edition (2006).

3. Quantum Optics, Marlan O. Scully and M. Suhail Zubairy, Cambridge University Press, First Edition (1997).
4. Quantum Optics, Girish S. Agarwal, Cambridge University Press, First Edition (2013).
5. Quantum Computation and Quantum Information, Michael A. Nielsen and Isaac L. Chuang, Cambridge University Press, First Edition (2010).
6. https://onlinecourses.nptel.ac.in/noc25_ph31/preview
NPTEL course on Essentials of Quantum Optics by Prof.Amarendra Kumar Sarma, IIT Guwahati.
7. https://onlinecourses.nptel.ac.in/noc21_cs103/preview?utm_source=chatgpt.comNPTEL course on Introduction to Quantum Computing, Prof. Prabha Mandayam, IIT Madras.

Course Outcomes		Level
CO-1	Understand the fundamental concepts of quantum field theory, including field quantization and vacuum fluctuations.	Understand
CO-2	Apply the theory of coherence to quantum electromagnetic fields and understand related phenomena like the Hanbury Brown-Twiss experiment.	Apply
CO-3	Analyze quantum optics phenomena using beam splitters and interferometers and apply them to practical systems.	Analyze, Apply
CO-4	Understand and analyze atom-field interactions, including Jaynes-Cummings model, and its significance in quantum optics..	Analyze, Apply
CO-5	Gain a basic understanding of quantum computation, including quantum gates, algorithms, and key quantum protocols.	Understand

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	1	2	1
CO-2	3	3	1	2	1
CO-3	3	3	1	2	1
CO-4	3	3	1	1	1
CO-5	3	3	1	1	1

Course Title: Quantum Computation and Quantum Information
Course Type: Theory (DSE)

Quantum Computation and Quantum Information

Unit I:
Quantum Entanglement: Quantum Correlations: Bipartite entanglement measures such as concurrence, entanglement entropy, entanglement witness, Mixed state entanglement , PPT criterion. Multipartite entanglement: tangle; mutual information; monogamy of correlations.Quantum Discord: definition and properties

Unit II:
Quantum Computation: Quantum bits, single qubit gates, phase gates, generation of single qubit states, Multiple qubits – Controlled Not gate, Swap gate, Toffoli gate, Bell states, No-Cloning theorem, Quantum Teleportation, Deutsch's Algorithm, Deutsch-Jozsa Algorithm, Quantum Fourier transform. Search Algorithms, Quantum key distribution.

Unit III:
Quantum Information: Introduction to Shannon entropy - classical information-classical information from measurements - von Neumann entropy - properties-subadditivity and concavity-quantum data compression - classical information in quantum mechanics- Holevo bound. Quantum Information.

Unit IV:
Quantum Noise: Noise in quantum systemsand quantum operations - Operator-sum representation -qubit channels, decoherence. Distance measures - trace distance - fidelity, Quantum state tomography, unbiased measurements, mixed state reconstruction.

Unit V:
Quantum Error Correction: Shor code - Quantum error correction -Stabilizer codes -fault tolerant quantum computation, decoherence free subspace. Quantum state discrimination, error probability analysis, the quantum-Chernoff bound. Introduction to quantum illumination.

Books Recommended:

1. Quantum Computation and Quantum Information, Michael A. Nielsen & Isaac L. Chuang, Cambridge University Press, First Edition (2010).
2. Quantum Information and Computation, John Preskill, California Institute of Technology, Lecture Notes (1998).
3. Quantum Theory: Concepts and Methods, Asher Peres, Springer, First Edition (1995).
4. Geometry of Quantum States: An Introduction to Quantum Entanglement, Ingemar Bengtsson and Karol Życzkowski, Cambridge University Press, First Edition (2006).
5. Quantum Information Theory, Mark M. Wilde, Cambridge University Press, Second Edition (2017).
6. Quantum Error Correction, Daniel A. Lidar and Todd A. Brun, Cambridge University Press, First Edition (2013).
7.https://onlinecourses.nptel.ac.in/noc21_cs103/preview?utm_source=chatgpt.comNPTEL course on Introduction to Quantum Computing, Prof. Prabha Mandayam, IIT Madras.

Course Outcomes		Level
CO-1	Explain quantum entanglement, entanglement measures, and quantum discord.	Understand
CO-2	Analyze quantum logic gates and quantum computation algorithms.	Analyze
CO-3	Apply principles of classical and quantum information theory.	Apply
CO-4	Analyze quantum noise models, decoherence, and quantum state reconstruction.	Analyze
CO-5	Understand quantum error correction codes and fault-tolerant quantum computation techniques.	Understand

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	1	2	1
CO-2	3	3	1	2	1
CO-3	3	3	1	2	1
CO-4	3	3	1	1	1
CO-5	3	3	1	1	1

Course Title: Semiconductor Physics and Devices
Course Type: Theory (DSE)

Semiconductor Physics & Devices

Unit-I

Physics and Properties of Semiconductors: Crystal Structure, Energy Bands and Energy Gap, Carrier Concentration at Thermal Equilibrium, Carrier-Transport Phenomena, Phonon, Optical and Thermal Properties, Heterojunctions and Nanostructures.

p-n Junctions: Depletion Region, Current-Voltage Characteristics, Junction Breakdown, Transient Behavior and Noise, Terminal Functions, Heterojunctions.

Unit-2

Metal-Semiconductor Contacts:Formation of Barrier, Current Transport Processes, Measurement of Barrier Height, Device Structures, Ohmic Contact.

Metal-Insulator-Semiconductor Capacitors: Ideal MIS Capacitor, Silicon MOS Capacitor.

Unit-3

Bipolar Transistors: Static Characteristics, Microwave Characteristics, Related Device Structures, Heterojunction Bipolar Transistor.

MOSFETs: Basic Device Characteristics, Non-uniform Doping and Buried-Channel Device, Device Scaling and Short-Channel Effects, MOSFET Structures, Circuit Applications, Nonvolatile Memory Devices. JFETs, MESFETs, and MODFETs:JFET and MESFET, MODFET.

Unit-4

Negative-Resistance and Power Devices: Tunnel Diode, Tunnel Devices, Resonant-Tunneling Diode, IMPATT Diodes, Transferred-Electron Device, Real-Space-Transfer Devices, Thyristors, Thyristor Characteristics, Thyristor Variations, Power Devices.

Unit 5

Photonic Devices and Sensors: RadiativeTransitions,Light-Emitting Diode (LED),Laser Physics, Laser Operating Characteristics, Photoconductor,Photodiodes, Avalanche Photodiode, Phototransistor, Solar Cell, Sensors, Thermal Sensors, Mechanical Sensors, Magnetic Sensors, Chemical Sensors.

Books recommended:

1. Sze S M, “Physics of Semiconductor Devices”, John Wiley and Sons,2001.
2. Kevin F Brennan, “The Physics of Semiconductors”, CambridgeUniversity Press, 1999.
3. MichealShur, “Physics of Semiconductor Devices”, Prentice Hall ofIndia, 1999.
4. Jasprit Singh, “Semiconductor Optoelectronics Physics and Technology”,McGraw Hill Co., 1998.
5. P. Y. Yu and M Cardona, Fundamentals of Semiconductors, Springer,1992.
6. K. Seeger, Semiconductor Physics, 9th Edition, Springer, 2004.

Supplementary Reading:

1. Michael Shur, "Physics of Semiconductor Devices", Prentice Hall ofIndia, 1995.
2. Allen Mottorshed, “Electron Devices and Circuits”, Prentice Hall Inc,2002.
3. Jacob Millman, “Integrated Electronics”, Tata McGraw Hill PublishingCo. Ltd., 2002.
4. Schwartz S, “Integrated Circuit Technology”, McGraw Hill PublishingCo. Ltd., 2000.
5. Sze S M, “Semiconductor Devices – Physics and Technology”, JohnWiley and Sons, 2002.
6. R.F. Pierret. Advanced Semiconductor Fundamentals Vol.11 Addison-Wesley (1989).
7. M. Shur, Physics of Semiconductor Devices, Prentice Hall (1990)

Course Outcomes		Level
CO-1	To get knowledge about various aspects of semiconductingmaterials and their Properties.	Acquire, Understand, Remember

CO-2	Understand the electrical transport across interface between metal-semiconductor, and also the capacitance effects at the junctions.	Understand, Analyze
CO-3	Understand the fundamentals of transistors, analyze their operation, design and analyze various transistor circuits, and apply their knowledge in practical applications	Analyze
CO-4	Able to describe the characteristics of power semiconductor devices and identify suitable switch choices for a given application.	Apply
CO-5	ability to understand the design and analyze photonic structures, and apply these concepts to various photonic devices and sensors	Evaluate

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	1	1	2	1	1
CO-2	1	1	3	1	1
CO-3	1	1	3	1	1
CO-4	3	2	2	1	1
CO-5	3	2	2	1	2

Course Title: Vacuum science and thin film physics
Course Type: Theory (DSE)

Vacuum science and thin filmphysics

Unit-I

Basic concepts of vacuum and its generation: Brief history of vacuum; kinetic theory; gas transport and pumping of gases; conductance; Physico and chemical phenomenon in vacuum; basic principles and processes for production of vacuum and ultra-high vacuum; vacuum generation; diaphragm pumps; vacuum blowers; vacuum jet pumps; cryogenic pumps; turbo molecular pumps etc

Unit-2

Measurement of vacuum and leak detection: Mechanical gauges; gauges using liquids, molecular gauges, kundsenguage, thermal conductivity gauges; Ionization gauges; calibration of gauges; sealing techniques and leak detection

Unit-3

Introduction and preparation of thin films: Crystal structures of thin films; defects in thin films (vacancies and interstitials, dislocations, grain boundaries etc.) nanocrystalline, polycrystalline and epitaxial thin films; thermal dynamics and diffusion mechanisms in thin films; thin film surface,

nucleation and growth models (2D, 3D, and 2D-3D combination);preparation of thin films; physical vapor deposition techniques includes thermal evaporation, sputtering, pulsed laser deposition, molecular beam epitaxy; e-bean evaporation; chemical vapor deposition; solution based techniques..

Unit-4

Characterization of thin films: Measurement of film thickness; structural characterization; x-ray diffraction, grazing incidence small angle x-ray scattering technique; transmission electron microscopy; scanning electron microscopy; ellipsometry; chemical characterization x-ray photoelectron spectroscopy; Rutherford back scattering; secondary ion mass spectroscopy

.

Unit 5

Thin film properties and applications: Conduction in metallic thin films; electrical transport in insulating films; semiconductor contacts; superconductivity in thin films; magnetic film size effects; thin film optics; thin films for electrical and optical devices (LED), Solar Cells, thin film transistors and memories**.**

Reference Books:

a. Hand book of thin film technology by H. Frey, H. R. Khan, 2015
b. Materials science of thin films: deposition and structure, by M. Ohring, 2002.
c. L.B. Freund and S. Suresh; Thin film materials: Stress, defect formation and surface evolution, 2004
d. Hand book of thin film deposition, third edition by Krishna Seshan 2012
e. Vacuum technology by A Roth 2012
f. Hand book of vacuum science and technology by D. Hoffman, B. Singh, J.H. Thomas 1997
g. Materials science and engineering: An Introduction 6th Edition. William D. Callister, Jr. 2003, John Wiley & Sons, Inc.
h. Introduction to Surface and Thin Film Processes, by J. A. Venables, 2000
i. Basic vacuum technology 2nd edition by A. Chambers

Course Outcomes		Level
CO-1	Able to discuss the vacuum concepts (ideal, rough, low, high, ultrahigh, etc…)	Remember
CO-2	Identify and explain the different vacuum pump systems and pressure guagues.	Analyze
CO-3	Know how the thin films can be grown by various techniques; their advantage and disadvantages	Apply
CO-4	Able to select the most suitable synthesis or processing techniques for a given application and characterization techniques.	Apply
CO-5	Able to analyze the electrical, magnetic, and optical properties thin films and their utility in optoelectronic devices .	Analyze

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	2	1	1
CO-2	1	3	2	2	1
CO-3	2	1	3	1	1
CO-4	3	2	2	1	1
CO-5	2	2	2	2	2

Course Title: Introduction to Monte Carlo techniques
Course Type: Theory (DSE)

Introduction to Monte Carlo Techniques

1.**Introduction :**Basic concepts of computation and simulation. Difference between numerical computation and simulation. Computational Languages, Algorithms, Codes, Pseudo Codes, Flow charts. Modelling of Natural phenomena: Interatomic potentials, Equations of motion. Various computation techniques for different physical systems.

2. **Probability distributions:** Probability theory, Probability density or distribution, Discrete and Continuous Distributions. Uniform distribution, Binomial, Poisson's, Gaussian, Lorentz and Exponential distributions. Marginal density and Joint density. Mean, Variance, Covariance and correlation functions.

3. **Random Numbers:** Random processes, random variables, random number. True random numbers, Pseudo random numbers. Pseudo random number generators: Linear congruential generator, Lagged Fibbonacci generator, ran3 generator, Mersenne Twister generator. Various test for pseudo random number generators.

4. **Monte Carlo Methods:** Coin tossing experiments, Die Experiment, Validity of Stirling Approximation, Box-Muller algorithm, Inversion Method, Rejection Method, Averages and Standard deviations, Errors and Numerical convergence. Numerical Verification of Central Limit Theorem.

5. **Sampling Techniques:**Simple sampling, importance sampling, acceptance ratio, Details balance condition, Metropolis algorithms; Implementation of Monte Carlo algorithms: Random walk, self-avoiding walk, Ising model, nucleation, crystal growth, fractal system etc.

Books recommended:

1. Monte Carlo Methods in Statistical Physics,K.P.N. Murthy, University Press(2004).

2. ,A Guide to Monte Carlo Simulation in Statistical Physics, D. P. Landauand K. Binder, Cambridge University Press. (2005).

3. Understanding molecular simulation from algorithm to applications,D. Frenkel and B. Smith, Kluwar Academic Press(1999).
4. Monte Carlo Methods in Statistical Phyiscs, M. E. J. Newman and G.T. Barkema, Oxford University Press.(1999).
5. An Introduction to Computer Simulation, M. M. Wolfson,and G. J. Pert,Oxford Press. (1999).
6. https://www.youtube.com/watch?v=rw5OUnN8soQ
7. https://www.isibang.ac.in/~athreya/Teaching/statistics1/dootika.pdf
8. https://www.youtube.com/watch?v=0ikk_VEBkJw

Course Outcomes		Level
CO-1	Understand the fundamental concepts of computaion and simulation.	Understand
CO-2	Understand the different PropbabilityDistrributionfuncation.	Understand
CO-3	Analyzethe principle of different random number generators and it application	Analyze, Apply
CO-4	Apply and analyse Monte Carlo methods in different physical systems.	Analyze, Apply
CO-5	Gain a basic understanding of sampling techniques and its application in different Physical system.	Understand Apply

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	1	2	1
CO-2	1	2	1	2	1
CO-3	2	2	1	2	1
CO-4	3	3	1	1	1
CO-5	3	3	3	2	1

Course Title: Microwave Physics
Course Type: Theory (DSE)

Microwave Physics

Unit 1:
Introduction to microwaves: Microwave frequencies and the band names. Role of microwaves in the history of communications and the world wars. Microwave systems. Review of interaction of electrons and fields. Electron motion in electric field, magnetic field and electromagnetic fields. Review of guided waves and the modes of rectangular, circular and coaxial waveguides.

Unit 2:
Microwave Sources: Vacuum tubes, solid state microwave generators. Vacuum tubes: Klystron, Magnetron and TWT. Solid state devices: Classification of solid-state devices. Conditions for radiation of microwaves. Transit time effects. Power-frequency limitations. Transferred electron effects – concept of negative resistance. Working of special diodes – Gunn, tunnel, IMPATT, TRAPATT, BARITT.

Unit 3:
Microwave components: Guided wave vs. free space propagation. Forward wave and backward wave in waveguides. Analysis of microwave networks. Basics of S parameters. Impedance and admittance. ABCD parameters. Impedance matching. VSWR and Smith Charts.

Unit 4:
Waveguide components: directional couplers, attenuators, E-bend and H-bend, slotted sections, T and Y circulators. Introduction to planar waveguides.

Unit 5:
Applications of microwaves: Material characterization using microwaves – broadband dielectric spectroscopy and microwave rotational spectroscopy. ESR. Microwave synthesis of material. Radar. Satellite and Cellular communications. Defense applications. Navigation and GPS. Microwave Ovens. Radio Astronomy and CMBR and COBE.

Reference Books:

1 Microwave Engineering David M. Pozar, Wiley, 4th Edition, 2011.

2 Foundations for Microwave Engineering Robert E. Collin, IEEE Press, 2nd Edition, 2001.

3 Microwave Devices, Techniques, and Applications K. C. Gupta, R. Garg, I. Bahl, and P. Bhartia, Wiley, Latest Edition.

4 Microwave Circuit Design Using Linear and Nonlinear Techniques G. D. Vendelin, A. M. Pavio, and U. L. Rohde, Wiley, 2nd Edition, 1996.

5 Microwave and RF Design: A Systems Approach Michael Steer, Wiley, Latest Edition.

6 https://onlinecourses.nptel.ac.in/noc19_ee68/preview by Ratnajit Bhattacharjee, IIT Guwahati

7 https://archive.nptel.ac.in/courses/108/101/108101112/ by Prof. S. C. Dutta Roy, IIT Delhi

8 https://archive.nptel.ac.in/courses/117/101/117101119/ by Prof. Jayanta Mukherjee, IIT Bombay

Course Outcomes		Level
CO-1	Recall fundamental concepts and terminology of microwaves and components.	Recall
CO-2	Explain the working principles and physical interpretations of microwave devices, systems, and applications.	Explain
CO-3	Analyze the behavior and performance of microwave sources and networks.	Analyze
CO-4	Apply physical and mathematical principles to solve problems involving microwave propagation and components.	Apply
CO-5	Evaluate real-world microwave systems and assess their effectiveness and limitations.Design or propose microwave-based systems or experiments for practical applications.	Evaluate

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	2
CO-2	3	3	3	3	1
CO-3	3	2	3	3	1
CO-4	3	2	3	3	1
CO-5	3	3	3	3	2

Course Title: Soft Condensed Matter Physics
Course Type: Theory (DSE)

Soft Condensed Matter Physics

Unit -1
Inter and intra molecular interactions, self-assembly and self- association, correlations, formation of condensed phases, length, time and energy scales in condensed matter systems Basic phenomenology of soft condensed matter systems: phase behaviour, diffusion and flow, viscoelasticity.

Unit -2
Order Parameter, Phases and Phase transitions Mean Field theory and phase diagrams, order parameter, metastable states. Interfaces and wetting, Young's equation, solid-liquid interaction.

Unit -3
Introduction to Liquid crystals, classification of liquid crystals, Frank free energy, Landau de Gennes model of isotropic-nematic transition, Onsager's mean field theory, nematic-smectic transition. Characterization of Liquid crystals Polarizing microscopy, Dielectric anisotropy, DSC, NMR. Industrial applications of Liquid Crystals.

Unit -4
Introduction to colloids, classification of colloids, Poisson- Boltzmann theory, DLVO theory, sheared colloids, stability of colloidal systems, measurement of interaction. Experimental Techniques – Confocal microscopy, Zeta potential.

Unit -5
Introduction to Polymers & Membranes: Model systems, chain statistics, ideal polymers, role of solvent, Equivalent Kuhn chain, mean square end-to-end- length and radius of gyration, Probability distribution in an ideal polymer, Entropic "Hook's Law", ideas of self-avoidance, rubber elasticity, viscoelasticity and reputation.

Reference Books:

1. Soft Condensed Matter Richard A. L. Jones, Oxford University Press, 2002.
2. Principles of Condensed Matter Physics P. M. Chaikin and T. C. Lubensky, Cambridge University Press, 1995.
3. Liquid Crystals S. Chandrasekhar, Cambridge University Press, 2nd Edition, 1992.
4. Polymer Colloids: A Comprehensive Introduction R. H. Ottewill and R. I. Pashley, Academic Press, 1989.
5. Introduction to Liquid Crystals: Chemistry and Physics Peter J. Collings and Michael Hird, Taylor & Francis, 1997.
6. https://archive.nptel.ac.in/courses/112/108/112108289/ by Prof. Ranjini Bandyopadhyay, IISER Thiruvananthapuram
7. https://archive.nptel.ac.in/courses/112/104/112104039/ by Prof. S. K. Tripathy, IIT Kharagpur
8. https://archive.nptel.ac.in/courses/103/106/105106204/ by Prof. Basavaraj MadivalaGurappa, IIT Madras
9. https://archive.nptel.ac.in/courses/103/106/105106205/ by Prof. Basavaraj MadivalaGurappa, IIT Madras

Course Outcomes		Level
CO-1	Understand the origin of condensed phases and the scales involved.	Understand
CO-2	Apply the theory of phase transitions to soft matter	Apply
CO-3	Analyze colloids with respect to various theories	Analyze
CO-4	Analyze polymers with respect to statistical physics models.	Analyze
CO-5	Soft matter in industrial applications	Evaluate

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	1	2	1
CO-2	3	3	2	2	1
CO-3	3	3	3	3	1
CO-4	3	3	2	3	1
CO-5	3	2	3	2	3

Course Title: Optics
Course Type: Theory (DSE)

Optics

Unit-I

Wave Propagation: One dimensional wave, the differential wave equation, harmonic waves, superposition principle, graphical method for superposition principle, the complex representation, plane waves, three-dimensional wave equation, spherical waves, cylindrical waves, electromagnetic wave, Rayleigh scattering, origin of refractive index, Huygen's principle, Fermat and mirages, Fresnel's equation, total internalreflection.

Unit-2

Interference: Interference of light, Young's experiment, Newton's rings, fringes of equal inclination, fringes of equal thickness, Michaelson interferometer, Multiple beam-interference, Fabry-Perot Etalon, Fabry-Perot Interferometer, resolving power, spatial and temporal coherence.

Unit-3

Diffraction: Fraunhoffer diffraction: Single Slit and Double Slit diffraction, many-slit diffraction, the circular aperture, Airy disc, resolution of imaging systems, the diffraction grating, resolving power of gratings and prisms. Fresnel diffraction: Half period zones, obliquity factor, diffraction by a circular aperture, opaque disc, zone plate, The Cornu spiral, diffraction by a narrow obstacle, semi-infinite opaque screen.

Unit-4

Fourier Optics: Fourier series, nonperiodic waves, Fourier integrals, pulses and wave packet, phase and group velocity, Normal and anomalous dispersion, coherence length, Discrete Fourier transform, Coherence Time and Line width via Fourier Analysis, Spatial Coherence and Temporal Coherence, Transform of the Gaussian wave packet, Michelson Stellar Interferometer, Fourier Transform Spectroscopy.

Unit 5

Lasers and Fiber Optics: What is a laser? Properties of lasers, spot size, collimation, monochromaticity, tuning range, spectral width, efficiency, size and weight, operation of lasers, oscillators, amplifiers, generation of very short pulses, types of lasers, introduction to fiberoptics, light propagation in an optical fiber, Single mode and multimode propagation, Fiber amplifier, Fiberoptics applications in sensors and communications.

References:

1. Optics, E. Hecht and A. R. Ganesan, Pearson, 5th Edn, 2020.
2. Optics, AjoyGhatak, McGraw Hill, 8th Edn. 2024.
3. Introduction to Fiber Optics, AjoyGhatak and K. Thyarajan, Cambridge University Press, 1st Edn. 2017.
4. Fundamentals of Optics, F.A Jenkins and H.E White, McGraw-Hill, 1976.
5. Principles of Optics, Max Born and Emil Wolf, Pergamon Press, 7th Edn., 1999.
6. Principles of Optics, B.K. Mathur, Gopal Printing, 1995.
7. Optics, MIT OpenCourseWare,https://ocw.mit.edu/courses/2-71-optics-spring-2009/
8. Applied Optics, SWAYAM, https://onlinecourses.nptel.ac.in/noc22_ph32/preview

Course Outcomes		Level
CO-1	Learning about wave phenomenon and its representation	Analyze
CO-2	Learning about optical interference and its applications	Understand Apply
CO-3	Analyzing diffraction phenomenon and its applications	Apply Analyze
CO-4	Knowing about Fourier analysis of optical signals	Remember

CO-5	Introduction to LASER and its propagation through optical fiber	Remember

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	2	1	1
CO-2	3	1	1	1	1
CO-3	3	1	2	1	1
CO-4	1	1	1	2	1
CO-5	1	1	1	1	1

Course Title: Experimental Methods in Physics
Course Type: Theory (DSE)

Experimental Methods in Physics

Unit I:

Design of Experiments: Design of experiments – statistical and experimental, need for experiments (validation of theory/ verification of theory/ addition to database) Data collection and analysis – Error Analysis and Hypothesis testing – Propagation of errors – Plotting of Graph – Distributions – Least squares fitting – Criteria for goodness of fits – Chi square test. Reporting data – mean, variance, method of least squares fit, central limit theorem, error bars.

Unit II:

Fundamental Measurements: Measurement of fundamental constants: e, h, c – Millikan's oil drop, photoelectric effect and various methods to determine c, their need and the techniques, Measurement of energy and time Signal processing – A/D conversion – multichannel analyzers – Time-of-flight technique – Coincidence Measurements.

Unit III:

Cryogenics and Low temperature: Temperature scales, Production of Low Temperatures: Cryogenic Liquefaction,Helium and nitrogen liquefaction, Joule–Thomson effect, adiabatic expansion,Advanced Cooling Techniques,Adiabatic demagnetization, dilution refrigeration, laser cooling basics,Storage and Handling of Cryogens,Dewars, insulation, materials at low T, safety protocols,Temperature Measurement Techniques,Resistance thermometers, thermocouples, diode sensors, capacitance, noise thermometry.

Unit IV:

Measuring the High and Low: Electric Fields: Introduction to bridge circuits – Wheatstone bridge: Low Resistance – Kelvin Double Bridge, High Resistance – Megohm Bridge; Low Inductance – Maxwell Bridge, High Inductance – Hay's Bridge; Low Capacitance – Schering Bridge, High Capacitance – De Sauty Bridge

Magnetism: Fluxgate Magnetometer, Hall Effect Sensor, SQUID (Superconducting Quantum Interference Device), Magneto-resistive Sensors (AMR, GMR, TMR).

Unit V : Vacuum Techniques: Introduction to Vacuum (definition of vacuum, levels of vacuum, units Gas Kinetics and Vacuum Fundamentals (mean free path, conductance, throughput, outgassing, permeation, leaks) Measurement methods – mechanical gauges (Bourdon gauge, McLeod gauge), Thermal conductivity gauges (Pirani, thermocouple gauge) Ionization gauges: Cold cathode (Penning), hot cathode (Bayard–Alpert) Vacuum Pumps and Pumping Systems: Basics of Rotary vane pump, Diaphragm pump, Diffusion pump, Turbomolecular pump, Ion pumps, Cryopumps, Getter pumps.

Reference Books:

1. Experimental Methods for Engineers Jack P. Holman, McGraw Hill, 7th Edition, 2000.
2. Foundations of Vacuum Science and Technology James M. Lafferty (Editor), Wiley Interscience, Latest Edition.
3. Design and Analysis of Experiments Douglas C. Montgomery, John Wiley, 6th Edition, 2004.
4. Experimental Low-Temperature Physics Anthony Kent, Macmillan Physical Science, 1993.
5. Mechanical Measurements Thomas G. Beckwith, Roy D. Marangoni and John H. Lienhard, Prentice Hall, 6th Edition, 2006.
6. Measurement Systems: Application and Design Ernest O. Doebelin, Tata McGraw Hill, 5th Edition, Latest Reprint.
7. Modern Electronic Instrumentation and Measurement Techniques Albert D. Helfrick and William D. Cooper, Prentice Hall, 1992.
8. Instrument Transducers: An Introduction to Their Performance and Design Hermann K. P. Neubert, Oxford University Press, 2003.
9. Modern Instrumentation for Scientists and Engineers John A. Blackburn, Springer, 2001.
10. https://archive.nptel.ac.in/courses/127/105/127105231/ by Prof. R. K. Mishra, IIT Madras
11. https://archive.nptel.ac.in/courses/110/105/110105087/ by Prof. R. N. Tiwari, IIT Kharagpur
12. https://archive.nptel.ac.in/courses/110/105/110105087/ by Prof. JhareswarMaiti, IIT Kharagpur

Course Outcome	Course Outcome Statement	Level
CO-1	Apply principles of statistical and experimental design to analyze experimental data including error analysis, hypothesis testing, and curve fitting.	Apply
CO-2	Demonstrate measurement techniques for fundamental physical constants and apply signal processing methods like A/D conversion and coincidence measurements.	Apply
CO-3	Understand low temperature physics and evaluate cryogenic cooling techniques, temperature measurement, and cryogen handling.	Understand
CO-4	Apply various bridge circuits for electrical measurements and evaluate magnetic field sensing using advanced magnetometers.	Apply

CO-5	Understand vacuum techniques including gas kinetics, pressure measurement methods, and the working of different vacuum pumps.	Understand

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	**Program Outcomes**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	0
CO-2	3	2	2	3	0
CO-3	3	2	2	2	1
CO-4	3	2	2	3	0
CO-5	3	2	2	2	1

Course Title: An Introduction to Machine Learning for physicists
Course Type: Theory (DSE)

An Introduction to Machine Learning for physicists

Unit 1:
Idea of ML, challanges in ML- Setting up a problem in ML and data science, Polynomial Regression; Bias-Variance decomposition; Overview of Bayesian Inference- Bayes Rule, Bayesian Decisions, Hyperparameters.

Unit 2
Linear Regression - Least-square regression, Ridge-Regression, Least Absolute Shrinkage and Selection Operator (LASSO) and Sparse Regression, Using Linear Regression to Learn the Ising Hamiltonian, Convexity of regularizer, Bayesian formulation of linear regression; Logistic Regression- The cross-entropy as a cost function for logistic regression, Minimizing the cross entropy, Examples of binary classification (Identifying the phases of the 2D Ising model , Supersymmetry etc.), Softmax Regression.

Unit 3
Gradient Descent and its Generalizations - Gradient Descent and Newton's method, Limitations of the simplest gradient descent algorithm, Stochastic Gradient Descent (SGD) withmini-batches, Methods that use the second moment of the gradient, Comparison of various methods, Application of Gradient descent.

Unit 4
Revisiting the Bias-Variance Tradeoff for Ensembles, Bootstrap AGGregation (Bagging), Boosting, Random Forests, Gradient Boosted Trees and XGBoost, Applications to the Ising model.

Unit 5

Neural Network Basics - building block, Layering neurons and deep networks; Training deep networks, The Backpropagation algorithm and its implemention; Computing gradients in deep networks; Deep neural networks in practice: Deep learning packages, Approaching the learning problem, Phases of the 2D Ising model

Reference Books:

1. Learning from Data – Yaser S. Abu-Mostafa, Malik Magdon-Ismail, Hsuan-Tien Lin, AMLBook, Vol. 4, 2012.
2. Machine Learning: A Probabilistic Perspective – Kevin P. Murphy, MIT Press, 1st Edition, 2012.
3. Pattern Recognition and Machine Learning – Christopher M. Bishop, Springer, 1st Edition, 2006.
4. The Elements of Statistical Learning – Jerome Friedman, Trevor Hastie, Robert Tibshirani, Springer (Springer Series in Statistics), Vol. 1, 2001.
5. Neural Networks: Tricks of the Trade – Léon Bottou (Editor), Springer, 2nd Edition, 2012.
6. An Invariant Form for the Prior Probability in Estimation Problems – Harold Jeffreys, Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences, No publisher (journal article), 1946.

Course Outcomes		Level
CO1	Understand the foundational concepts of machine learning, including problem formulation, Bayesian inference, and regression.	Understand
CO2	Apply and evaluate linear and logistic regression models, including regularization methods, for classification tasks in physics.	Apply, Analyze
CO3	Analyze and compare optimization techniques such as gradient descent, SGD, and second-order methods for training models.	Analyze
CO4	Implement and evaluate ensemble learning techniques such as bagging, boosting, and random forests for predictive modeling.	Apply, Evaluate
CO5	Design, train, and test deep neural networks using backpropagation and modern ML frameworks in real-world physics applications.	Create

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO1	3	2	2	2	1
CO2	3	3	2	3	1
CO3	3	2	2	3	1
CO4	3	3	3	3	2

CO5	3	3	3	3	2

Course Title: Mathematics and Astronomy In India
Course Type: Theory (DSE)

Mathematics and Astronomy in India

Unit 1: Mathematics

Oerview of Indian Mathematics, Sulbasutra, Āryabhaṭīya of Āryabhaṭa ; Development of combinatorics, Magic square, Trogonomentry and Spherical trigonometry, Bijaganit of Bhaskaracharya, Development of calculus in India.

Unit 2 Ancient Astronomy

Astronomy before Āryabhaṭa a) Astronomical references in the Vedas b) Astronomical model and algorithms of the Vedāṅga-jyotiṣa c) The Pañca-siddhāntikā of Varāhamihira
Important astronomers and texts - A brief historical overview; Tantrasaṅgraha of NīlakaṇṭhaSomayājī ;suryasiddhanta

Unit 3: Calendrical computations

Construction of the Indian luni-solar calendar b) Important astronomical instruments described in Indian texts c) Indian records of astronomical observations (inscriptions, copper plates, texts etc.)

Unit 4: Celestial Sphere

The notion of celestial sphere and the need for its conception. The different coordinate systems (horizontal, equatorial and ecliptic) employed. The range of the coordinates in each of these systems.) The advantages and disadvantages of one system over the other. Some illustrative examples for converting one set of coordinates into another. Indian names for the fundamental circles and the coordinates used in these systems.

Reference Books:

1. The Science of the Śulba, B. Datta, University of Calcutta, 1932
2. History of Hindu Mathematics: A Source Book, B. Datta and A. N. Singh, Asia Publishing House, 1962
3. Āryabhaṭīya of Āryabhaṭa, K. S. Shukla and K. V. Sarma, Indian National Science Academy, 1976
4. Geometry in Ancient and Medieval India, T. A. Sarasvati Amma, Motilal Banarasidass, 2007
5. Gaṇita-yukti-bhāṣā of Jyeṣṭhadeva, K. V. Sarma et. al., Hindustan Book Agency, 2008

6. Studies in Indian Mathematics and Astronomy: Selected Articles of Kripa Shankar Shukla, Kolachana et. al. (eds.), Culture and History of Mathematics 12, HBA, 2019
7. Mathematics in India: From Vedic Period to Modern Times, M. D. Srinivas and K. Ramasubramanian and M. S. Sriram, NPTEL course

Course Outcomes		Level
CO-1	Describe key developments in Indian mathematics, including the Sulbasutras, works of Āryabhaṭa and Bhāskarācārya, and their contributions to calculus and combinatorics.	Understand
CO-2	Explain ancient Indian astronomical models and texts, such as the Vedāṅga-jyotiṣa, Pañca-siddhāntikā, and Sūryasiddhānta.	Understand
CO-3	Analyze the structure and calculations involved in the Indian luni-solar calendar and examine traditional astronomical instruments and records.	Analyze
CO-4	Illustrate the concept of the celestial sphere and apply knowledge of coordinate systems used in Indian and modern astronomy.	Apply

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	2	2
CO-2	3	2	3	2	2
CO-3	3	3	3	3	2
CO-4	3	2	2	3	2

Course Title: Astronomy and Astrophysics
Course Type: Theory (DSE)

Astronomy and Astrophysics

Unit 1:

Basics of Observation: Astronomical scales (Distance,Mass, Time), Brightness, Radiant Flux and Luminosity, Apparent and Absolute magnitude scales, Distance Modulus, Measurement of astronomical quantities- Distance, Stellar Radii, Masses of stars from binary orbits, Stellar

temperature, Color index of stars. Spectral types and their temperature dependence, Hertzsprung-Russell (HR) diagram.

Unit 2:

Positional Astronomy: Sphere, Geometry of a sphere, Astronomical coordinate systems - Horizon system, Equatorial system, Coordinate transformation between between Horizon and Equatorial system, Diurnal motion of the stars. Measurement of time, Sidereal time, apparent solar time, mean solar time, Equation of time, Julian date.

Unit 3:

Stellar Physics: Observing through the atmosphere- Atmospheric Windows, optical telescopes, Radio telescopes, telescope mountings, Magnification, Light gathering power, resolving power and diffraction limit, Detection limit of telescope. Derivation of Virial theorem, Basic equations of stellar structure, simple stellar models- Polytropic model, derivation of the Lane-Emden equation, analytic solution of Lane-Emden equation

Unit 4:

Galaxies: Morphological classification of the Galaxies. Basic structure and properties of the Milky way, Nature of rotation of the Milky Way- differential rotation of the Galaxy and Oort constants, rotation curve of the galaxy and the dark matter

Unit 5:

Cosmology: Cosmological observations, The cosmological principle, Homogeneous and isotropic universe, Friedmann model, Evolution of our universe

Reference Books:

1. An Introduction to Modern Astrophysics, Bradley W. Carroll, Dale A. Ostlie, Cambridge University Press, 2nd Ed (2017)
2. Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press, 1st Edition (2010)
3. Fundamentals of Astrophysics, Stan Owocki, Cambridge University Press, 1st Edition (2021)
4. The Physical Universe: An Introduction to Astronomy, Frank H. Shu, University Science Books, 1st Edition (1982)
5. Introduction to Astronomy and Astrophysics, Michael Zeilik, Stephen A. Gregory, Saunders College Publishing, 4th Edition (1998)
6. Fundamental Astronomy ,HannuKarttunen, Pekka Kröger, HeikkiOja, Markku Poutanen, Karl J. Donner, Springer, 6th Edition (2017)

Course Outcomes		Level
CO-1	Describe astronomical distance scales, brightness, magnitude systems, and use observational data to determine stellar properties.	Understand
CO-2	Interpret celestial coordinate systems, perform coordinate transformations, and explain the measurement of astronomical time scales.	Apply
CO-3	Explain the working principles of telescopes and derive basic stellar structure equations including the Lane-Emden equation.	Apply
CO-4	Classify galaxies based on morphology and analyze the structure and rotation curve of the Milky Way to infer the presence of dark matter.	Analyze
CO-5	Interpret cosmological observations, explain the cosmological principle, and analyze the evolution of the universe using the Friedmann model.	Analyze

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	2	2	3	1
CO-3	3	3	2	3	1
CO-4	3	2	3	3	2
CO-5	3	2	3	3	2

Course Title: Applied Dynamics
Course Type: Theory (DSE)

APPLIED DYNAMICS

Unit1

Introduction to Dynamical systems: Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. Simple mechanical systems as first order dynamical systems: simple and damped harmonic oscillator. Sketching flows and trajectories in phase space. Fixed points, attractors, stability of fixed points, basin of attraction, notion of qualitative analysis of dynamical systems. Examples of dynamical systems – Population models e.g. exponential growth and decay, logistic growth, predator-prey dynamics. Rate equations for chemical reactions e.g. auto catalysis, bistability

Unit 2

Introduction to Chaos and Fractals: Chaos in nonlinear equations - Logistic map and Lorenz equations: Dynamics from time series. Parameter dependence- steady, periodic and chaotic states. Cobweb iteration. Fixed points. Defining chaos- aperiodic, bounded, deterministic and sensitive dependence on initial conditions. Period- Doubling route to chaos. Self-similarity and fractal geometry: Fractals in nature – trees, coastlines, earthquakes, etc. Need for fractal dimension to describe self-similar structure. Deterministic fractal vs. self-similar fractal structure. Nonlinear time series analysis and chaos characterization: Detecting chaos from Return map, Power spectrum, Autocorrelation, Lyapunov exponent, Correlation dimension.

Unit 3

Elementary Fluid Dynamics: Importance of fluids: Fluids in the pure sciences, fluids in technology. Study of fluids: Theoretical approach, experimental fluid dynamics, computational fluid dynamics. Basic physics of fluids: The continuum hypothesisconcept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties- viscosity, thermal conductivity, mass diffusivity, other fluid properties and equation of state; Flow phenomena- flow dimensionality, steady and unsteady flows, uniform and non-uniform flows, viscous and inviscid flows, incompressible and compressible flows, laminar and turbulent flows, rotational and irrotational flows, separated and unseparated flows. Flow visualization - streamlines, pathlines, Streaklines.

Reference Books

1. Nonlinear Dynamics and Chaos, S.H. Strogatz, Levant Books, Kolkata, 2007
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. Nonlinear Dynamics: Integrability, Chaos and Patterns, M. Lakshmanan and S. Rajasekar, Springer, 2003.
4. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
5. Fluid Mechanics, 2nd Edition, L. D. Landau and E. M. Lifshitz, Pergamon Press, Oxford, 1987.

Course Outcomes		Level
CO-1	Explain the concept of dynamical systems, phase space, flows, fixed points, and stability using physical and biological system examples.	Understand
CO-2	Analyze population dynamics and chemical reaction systems using first-order differential equations and rate equations.	Analyze
CO-3	Interpret and model chaotic systems using tools like the logistic	Apply

	map, Lorenz equations, cobweb iteration, and nonlinear time series analysis.	
CO-4	Evaluate fractal structures in natural systems and differentiate between deterministic and self-similar fractals using fractal dimensions.	Evaluate
CO-5	Describe basic concepts and classifications in fluid dynamics, including flow types, fluid properties, and visualization techniques.	Understand

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	**Program Outcomes**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	3	2	3	2
CO-3	3	3	2	3	2
CO-4	2	2	2	3	2
CO-5	3	2	2	3	1

Course Title: Computational Condensed Matter Physics
Course Type: Theory (DSE)

Computational Condensed Matter Physics

Unit -1

Introduction and overview

Introduction and Basic concepts, Theoretical Background, Basic equations for interacting electrons and nuclei, Coulomb interaction in condensed matter, Independent electron approximations, Exchange and correlation, Periodic solids and electron bands, Structures of crystals: lattice + basis, The reciprocal lattice and Brillouin zone, and the Bloch theorem. Time reversal and inversion symmetries, Integration over the Brillouin zone and special points Density of states - Uniform electron gas and simple metals.

Unit -2

Introduction to quantum mechanical modeling: Hartree-Fock and Density function theory

Non-interacting and Hartree-Fockapproximation, the correlation hole and energy. Density functional theory: foundations, Thomas-Fermi-Dirac approximations: example of a functional. The Hohenberg-Kohn theorems, Constrained search formulation of density functional theory, Extensions of Hohenberg-Kohn theorems, The Kohn-Sham ansatz. Replacing one problem with another: The Kohn-Sham variational equations E_{xc}, V_{xc} and the exchange correlation hole - meaning of the eigenvalue. Intricacies of exact Kohn-Sham theory.

Unit -3

Exchange Correlation Functionals, Correlation effects. And SCF calculations

Functionals for exchange and correlation - The local spin density approximation (LSDA), Generalized-gradient approximation (GGAs) , LDA and GGA expressions for the potential Vxc(r), Non-collinear spin density, Non-local density formulations: ADA and WDA - Orbital dependent functionals I: SIC and LDA+U. Orbital dependent functional II: OEP and EXX, Hybrid functionals -Tests of functionals Solving Kohn-Sham equations – Self-consistent coupled Kohn Sham equations - Total energy functionals - Achieving self-consistency – Numerical mixing schemes - Force and stress.

Unit -4

Electronic structure from plane wave and localized basis methods

Determination of electronic structure – Atomic sphere approximation in solids, Plane waves and grids: basics - The independent particle Schrodinger equation in a plane wave basis. The Bloch theorem and electron bands - Nearly free-electron-approximation - Form factors and structure factors. Plane-wave method - 'Ab initio' pseudopotential method - Projector augmented waves (PAWs) - Simple crystals: structures, bands, - Supercells: surfaces, interfaces, phonons, defects - Clusters and molecules. Localized orbitals: tight-binding – Tight-binding bands: illustrative examples - Square lattice and CuO_2 planes - Examples of bands: semiconductors and transition metals - Electronic states of nanotubes. Localized orbitals: full calculations – Solution of Kohn-Sham equations in localized bases. Analytic basis functions: Gassians - Gassian methods: ground state and excitation energies - Numerical orbitals - Localized orbitals: total energy, force, and stress - Applications of numerical local orbital methods.

Unit -5

Mixed Basis Methods and Their Applications

Augmented plane waves (APW's) and 'muffin-tins' – Solving APW equations: examples Muffin-tin orbitals (MTOs). Linearized augmented plane waves (LAPWs) - Applications of the LAPW method - Linear muffin-tin orbital (LMTO) method - Applications of the LMTO method - Full potential in augmented methods - Molecular dynamics (MD): forces from the electrons - Lattice dynamics from electronic structure theory - Phonons and density response functions - Periodic perturbations and phonon dispersion curves - Dielectric response functions, effective charges - Electron-phonon interactions and superconductivity.

Books recommended:

1. H.Skriver, The LMTO Methods, Springer (1984).
2. Electronic Structure Basic Theory and Practical Methods Richard M. Martin, Cambridge University Press (2004).
3. Modeling Materials Continuum, Atomistic and Multiscale Techniques ELLAD B. TADMOR, Cambridge University Press (2012).
4. Atomic and Electronic Structure of Solids, Efthimios Kaxiras, Cambridge University Press (2003).
5. Computational Chemistry of Solid State Materials, *Richard Dronskowski*, WILEY-VCH (2005).
6. Mizutani U. Introduction to the Electron Theory of Metals (CUP,2001).
7. Roessler U. Solid State Theory.. An Introduction (2ed., Springer, 2009)
8. Lecture Notes by Prof.Ravindran

Course Outcomes

	Course Outcome	Level
CO-1	Introduce students to modelling of solids and predict as well as interpret their various properties using computational modelling.	Acquire, Understand,
CO-2	Show how these modelling methods can be used to understand fundamental material structure and properties as well as the relationships between material structure and material behaviour.	Evaluate, Analyse, Skill
CO-3	Develop an understanding of the assumptions and approximations that are involved in the modelling frameworks at the various time and length scales.	Remember, Understand, Analyse, Apply
CO-4	Students will be introduced to the basis for the simulation techniques, learn how to use computational modelling, and how to present and interpret the results of simulations.	Understand, Apply, Skill
CO-5	The students will learn various computational parameters and practical knowledge involve in modelling functional properties of solids and with that knowledge they can design materials in the computational lab for various applications.	Understand, Analyse, and Apply

Mapping of Program Outcomes with Course Outcomes

	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	3	1	1	2	3
CO-2	3	3	3	1	3
CO-3	3	1	3	2	3
CO-4	3	2	1	1	2
CO-5	3	3	3	2	2

Course Title: Nanomaterials And Nanotechnology
Course Type: Theory (DSE)

Nanomaterials And Nanotechnology

Unit 1
Introduction

Introduction to nanotechnology, physics of low-dimensional materials, quantum effects, 1D, 2D and 3D confinement, Density of states, Excitons, Coulomb blockade, Zero-, One-, Two- and Three- dimensional structure, Size control of metal nanoparticles and their properties: optical, electronic, magnetic properties; surface plasmon resonance, change of bandgap; Application: catalysis, electronic devices

Unit 2
Nanofabrication

Importance of size distribution control, size measurement and size selection, assembling and self-organization of nanostructures, Nanofabrication: patterning of soft materials by self-organisation and other techniques, chemical self-assembly, artificial multilayers, cluster fabrication, Langmuir-Blodget growth, Nanolithography, Scanning probe lithography, Micro contact printing.

Unit 3
Nanoelectronics and devices

Advantages of nano electrical and electronic devices, micro and nano-electromechanical systems – sensors, actuators, optical switches, bio-MEMS diodes and nano-wire transistors - data memory lighting and displays, filters (IR blocking) – quantum optical devices – batteries - fuel cells and photo-voltaic cells – electric double layer capacitors – lead-free solder – nanoparticle coatings for electrical products

Unit 4
Nanocatalysts and Nanoporous materials

Nanocatalyts, smart materials, heterogenous nanostructures and composites, nanostructures for molecular recognition (quantum dots, nanorods, nanotubes) – molecular encapsulation and its applications – nanoporous zeolites – self-assembled nanoreactors - organic electroluminescent displays

Unit 5
Nanotechnology for Nanomedince

Drug deliveries, drug delivery system, nanoparticle in drug delivery- available applications, nanotechnology future application understanding for treatment. Manufacture of nanoparticles, nanopowder and nanocrystals, targeting ligands applications of nanoparticle in drug delivery, cancer treatment, tissue regeneration, growth and repair, impact of drug discovery and development.

Tasks and Assignments:

Books recommended:

1. Nanolithography and patterning techniques in microelectronics, David G. Bucknall, Wood head publishing 2005.
2. Transport in Nanostructures, D.K. Ferry and S.M. Goodmick, Cambridge university press 1997.
3. Optical properties of solids, F. Wooten, Academic press 1972.
4. Micro and Nanofabrication, Zheng Cui, Springer 2005.

5. Nanostructured materials, Jackie Y. Ying, Academic press 2001.
6. Nanotechnology and nanoelectronics, W.R, Fahrner, Springer 2005.
7. Hand book of Nanoscience, Engineering, and Technology, William A. Goddard, CRC press 2003.
8. Nanoelectronics and Information Technology, Rainer Waser, Wiley-VCH 2003.
9. The MEMS Handbook Frank Kreith, CRC press 2002.
10. Charles P. Poole, Jr., Frank J. Owens, "Introduction to nano technology", Wiley, 2003.
11. Gunter Schmid, "Nanoparticles: From Theory to Applications", Wiley-VCH Verlag GmbH & Co., 2004.

Supplementary Reading:

1. Pradeep T "Nano: The Essentials", Mc Graw Hill Publishing Co. Ltd., 2007.
2. Mick Wilson et al, "Nanotechnology", Overseas Press (India) Pvt. Ltd., 2005.
3. Nanoengineering of structural, functional and smart materials, Mark J. Schulz, Taylor & Francis 2006.
4. Nanocomposite science and technology, Pulikel M. Ajayan, Wiley-VCH 2005.

Course Outcomes

	Course Outcome	Level
CO-1	To get brief introduction about the nanomaterials and nanotechnology. Also understand the size and shape dependent on the physical properties of materials at nanoscale.	Acquire, Understand, Apply, Skill
CO-2	Gain knowledge about the importance of size distribution, size selectivity, self-assembly on properties of nanoscale materials. Understand various nanofabrication techniques used to synthesis nanomaterials.	Remember, Evaluate, Analyse, Skill
CO-3	Analyse the advantages of using nanotechnology for various electronic applications.	Remember, Understand, Analyse, Apply
CO-4	Understand molecular recognition, molecular encapsulation, nanocomposites, nanoreactors, nanoporous materials for catalysis and smart applications.	Acquire, Understand, Apply, Skill
CO-5	Gain knowledge about nanomedicine, targeted drug delivery, diagnosis and treatment. Understand bio-inspired, bio-mimicking and bio-compatible nano-materials.	Understand, Analyse, Apply.

Mapping of Program Outcomes with Course Outcomes

	PO-1	PO-2	PO-3	PO-4	PO-5

CO-1	2	2	3	2	1
CO-2	2	2	3	2	1
CO-3	2	2	3	2	2
CO-4	3	2	2	2	1
CO-5	2	3	3	2	1

Course Title: Properties of Materials
Course Type: Theory (DSE)

Properties of Materials

Unit 1
Mechanical properties
Factors affecting mechanical properties - mechanical tests - tensile, hardness, impact, creep and fatigue - Plastic deformation by slip - shear strength - work hardening and recovery - fracture - Griffith's theory - slip and twinning - creep resistant materials - diffusion – Fick's law.

Unit 2
Optical Properties:

Electrons in electromagnetic field, optical absorption in insulators, semiconductors and metals – band to band absorption – Inter band and intra band transitions - charge injection and radiative recombination – The continuity equation: Diffusion length, excitonic effects and modulation of optical properties. Luminescence – photoconductivity, photoelectricity, LED and liquid crystal displays. Non-linear optics - wave propagation in Non-linear dielectrics - Electrooptic and Nonlinear optic co-efficients -The nonlinear susceptibility - Optical second Harmonic generation.

Unit 3
Thermal and Thermoelectric Properties:
Thermal conduction - Thermal conductivity, Flow of heat through compound media. Determination of thermal conductivity of conductors by Forbe's method, Lattice vibrations, harmonic approximation, dispersion relations and normal modes, quantization of lattice vibrations and phonons. thermal expansion and need for anharmonicity. Transport properties of solids. Boltzmann transport equation. Wiedemann-Franz law. Lattice vibrations, phonons, adiabatic & harmonic approximations, lattice heat capacity, Einstein and Debye models.

Unit 4
Magnetic Properties:
Classification - dia, para, ferro, antiferro and ferrimagnetism – Langevin and Weiss theories - Heisenberg's theory of exchange interaction - magnetic aniostrophy - magnetic domains - Weiss molecular field theory – Classical and quantum theory of paramagnetism, Curie's law, spontaneous magnetization and domain structure, spontaneous magnetization and its temperature dependence. Curie-Weiss law, explanation of hysteresis. - hard and soft magnetic materials - ferrite structure and uses - - magnetoresistance - GMR materials - dilute magnetic semiconductor materials. Spin waves and magnons.

Unit 5

Dielectric and Ferroelectric Properties:

Dielectric constant and polarizability - Static dielectric constant, electronic, ionic and orientation polarizations - Internal or local fields in dielectrics Clausius- Mossatti equation - complex dielectric constant - determination of dipole moment for polar substances - dielectric losses - frequency dependence of electronic, ionic, orientation polarisabilities - dielectric loss. General properties of ferroelectrics- Curie Weiss behavior - classification of ferro electric materials - dipole theory of ferro electricity - ferro electric domains - applications - piezoelectric and pyroelectric materials and applications.., Ferroelectric materials- Pervoskite crystal structure (eg.$BaTiO_3$ and PZT).

Books recommended:

1. V. Raghavan, “Materials Science and Engineering: A First Course", Prentice Hall, 2006.
2. S. O. Pillai,“ Solid state physics”, New age International Pvt Ltd, 6th edition, 2005
3. Wahab, M. A.,“ Solid State Physics”, Narosa Publishing, 2nd Edition, 2005
4. C. Kittel, "Introduction to Solid State Physics" Wiley Eastern Ltd., 2005.
5. N.W. Ashcroft and N.D. Mermin Solid state physics, India edition IE, Thomsom books, Reprint, 2007.
6. John Singleton: Band theory and Electronic properties of Solids (Oxford University Press; Oxford Master Series in Condensed Matter Physics).
7. Electricity and Magnetism: Brijlal& Subrahmanyam Ratan Prakashan Mandir Publishers - 1995.
8. Harald Ibach and Hans Lüth“ An Introduction to principles of Materials Science”, Springer, 2003.
9. James D. Patterson, Bernard C. Bailey,“ Solid State Physics: Introduction to the theory”, Springer-Verlag, edition 1, 2005
10. Jasprit Singh, “Semiconductor Optoelectronics Physics and Technology”, McGraw Hill Co., 1998
11. H.P.Myers, Introductory Solid State Physics, 2nd edition, Viva Books Pvt. Ltd (1998)
12. M.Ali Omar, Elementary Solid State Physics, revised printing Pearson Education (2000)
13. M.S. Rogalski and S.B. Palmer, Solid Statae Physics, Gordon Breach Science Publishers (2000)
14. Y.K. Lim, Problems and solutions on Solid State Physics, Sarat Book Publishers (2002)
15. Fundamentals of Electricity and Magnetism: R.G.Mendiratta and B.K.Sawhney East - West Press(1976)
16. E. Lines and A.M.Glass, Principles and applications of ferroelectrics materials, Clarendon press, Oxford ,1979.
17. K.V.Keer, Principles of solid state physics, Wiley - Eastern, 1993.

Supplementary Reading:

1. W. D. Callister, "Materials Science and Engineering: An Introduction", John Wiley & Sons, 2007.
2. Michael Shur, "Physics of Semiconductor Devices", Prentice Hall of India, 1995.
3. S. Blundell, Magnetism in condensed matter, Oxford university press, 2001.
4. A. Aharoni, Introduction to the theory of ferromagnetism, Oxford university press, 2001.
5. Y. D. Jiles, Introduction to magnetism and magnetic materials, Chapmean and Hall. (2nd edition).
6. L. L. Hench, J. K. West, Principles of electronic ceramics, John Wiley and sons,1995.

7. D.R.Tilley and J.Tilley, Superfludity and superconductivity, 3rd Edition, Hilger,1990.
8. M. Marder, Condensed Matter Physics
9. A.J.Dekkar, Electrical Engineering Materials, Prentice Hall, New Delhi, 1996 .
10. A.J. Dekker, "Solid State Physics", Macmillan & Co., 2000.

Course Outcomes

	Course Outcome	Level
CO-1	Gain fundamental understanding about stress-strain relation and the role of micro/nano structures on mechanical properties.	Acquire, Understand, Apply, Skill
CO-2	Develop fundamental knowledge about the interaction of light with matter and explain optical properties of insulators, semiconductors and metals through interband and intraband transitions. Understand electro-optic and non-linear optical properties microscopically and gain knowledge about various optical transitions such as photoconductivity, luminescence, excitonic effects, photoelectricity etc.	Remember, Evaluate, Analyse, Skill
CO-3	Acquire knowledge about the origin of thermal properties in solids and the role of phonon on transport properties. Get brief introduction about the thermoelectric properties of solids.	Remember, Understand, Analyse, Apply
CO-4	Gain knowledge about the origin of various magnetic ordering and the theory to explain the magnetic properties and its applications.	Acquire, Understand, Apply, Skill
CO-5	Understand the origin of dielectric polarization and the role of symmetry on spontaneous electric polarization. Classify the piezoelectric, pyroelectric and ferroelectric materials and gain knowledge about the relevant theoretical developments.	Understand, Analyse Apply,

Mapping of Program Outcomes with Course Outcomes

	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	2	3	1	2	1
CO-2	2	3	3	1	1
CO-3	2	2	2	3	1
CO-4	1	2	2	3	1
CO-5	2	2	3	3	1

Course Title: Nonlinear Dynamics
Course Type: Theory (DSE)

Nonlinear Dynamics

Unit-I

Linear and Nonlinear Dynamical systems: Linear and Nonlinear systems - Mathematical models examples – Mathematical Implications ofNonlinearity:superpositionprincipleanditsvalidity-Examplesandproblems-linearandnonlinear oscillators – Frequency response curve - Resonance and Hysteresis - Examples andproblems-Autonomousandnonautonomoussystems-Phaseplanetrajectories-stability,attractors and repellers - limit cycle - Examples and problems - Phase space - classification ofequilibriumpointsandEigenvalues- stabilityoffixedpoints-Examplesandproblems.

Unit-II

Bifurcation Dynamics: Bifurcation - the logistic map – Feigenbaum ratio - period doubling phenomenon- Bifurcationdiagram - onset of chaos- other routes to chaos -Lorentz systems - Sensitive dependence on initialcondition-controllingofchaos-bifurcationscenarioinDuffingoscillator-Examplesandproblems

Unit-III

Nonlinear wave propagation: Linear and nonlinear dispersive wave propagation - Fourier transformation and solution of initialvalue problem - wave packet and dispersion - Nonlinear dispersive system - Korteweg-de Vriesequation and the solitary waves and Cnoidal waves - Scott Russel's phenomenon and Korteweg-de Vries equation - Fermi-Pasta-Ulam lattice problem - FPU recurrence phenomenon – discreteKorteweg-deVriesequations(KdVandmKdV)-numericalexperimentofZabuskyandKruskal- birth ofsoliton.

Unit-IV

Integrability: Integrability and methods to solve soliton equations - The notion of integrability – Nonlinearperturbation theory - multiple scale perturbation method - soliton solutions of perturbed nonlinearSchrödinger equation - Hirota's direct method and 'N' soliton solutions **–** Painleve's analysis;Leadingorder–Resonance–ArbitaryAnalysisanditsapplicationtoKorteweg-deVriesequation,nonlinearSchrödinger equation-Lax pairfor Korteweg-deVriesequation.

Unit-V

Applications of Nonlinear dynamics: Applications of Nonlinear dynamics - soliton applications in all optical communication - EnergytransfersolitoninpolypetidesproteinandDavydovSolitonDNA-Functionofsolitonincytoskeleton neuronal microtubules - Ion-acoustic solitons in plasma: an application to Saturn'smagnetosphere- Pulse solitonsin blood circulatorysystems.

References:

1. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering Steven H. Strogatz ,Chapman and Hall/CRC, 2nd Edition, 2018.

2. Nonlinear Dynamics and Chaos, Second Edition .Steven H. Strogatz Addison-Wesley, 2nd Edition, 2000.
3. Nonlinear Dynamics Integrability, Chaos and Patterns Muthusamy Lakshmanan, ShanmuganathanRajaseekar , Springer Berlin Heidelberg, 2012
4. Nonlinear Dynamics: A Concise Introduction Interlaced with Applications. Ulrich Parlitz,Springer, 2022
5. Nonlinear Dynamics and Chaos, Third Edition. Z Steven H. Strogatz Chapman and Hall/CRC, 3rd Edition, 2024.
6. A First Course in Discrete Dynamical Systems, R. A. Holmgren Springer, 1996
7. Chaos in Duynamical Systems, E. Ott Cambridge, 2002.
8. https://youtu.be/ga48Rue5fBgBy Prof.RamkrishnaRamaswamy , IIT Delhi
9. https://youtu.be/nh4TFzg30eQ?si=zqGDGy486uhDEHtr . Lecture on Topics in Nonlinear Dynamics by Prof. V. Balakrishnan,Department of Physics,IIT Madras.
10. https://www.youtube.com/watch?v=oOpFvkqAnG4
Lecture series "Basics of Nonlinear Dynamics I" by Professor M Lakshmanan, Bharathidasan University

Course Outcomes

	Course Outcome	Level
CO-1	To be able to understand basic concepts of dynamical system and analyse the mathematical Implications ofNonlinearity (e.g. linearandnonlinear oscillators – Frequency response curve). To be able to finding fixed points and determine their stability (e.g. Phase space, classification ofequilibriumpointsandEigenvalues)	Understand
CO-2	To be able to analyse changes (i.e. bifurcations) to dynamical systems as system parameters are varied including the logistic map, period doubling phenomenon Feigenbaum ratio, Bifurcationdiagram with appropriate examples.	Analyse
CO-3	To understand the properties of linear and nonlinear dispersive waves and localization with various phenomenon such as Korteweg-de Vriesequation and the solitary waves and Cnoidal waves, Scott Russel's phenomenon and Korteweg-de Vries equation, Fermi-Pasta-Ulam lattice problem, FPU recurrence phenomenon, discreteKorteweg-deVriesequations(KdVandmKdV), etc..	Understand
CO-4	To analyse the integrability and concept of nonlinear perturbation theory and applying various mathematical methods (multiple scale perturbation method, Hirota's direct method and 'N' soliton solutions) to solve the nonlinear equations for soliton solution. To apply the analysis of Painleve's analysis,LeadingorderResonance and ArbitaryAnalysis to the nonlinear equations	Analyse
CO-5	To study the applications of solitons in different biological systems as Energytransfersolitoninpolypetidesprotein,DavydovSolitonDNA, soliton functioningincytoskeleton neuronal microtubules and	Apply

	Pulse solitonsin blood circulatorysystems and the applications to the several field like optical communication, Ion-acoustic solitons in plasma and an application to Saturn'smagnetosphere.	

Mapping of Program Outcomes with Course Outcomes

	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	**3**	**2**	**1**	**2**	**1**
CO-2	**3**	**2**	**2**	**3**	**1**
CO-3	**3**	**2**	**3**	**3**	**1**
CO-4	**3**	**2**	**2**	**2**	**1**
CO-5	**3**	**2**	**3**	**2**	**3**

Course Title: Advanced Particle Physics
Course Type: Theory (DSE)

Advanced Particle Physics

Unit 1:
Relativistic kinematics and Particle discovery: Relativistic Kinematics: Lorentz transformations, four-vectors, relativistic collisions. Discovery of particles and particle accelerators: hadronic zoo, accelerators, detectors, discovery of short-lived particles: resonances and reconstruction of events.

Unit 2:
Discrete Quantum numbers and their Transformations: Two nucleon state vectors, Isospin, Strangeness and Hypercharge, Lepton and Baryon number conservation, Yukawa's theory, Parity, Parity conservation and non-conservation, Time reversal, Consequences of time reversal invariance, Charge conjugation, G-parity, Statement of CPT theorem and its consequences, Proof of equality of mass and life time for particle and antiparticle.

Unit 3:
Symmetries and Groups: Unitary Symmetry and the classification of state, Hadrons and SU (3) multiplets, properties of representations, Young-Tableux method for direct products of representations, Applications of SU(3) flavour symmetry and of broken SU(3) flavour symmetry, Gell-Mann- Okubo mass formula for Baryons and Mesons, , Quarks and Gluons, Colour hypothesis, Evidence of color, Magnetic moment of baryons, Baryon wave functions.

Unit 4:
Feynman Calculus and introduction to QED processes: Feynman Calculus: Decay, Fermi's Golden rule, Lorentz invariant phase space, decay and scattering (2 -body), Feynman rule's for matrix element calculation, Feynman's rule for QED process (with examples)

Unit 5:
Weak Interaction and BSM Physics: Weak Interaction: introduction, parity violation, helicity and chirality, charged pion decay, CKM matrix.
Beyond Standard Model Physics: Unification, The Higgs Boson, Dark matter and Dark energy, Baryogenesis and primordial fluctuations, Supersymmetry.

Reference Books::

1. Quantum Field Theory, F. Mandl and G. Shaw, Wiley, 2nd Edition(2010).
2. Introduction to High Energy Physics, D. H. Perkins, , Cambridge University Press, 4th Edition (2000).
3. Elementary Particle Physics, D.J.Griffiths, Wiley, , 2nd Edition (2008).
4. Quarks and Leptons, F.Halzen and A.D. Martin, Wiley, 1st Edition (1984)
5. Quantum Field Theor, M.Peskin and Schroeder, CRC Press, 1st Edition (2019)
6. E-content: https://www.pp.rhul.ac.uk/~cowan/advpp/lectureNotes.pdf
7. https://onlinecourses.swayam2.ac.in/ini24_ph01/preview
8. https://ocw.mit.edu/courses/8-811-particle-physics-ii-fall-2005/pages/lecture-notes/

Course Outcomes		**Level**
CO-1	Four momentum, conservation of quantum numbers, Feynman's calculus, weak interaction	Understand
CO-2	2-body decay problem, elementary particle reaction, decay and scattering cross section calculation	Apply
CO-3	Relativistic kinematics in COM and Lab frame, discrete quantum numbers and invariance principles, Weak interaction.	Analyze
CO-4	Fermi Golden rule for 2-body decay and scattering process, Gell-Mann-Okuba mass formula, Young-Tableux method.	Remember
CO-5	Solve numerical problems related to 2 body decay and scattering, cross section and decay rate of lowest order QED process.	Evaluate

Course Outcomes	**Program Outcomes**				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**

CO-1	3	2	2	3	1
CO-2	3	1	3	3	1
CO-3	3	2	1	2	1
CO-4	3	2	2	3	1
CO-5	3	2	2	3	1

Course Title: Research Methodology for Scientific Research
Course Type: Theory (DSE)

Research Methodology for Scientific Research

UNIT-I: Introduction:
Meaning, objectives and motivations in research, Characteristics and limitations of research – Components of research work - Criteria of good research, Research process – Types of Research, Fundamental, Pure or Theoretical Research –Applied Research –Descriptive Research – Evaluation Research –Experimental Research – Survey Research – Qualitative Research – Quantitative Research – Historical Research.

UNIT-2: Research design:
Research Design – definition – essentials and types of research design – errors and types of errors in research design. Research problem: Selecting and analyzing the research problem – problem statement formulation – formulation of hypothesis. Literature review: purpose, sources, and importance - literature review procedure. Objectives: Learning Objectives; Definitions; Formulation of the research objectives.

UNIT-3: Measurements and data analysis:
Concept of measurement– what is measured? Problems in measurement in research – Validity and Reliability. Levels of measurement – Nominal, Ordinal, Interval, Ratio. Sampling and Sampling designs; Data analysis: Mean deviation, Root mean square deviation, Histogram, Skewness, Kurtosis, Moments, Variance, Chi-square, Correlation, Factor analysis, Mean square weighted deviation, Regression, Time series analysis.

UNIT-4: Experimental Techniques:
Simple description and working principle of vacuum pumps (Rotary, diffusion and turbo pumps) and penning and Pirani gauges: Sample preparation by PVD and CVD techniques; Basic principles and measurements procedures of XRD, XPS, Raman spectroscopy, SEM, TEM and Visible spectroscopy.

UNIT-5: Scientific Writing and Reports:
Writing the abstract - The literature review – (purpose, stage, style and subdivision) The Nature and Varieties of thesis - Characteristics of good thesis - The intellectual content of the thesis - Layout of the thesis - Procedure of submitting the thesis - Publishing the research findings in academic journal - The structure of the viva - Defending the Thesis.

Reference Books:
1. C. R. Kothari, Research methodology: Methods and techniques, New Age International, 2004.

2. K. N. Krishnaswamy, Management Research Methodology: Integration of Principles,Medthods and Techniques. Pearson Education India2006.
3. Lecture notes from the course.

Course Outcomes		Level
CO-1	Introduce research methodologies and various types of research.	Understand/Apply
CO-2	Gain knowledge on how to design research problem by setting up literature survey, hypothesis and objectives.	Understand/analyse Apply
CO-3	Get understanding about the statistical analysis of acquired data	Understand/Analyze
CO-4	Give insight into various experimental techniques used in scientific research.	Analyse and Apply
CO-5	Give knowledge about how to prepare the thesis, project reports and scientific publications.	Understand/analyse Apply

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	3	3	2	1
CO-2	2	2	3	3	1
CO-3	2	2	3	2	1
CO-4	3	3	2	2	1
CO-5	2	3	2	3	1

MULTIDISCIPLINARY/OPEN ELECTIVES

Course Code: PHYOE01
Course Title: Gender Concerns in STEM Studies
Course Type: Theory (MD)
Credits: 03 (45 Hours)

Gender Concerns in STEM studies

Unit 1: Concepts of Gender: Sex – Gender – Understanding sex and gender - Biological Determinism – Patriarchy – Feminism – Gender Discrimination – Gender Division of labour – Gender Stereotyping – Gender Sensitivity – Gender Equity – Equality

Unit 2: Women's Studies vs Gender Studies : UGC's Guidelines – SAKSHAM and its recommendations, VII to XI Plans – Gender Studies : Beijing Conference and CEDAW – Exclusiveness and Inclusiveness.

Unit 3: Gendering of Science and Technology Masculization of science and technology – examples from agriculture and military technology in ancient and medieval times, knowledge monopoly and modern science.

Unit 4: Low participation of women in S&T: Understanding the reasons – debates on Nature vs. Nurture, leaky pipeline, glass ceiling.

Unit 5: Affirmative Actions: Governmental initiatives – scholarships, fellowships (SERB initiatives, WIS, KIRAN), special provisions (mobility measures, leave and break in career opportunities), institutional mechanisms (GATI, Gender Policy); Informal and semi-formal initiatives by individuals and collectives – examples from the field of Physics in India.

Reference Books:

1. Gender: The Basics Hilary M. Lips, Routledge, 2nd Edition, 2020.
2. Feminist Theory: From Margin to Center bell hooks, South End Press, 2nd Edition, 2000.
3. Gender and Technology: A Reader Nina Lerman, Arwen Mohun, Ruth Oldenziel, Johns Hopkins University Press, 2003.
4. Women in Science: 50 Fearless Pioneers Who Changed the World Rachel Ignotofsky, Ten Speed Press, 2016.
5. Gender and the Politics of History Joan Wallach Scott, Columbia University Press, Revised Edition, 1999.
6. Kamala Bhasin, Understanding Gender: Gender Basics, Women Unlimited, New Delhi, 2004.
7. Kamala Bhasin, Exploring Masculinity: Gender Basics, Women Unlimited, New Delhi, 2004.
8. LondaSchiebinger (Ed.), Women and Gender in Science and Technology, Routledge, 2014.
9. https://onlinecourses.swayam2.ac.in/arp19_ap54/previewbyProf. Nivedita Menon, Jawaharlal Nehru University
10. https://onlinecourses.swayam2.ac.in/cec25_hs108/ by Dr. Jasleen Kewlani, Rajiv Gandhi National University of Law
11. https://onlinecourses.swayam2.ac.in/nou21_hs03/ by IGNOU staff

Course Outcomes		Level
CO-1	Explain basic gender concepts such as sex vs gender, feminism, patriarchy, equity, and sensitivity.	Understand
CO-2	Describe the evolution of Gender Studies and analyze institutional frameworks supporting gender equality.	Apply
CO-3	Analyze the gendering of science and technology, including masculinization and knowledge monopoly.	Analyze
CO-4	Evaluate reasons for low participation of women in STEM through Nature vs Nurture debate and the leaky pipeline concept.	Apply
CO-5	Examine affirmative actions, policies, fellowships, and informal efforts aimed at improving gender inclusion.	Evaluate

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	0	0	2	3
CO-2	2	0	2	0	3
CO-3	0	2	0	2	3
CO-4	2	2	2	2	2
CO-5	2	3	2	3	3

Course Code: PHYOE02
Course Title: Physics of Arts
Course Type: Theory
Credits: 03 (45 Hours)

Physics of Arts

Unit 1: Introduction to Music

Introduction to music and its forms ,Physics of pitch, loudness, and timbreMelody and symphonybasics.

Unit 2: Physics of Music

Harmony – basic understanding of western classical and Indian classical music, Time scales and rhythm in music, Handling of time in Physics, Acoustics of auditoria – reverberation, echoes, and good acoustics.

Unit 3: Introduction to Dance

History of dance, Main elements of western classical dance, Indian classical dance basicsModern dance.

Unit 4: Physics of Dance

Physics of rotations and application in western classical dancing, Role of centre of gravity in basic stances (plie and ardhamandala/araimandi), Tension and its resolution, Projectiles and jumps – velocity, friction, and angular momentum.

Unit 5: Physics of Paintings/Photography

Introduction to electromagnetic spectra, Colours and wavelengths, Colour wheel, mixing of colours, and complementary colors, Symmetry and its role in nature and paintings, The golden ratio, Introduction to the physics of cameras – parts of a camera, lenses and their properties, aperture, shutter speed, and ISO.

Reference Books:

1. Thomas D. Rossing, *The Science of Sound*, Pearson Education, 3rd Edition, 2001.
2. Neville H. Fletcher and Thomas D. Rossing, *The Physics of Musical Instruments*, Springer, 2nd Edition, 1998.
3. Kenneth Laws, *Physics and the Art of Dance: Understanding Movement*, Oxford University Press, 1st Edition, 2002.
4. G. D. Rai, *Photographic and Optical Instruments*, Khanna Publishers, 2nd Edition, 2004.
5. Sidney F. Ray, *Applied Photographic Optics*, Focal Press (Elsevier), 3rd Edition, 2002.
6. Rudolf Arnheim, *Art and Visual Perception: A Psychology of the Creative Eye*, University of California Press, Revised Edition, 1974.
7. A. V. Sharma, *Sound: An Introduction to Acoustics*, Himalaya
8. Publishing House, 1st Edition, 2005.
9. https://onlinecourses.nptel.ac.in/noc24_me106/preview by Prof. Venkata R. Sonti, IISc
10. https://www.coursera.org/learn/music-physics-acoustics Coursera
11. https://youtu.be/d9Byz1ftRdk?si=SbTpXKQ0dhS7bsNQ IGNOU related

Course Outcomes		Level
CO-1	Understand the physics of rhythm, melody, symphony, harmony, and time scales in Western and Indian classical music.	Understand
CO-2	Analyze the relationship between physical principles (e.g., acoustics, sound propagation) and the quality of music in auditoria.	Analyze
CO-3	Apply principles of mechanics such as center of gravity, angular momentum, and friction to dance movements and analyze their impact.	Apply
CO-4	Analyze the role of symmetry, color theory, and light in paintings and visual arts, and evaluate their relationship with natural phenomena.	Analyze
CO-5	Analyze the working of cameras, focusing on lenses, aperture, shutter speed, and ISO, and evaluate their impact on visual arts and photography.	Analyze

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	2
CO-2	3	2	2	3	2
CO-3	3	2	2	3	2
CO-4	3	2	2	3	2
CO-5	3	2	2	3	2

Course Code: PHYOE03
Course Title: Introduction to Astronomy and Astrophysics
Course Type: Theory
Credits: 03 (45 Hours)

Introduction to Astronomy and Astrophysics

Unit 1: Elementary Concept Astronomical scales (Distance,Mass, Time), Brightness, Radiant Flux and Luminosity, Apparent and Absolute magnitude scales, Distance Modulus, Measurement of astronomical quantities- Distance, Stellar Radii, Masses of stars from binary orbits, Stellar temperature, Color index of stars. Spectral types and their temperature dependence, Hertzsprung-Russell (HR) diagram.

Unit 2:Positional Astronomy: Celestial Sphere, Geometry of a sphere, Astronomical coordinate systems - Horizon system, Equatorial system, Coordinate transformation between between Horizon and Equatorial system, Diurnal motion of the stars. Measurement of time, Sidereal time, apparent solar time, mean solar time, Equation of time, Julian date.

Unit 3:Stellar Physics: Hydrostatic equilibrium, mass continuity, radiative energy transport, Basic Familiarity with Compact Stars, Chandrasekhar Limit, White Dwarf, Neutron Star, Black Hole

Unit 4:The Sun: Solar Parameters, Solar Photosphere,Solar Atmosphere, Chromosphere, Corona, Solar Activity, Basics of Solar Magnetohydrodynamics, Helioseismology

Unit 5: Cosmology: Cosmic Distance Ladder, Distance Measurement using Cepheid Variables, Hubble's Law, Clusters of Galaxies, Distance-Velocity Relation, Dark Matter, Friedmann Equation and its Solutions, Cosmic Background Radiation

Reference Books:

1. An Introduction to Modern Astrophysics, Bradley W. Carroll, Dale A. Ostlie, Cambridge University Press, 2nd Ed (2017)
2. Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press, 1st Edition (2010)
3. Fundamentals of Astrophysics, Stan Owocki, Cambridge University Press, 1st Edition (2021)
4. The Physical Universe: An Introduction to Astronomy, Frank H. Shu, University Science Books, 1st Edition (1982)
5. Introduction to Astronomy and Astrophysics, Michael Zeilik, Stephen A. Gregory, Saunders College Publishing, 4th Edition (1998)
6. Fundamental Astronomy, HannuKarttunen, Pekka Kröger, HeikkiOja, Markku Poutanen, Karl J. Donner, Springer, 6th Edition (2017)

Course Outcomes		Level
CO-1	Understand and apply basic astronomical scales and magnitudes, and interpret stellar properties using the Hertzsprung-Russell (HR) diagram.	Understand , Apply
CO-2	Explain celestial coordinate systems and time measurement methods, and perform coordinate transformations for observational astronomy.	Understand , Apply
CO-3	Describe the structure and equilibrium conditions of stars, and recognize the nature of compact stellar objects like white dwarfs, neutron stars, and black holes.	Understand ,Analyze
CO-4	Understand solar structure and processes including solar activity, magnetic fields, and helioseismology.	Understand
CO-5	Explain key concepts in cosmology including the cosmic distance ladder, Hubble's Law, and the Friedmann model, and analyze evidence for dark matter and expansion.	Understand ,Analyze

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	2	1
CO-2	3	2	2	3	1
CO-3	3	3	2	3	1
CO-4	3	2	2	2	1
CO-5	3	3	3	3	1

Course Code: PHYOE04
Course Title: Solar Energy and its Applications
Course Type: Theory
Credits: 03(45 Hours)

Solar Energy and its Applications

Unit 1
Introduction

Energy scenario current, energy future, energy sources - Energy demand and availability; Conventional, Nonconventional, and Renewable energy resources; Environmental impacts of conventional energy usage.

Unit 2
Solar Collector, Thermal Technology, and Applications

Solar radiation and electromagnetic spectrum, solar radiation entering the earth system, Solar angle of incidence on tilted surface - measurement and estimation on horizontal and tilted surfaces - flat plate collector thermal analysis - testing methods - evacuated tubular collectors - concentrator collectors – compound parabolic concentrators - parabolic trough concentrators – performance of the collectors.

Unit 3
Solar Photovoltaic System and Applications

Basic principle of solar photovoltaic conversion, Solar cell parameters and characteristics. Block diagram of general PV conversion system and their characteristics,– Photovoltaic cell technologies - p-n junction under equilibrium and biasing, open circuit voltage and short circuit current, I-V and P-V curves, calibration and efficiency measurement – PV cell, modules, and array, - Array design, peak power point operation - Load estimation, Selection of inverters, Battery sizing, array sizing. Voltage regulation - maximum tracking - centralized and decentralized PV systems - stand alone - hybrid and grid connected system - System installation - operation and maintenances - field experience – Applications - PV market analysis and economics of PV systems.

Unit 4
Solar refrigeration and Air-conditioning

Potential and scope of solar cooling, Types of solar cooling systems, solar collectors and storage systems for solar refrigeration and air-conditioning, solar operation of vapor absorption cycle, temperature concentration diagram, enthalpy concentration diagram, steady flow process with binary mixtures, Energy balance for various components of vapor absorption cycle, Analysis of absorption system using concentration chart.Solar Passive Architecture - passive cooling concepts: evaporative cooling - radiative cooling.

Unit 5
Other Applications of Solar Energy Technologies

Solar water heaters– Solar cooker – desalination - Solar Air heaters - Application of solar air heaters. Solar Drying with various driers – Heating and Drying of Agricultural products – moisture content and its measurement – solar ponds – Application of solar ponds – Solar pumping.

Books recommended:

1. 1 S.P. Sukhatme, Solar Energy, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1997.
2. S Sukhatme and J Nayak: Solar Energy: Principles of Thermal Collection and Storage, Third Edition (Tata McGraw Hill, 2008).
3. G.N.Tiwari, Solar Energy: Fundamentals, design, Modeling and ApplicationsNarosa

Publishing house2002.
4. Fonash Solar Cell Devices : (Academic Press, New York)(1981).
5. Stooker W.F, Jones J.W. Refrigeration And Air Conditioning, Tata McGraw-Hill (2009).
6. C.P.Arora, Refrigeration And Air Conditioning Tata McGraw-Hill(2000).
7. Kreider, J.F. and Frank Kreith, Solar Energy Handbook, McGraw Hill, 1981.
8. Tiwari G.N., Tiwari A.K., Solar Distillation Practice, Anamaya Publishers, New Delhi(2008).
9. VVN Kishore, Renewable Energy Engineering and Technology – A Knowledge Compendium, ed. (TERI Press, 2008).
10. Goswami, D.Y., Kreider, J. F. and & Francis, Principles of Solar Engineering, 2000.
11. G.D. Rai, Non Conventional Energy Sources, Khanna Publishers, New Delhi, 1999.
12. G. D. Rai , Solar Energy Utilisation, ,, Khanna Publishers,Delhi.(1996).
13. Volker Quaschning, Understanding Renewable Energy Systems, Vol.1 (2005)
14. Marcelo Godoy Simmoes Renewable Energy Systems CRC Press (2004)
15. John Twidell Renewable Energy Resources Taylor and Francis (2006).
16. Renewable Energy Sources and Their Environmental Impact Abbasi & Abbasi Prentice Hall of India (2004).

Supplementary Reading:

1. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, 2000.
2. Duffie, J. A. and Beckman, W. A., Solar Engineering of Thermal Processes, John Wiley, 1991.
3. Alan L Fahrenbruch and Richard H Bube, Fundamentals of Solar Cells: PV Solar Energy Conversion, Academic Press, 1983.
4. Larry D Partain, Solar Cells and their Applications, John Wiley and Sons, Inc, 1995.
5. Roger Messenger and Jerry Vnetre, Photovoltaic Systems Engineering, CRC Press, 2004.
6. Sodha, M.S, Bansal, N.K., Bansal, P.K., Kumar, A. and Malik, M.A.S. Solar Passive Building, Science and Design, Pergamon Press, 1986.
7. Krieder, J and Rabi, A., Heating and Cooling of Buildings: Design for Efficiency, McGraw-Hill, 1994.
8. MA Green: Solar Cells Operating Principles, Technology, and System Applications (Prentice-Hall, 1981).
9. MA Green: High Efficiency Silicon Solar Cells (Trans Tech Publications)(1987).
10. SJ Fonash: Solar Cell Device Physics (Academic Press, 1982).
11. Handbook of photovoltaic science and engineering, ed. Antonio Luque and Steven Hegedus (John Wiley and Sons)(2010).
12. Anna Mani, S Rangarajan: Handbook of Solar Radiation Data for India, 1980 (Allied Publishers).
13. Richard C Neville, RC Neville, Bas Van Der Hoek: Solar Energy Conversion: The Solar Cell (Elsevier Science & Technology)(1995).
14. Peter Würfel : Physics of Solar Cells: From Basic Principles to Advanced Concepts (Wiley-VCH)(2009).
15. JF Kreider and F Kreith: Solar Heating and Cooling: Active and Passive Design (Hemisphere Publishing Corporation, 1982).
16. Low Temperature Engineering Application of Solar Energy, ed. RC Jordan (ASHRAE)(1967).
17. HP Garg and J Prakash: Solar Energy: Fundamentals and Applications (Tata McGraw Hill)(2006).
18. Climatological and Solar data for India, Seshadri, (Sarita Prakashan), 1969.
19. Energy Technology, S. Rao and B. B. Parulekar, (Khanna Publishers), 1995.

20 Terrestrial Solar Photovoltaics, Tapan Bhattacharya, (Namsa : Publication House, New Delhi), 1998.
21. Renewable Energy Sources and Conversion Technology, N. K. Bansal, M. Kleeman and S. N. Srinivas, (Tata Energy Research Institute, New Delhi), 1996.
22. Fundamentals of Solar Cells, F. A. Faherenbruch and R. H. Bube, (Academic Priess)(1983).
23. Thin Film Solar Cells, K. L. Chopra and S. R. Das, (Plenum Press), 1983.

Course Outcomes

	Course Outcome	Level
CO-1	Gain basic understanding about energy use and its environmental impact and various renewable energy technologies adopted to mitigate climate change and sustainable development.	Acquire, Understand, Apply, Skill
CO-2	Acquire knowledge about the various parameters involved in measuring the solar irradiance on earth and its variation and various solar thermal technologies including collectors and concentrators.	Remember, Evaluate, Analyse, Skill
CO-3	Understand the basic aspects of photovoltaic technologies and apply it to various solar cell applications including efficiency improvement, tracking, energy storage, grid balancing etc.	Remember, Understand, Analyse, Apply
CO-4	Gain knowledge about solar passive and active cooling./heating and various solar refrigeration technologies, various solar cooling technologies.	Acquire, Understand, Apply, Skill
CO-5	The students will learn various applications of solar energies including solar heaters, cookers, solar ponds, solar collectors, solar desalination, solar driers and their basic working principles.	Understand, Analyse Apply,

Mapping of Program Outcomes with Course Outcomes

	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	2	2	3	2	2
CO-2	3	2	3	2	2
CO-3	2	2	3	3	2
CO-4	3	3	2	2	2
CO-5	3	2	3	2	2

Course Code: PHYOE05
Course Title: Physics and Meditation
Course Type: Theory
Credits: 03(45 Hours)

Physics and Meditation

Unit 1

Physics: Introduction to Science; Different branches of Science; Introduction to Physics; Different branches of Physics; Every day Physics with various examples.

Unit 2

Meditation: Introduction to Meditation, Different types of Meditation: Mindfulness Meditation: Focused attention: Mantra Meditation: Transcendental Meditation: Metta Meditation: Visualization Meditation: Spiritual Meditation: Chakra Meditation: Relaxation - Body scan Meditation: Vipassana Meditation:

Unit 3

Waves in Physics: Introduction to waves, wave length and Frequency; different type of waves; mechanical waves: transverse waves: l waves:surface waves with everyday life example;Electromagnetic waves: Light (visible light), radio waves, microwaves, infrared radiation, ultraviolet radiation, X-rays, and gamma rays;Electromagnetic spectrum.: everyday life example.

Unit 4

Waves in Meditation: Alpha waves,Theta waves,Delta waves:Beta waves,Gamma waves;Shift towards Alpha and Theta;Increased Alpha activity:Suppression of Beta waves.

Unit 5

Teleportation: Teleportation in Meditation; Teleportation in Physics; The branch of Physics closely related to Meditation; Matter waves; Practice of Meditation with Physics background.

Course Outcomes

	Course Outcome	Level
CO-1	Understand Science and Physics	Understand
CO-2	Understand Meditation	Understand
CO-3	To know waves in Physics	Remember
CO-4	Remember waves in Meditation	Remember
CO-5	Communications with Meditation	Analyse

Mapping of Program Outcomes with Course Outcomes

	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	**3**	**1**	**1**	**1**	**3**
CO-2	**3**	**1**	**1**	**1**	**3**
CO-3	**3**	**1**	**1**	**1**	**3**
CO-4	**3**	**1**	**1**	**1**	**3**
CO-5	**3**	**1**	**1**	**1**	**3**

Skilled Enhancement Course

Course Code: PHYSE01
Course Title: Machine Shop (Practical)
Course Type: SEC
Credits: 02(30 Hours)

List of Experiment:
Part A
1. Lines and Lettering
2. Scales and paper sizes
3. Title blocks
4. Basic instruments used
    a) T-square
    b) Set-square
    c) Parallel rules
    d) Drafting Machine
5. Axonometric projections
    a) Dimetric projection
    b) Isometric projection
6. Orthographic projection
    a) First angle projection
    b) Third angle projection
7. Introduction to CAD

Part B
1. Introduction to machine tools
2. Safety aspects in machine shop
3. Milling
4. Turning
5. Shaping
6. Filing
7. Keyway/slot/groove making
8. Surface/slot milling

References:
1. R.K. Dhawan, “A text book of Engineering Drawing”, S. Chand Publishers, Delhi,2010. 2.G.S. Phull and H.S.Sandhu, “Engineering Graphics”, Wiley Publications, 2014.
3. K.Venugopal and V.Prabhu Raja, “Engineering Graphics”, New Age International Private Limited, 2008.
4. P.J.Shah, A Text Book of Engineering Graphics, S.Chand& Company Ltd.

Course Code: PHYSE02
Course Title: LaTeX Typesetting for Beginners
Course Type: SEC
Credits: 03 (45 Hours)

LaTeX Typesetting for Beginners

Unit 1: Introduction to LaTeX and Document Structure: Introduction to LaTeX: Features and use cases, Installing LaTeX distributions (TeX Live, MiKTeX) and editors (TeXstudio, Overleaf), Writing your first LaTeX document, Document structure: \documentclass, preamble, packages, \begin{document}, Formatting text: Fonts, sizes, emphasis, special characters, Environments: center, itemize, enumerate, description, Creating custom commands and comments

Unit 2: Document Elements: Lists, Tables, Images, and Mathematical Typesetting Creating and customizing lists, Tables: Basic tables, aligning, spanning rows/columns, adding captions. Inserting and positioning images using graphicx package, Mathematical typesetting using amsmath- Inline and display math, Fractions, powers, indices, roots, Equations, align environment, symbols, Matrices and cases

Unit 3: Cross-Referencing, Bibliography, and Advanced Document Structure: Sections, subsections, and table of contents, Cross-referencing with \label, \ref, \pageref, Footnotes, margins notes, and endnotes, Including bibliography using bibtex and biblatex, Citations: \cite, \parencite, \textcite, Creating multi-file documents with \input and \include

Unit 4: Professional Typesetting: Books, Presentations, and Indian Language Support: Creating book/report-style documents with chapters, Page layout: margins, headers, footers with geometry and fancyhdr, Typesetting presentations using beamer, Working with classes: article, report, book, beamer, Typesetting in Indian languages using packages like polyglossia, fontspec, and ITRANS, Transliteration techniques and example documents in Devanagari, Tamil, etc**.**

References Books:

1. LaTeX Beginner's Guide, Stefan Kottwitz, Packt Publishing, 1st Ed (2011)
2. Guide to LaTeX, Helmut Kopka, Patrick W. Daly, Addison-Wesley Professional, 4th Ed. (2003) Authors: Publisher: Edition: 4th Edition
3. First Steps in LaTeX, George Grätzer, Birkhäuser Boston, 1st Ed. (1999)

Course Outcomes		Level
CO-1	Describe the structure and basic commands of LaTeX for document creation.	Understand
CO-2	Create and format documents including text, lists, tables, images, and mathematical expressions in LaTeX.	Apply
CO-3	Manage advanced document features like cross-referencing, citations, and modular documents using LaTeX tools.	Apply
CO-4	Design professional documents such as books and presentations, and typeset text in Indian languages using LaTeX.	Analyze

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	1	1	3	2
CO-2	3	2	2	3	2
CO-3	2	2	2	3	2
CO-4	3	2	2	3	3
CO-5	2	1	1	3	2

Course Code: PHYSE03
Course Title: Introduction to python programming and graph plotting
Course Type: SEC
Credits: 03 (45 Hours)

Introduction to python programming and graph plotting

Unit 1

Introduction to programming in python: Using the python interpreter as a calculator ; Variable and data types; Basic mathematical operations ; Compound statements in python – Conditionals (if, elif, else); Loops (for, while) ; User defined functions def: lambda function; Importing modules with math and cmath as examples; Using help and dir command to use the inbuilt manual ; Python scripts, I/O operations (including opening and writing to files) ; List: defining lists, reading and changing elements from lists, slicing, list comprehension; built in functions involving lists: range(), len(), sum(), min(), max() – list methods: append(), extend(), count(), index(), sort(), insert(), pop(), remove(), reverse().

Unit 2

Data Structures and File Handling Lists: creation, indexing, slicing, and list comprehension, Tuples and dictionaries: basic operations, Built-in list methods: append(), pop(), sort(), remove(), etc, Reading and writing to text files, Working with numerical data using math and random modules

Unit 3

Introduction to simply: a package for symbolic calculation: Introduction to symbolic calculation; variable assignments, symbols, equal sign, functions, ^ and / commands; Evaluating Expressions with Floats and Rationals; SymPy features - Basic Operations, Printing, Simplification, Calculus, Solvers, Matrices

Unit 4

Introduction to Plotting in Python: Overview of Matplotlib: importing and basic plotting, Line plots, scatter plots, bar graphs, histograms, pie charts, Customizing plots: titles, labels, legends, grid; Subplots and figure handling, Plotting from data files (CSV, TXT)

Unit 5

Introduction to Graph Plotting using Matplotlib and GNUPLOT: Introduction to GNUPLOT; Plotting 2D graphs: both functions and data files. Changing plot range and plot styles: the options- with points (w p), with dots (w d), with lines (w l), with linespoints (w lp), linetype (lt), linewidth (lw). Using the set command for samples, xrange, yrange, xlabel, ylabel, title.

References Books:

1. Python Programming: An Introduction to Computer Science, John Zelle, Franklin, Beedle & Associates Inc., 3rd Edition, 2010
2. Python Plotting Cookbook, Alexandre Devert, Packt Publishing, 1st Edition 2014
3. Gnuplot in Action: Understanding Data with Graphs, Philipp K. Janert, Manning Publications, 1st Edition, 2010
4. https://matplotlib.org/stable/tutorials/index.html
5. http://www.gnuplot.info/
6. https://docs.sympy.org/latest/tutorials/index.html#tutorials

Course Outcomes		Level
CO-1	Use Python to perform basic computations, control program flow using conditionals and loops, and manipulate data structures like lists.	Apply
CO-2	Develop and execute Python scripts for file input/output and user-defined functions including use of built-in modules.	Apply
CO-3	Perform symbolic mathematics using SymPy for expression manipulation, calculus, equation solving, and matrix operations.	Apply
CO-4	Generate and customize 2D plots using GNUPLOT for visualizing data and mathematical functions.	Apply
CO-5	Create and modify various types of plots using Matplotlib to effectively visualize scientific data.	Apply

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	2	2	3	1
CO-2	3	2	2	3	1
CO-3	3	2	2	3	1
CO-4	2	2	2	3	1
CO-5	2	2	2	3	2

Course Code: PHYSE04
Course Title: Optical Instrumentation
Course Type: SEC
Credits: 03 (45 Hours)

Optical Instrumentation

Unit-I
Interferometry: Interference, Interferometers, wavefront splitting interferometers, Young's double-slit experiment, amplitude splitting interferometers, Michelson interferometer, Interference filters, Multiple-beam interference, Fabry-Perot interferometer.

Unit-2
Hands-on training:Perform the following experiments:

1) Newton's ring experiment / Michelson Interferometer
2) Double-slit Experiment
3) Fabry-Perot Interferometer

Unit-3
Diffractometry: Fraunhofer diffraction, single-slit diffraction pattern, diffraction from a circular aperture, Imaging, resolution of imaging system, Diffraction and Fourier transform.

Unit-4
Hands-on training: Perform the following experiments:

1) Determination of the wavelength of the laser from single slit-diffraction pattern.
2) Determine the thickness of a human hair using its diffraction pattern.
3) Diffraction due to a helical structure.

Unit 5
Characterization of Optical fiber: Optical fibers, acceptance angle, numerical aperture, free space coupling, bending loss
Hands-on training: To determine the numerical aperture and the bending loss of a given optical fiber.

Reference Books:

1. Optics, E. Hecht and A. R. Ganesan, Pearson, 5thEdn, 2020.
2. Optics, AjoyGhatak, McGraw Hill, 8thEdn. 2024.\
3. Introduction To Fiber Optics, AjoyGhatak and K. Thyarajan,Cambridge University Press, 1stEdn. 2017.
4. An Introduction to Practical Laboratory Optics, J. F. James, Cambridge University Press, 2014.
5. A First Course in Laboratory Optics, Andri M. Gretarsson, Cambridge University Press, 2021.
6. Video Demonstrations in Lasers and Optics, http://ocw.mit.edu/RES-6-006S08
7. Modern Optics Project Laboratory, https://ocw.mit.edu/courses/6-161-modern-optics-project-laboratory-fall-2005/

Course Outcomes		Level
CO-1	Learning fundamental concepts of interference and interferometry	**Remember**
CO-2	Use the knowledge of interferometry to set-up and analyze different interferometers.	**Apply Analyze**
CO-3	Learning the concepts of diffraction and imaging.	**Remember**
CO-4	Use the concepts of diffraction theory to set-up and analyze various diffraction pattern.	**Apply Analyze**
CO-5	Knowing and characterizing optical fiber	**Apply**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	1	1	2	2	1
CO-2	2	1	3	3	1
CO-3	1	1	2	2	1
CO-4	2	1	3	3	1
CO-5	2	1	3	3	1

Course Code: PHYSE05
Course Title: Renewable Energy Technologies
Course Type: SEC
Credits: 03 (45 Hours)

Renewable Energy Technologies

Unit 1

Fossil fuels and Alternate Sources of energy:

Introduction to Energy Sources - Energy consumption as a measure of Prosperity – World energy futures – Energy sources and their availability –Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources – Renewable energy sources – Materials limitation - Hydropower resources, hydropower technologies, environmental impact of hydro power sources.

Unit 2

Solar Energy

Solar radiation geometry – Solar radiation measurements – Principles of the conversion of solar radiation in to heat – Flat plate collectors – Energy balance equation and collector efficiency – Concentrating collector: Focusing type – Performance analysis of a parabolic collector – Solar energy storage systems – Solar pond – Principle of operation and extraction of thermal energy – Solar heating and solar cooling of buildings – Solar electric power generation: Solar photo-voltaic.

Unit 3

Wind Energyand Energy from Biomass

Basic principles of wind energy conversion – site selection considerations – Classification of wind energy conversion systems – types of wind machines – Performance analysis of wind machines – Schemes for electric generation – Applications of wind energy – Environmental aspects.- Biomass conversion technologies – Biomass as a source of energy – Methods for obtaining energy from biomass – Biogas generation – Biodegradation — Biogas from waste – Community biogas plants – Thermal gasification of biomass.

Unit 4

Geothermal Energy and Energy from the Oceans

Nature of geothermal fields - Geothermal resources – Hot dry rock resources – Magma resources – Geothermal exploration – Advantages and disadvantages of geothermal energy – Applications of geothermal energy – Operational and environmental problems. Ocean thermal electric conversion (OTEC) – Introduction – Open cycle OTEC system - – Closed cycle OTEC system – Energy from Tides – Basic principle of tidal power – Operation methods of utilization of tidal energy – Single cycle and double cycle systems – Advantages and limitations of tidal power generation - Ocean waves – Energy and power from the waves – Wave energy conversion devices - Advantages and limitations of wave energy.

Unit 5

Energy storage

Hydrogen economy, Hydrogen energy – Hydrogen production (Electrolysis, thermochemical and photoelectrochemical methods) – hydrogen storage methods - hydrogen as an alternative fuel for motor vehicles. Fuel cells – Design and principle of operation of a fuel cell – Classification of fuel cells - Conversion efficiency of fuel cells – Applications of fuel cells – Rechargeable

batteries.

Reference Books:

1. Non – Conventional Energy Sources: G D Rai (Khanna Publishers), New Delhi, 6th Ed. 2018.
2. Renewable Energy Technologies : Solanki C S (Prentice-hall Of India Pvt Ltd).
3. Renewable Energy Sources & Their EnvironmetalImpact : Abbasi (Prentice-hall of India Pvt Ltd).
4. Renewable Energy Sources for Sustainable Development N.S.Rathore and N.L.Panwar (New India Publishing Agency) 2007.
5. Renewable Energy : Ulrich Laumanns And Dieter Uh Dirk Abmann (James & James Science Publishers).
6. Understanding Renewable Energy Systems : Volker Quaschning (James & James Science Publishers) 2016.
7. Renewable Energy: Global Perspectives :Azmal Hussain (Icfai University Press).
8. New And Renewable Energy Technologies For Sustainable Development :Naim HamdiaAfgan, Da Graca Carvalho Maria, Maria Da Graca Carvalho (Taylor & Francis Group).
9. Renewable Energy from the Ocean : Avery, William H.; Wu, Chih; Craven, John P. (Oxford University Press).
10. Fundamentals of Renewable Energy Systems : Mukherjee D (New Age International (p) Limited).
11. Renewable Energy Sources & Emerging Tech., : Kothari D P (Prentice-hall Of India Pvt Ltd) .
12. Energy From Biomass :WillekePalz, D. Pirrwitz (Springer) 1983.
13. Understanding Renewable Energy Systems : Volker Quaschning (James & James).
14. Solar energy - M P Agarwal - S Chand and Co. Ltd.
15. Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.
16. Godfrey Boyle, “Renewable Energy, Power for a sustainable future”, Oxford University Press, in association with The Open University, 2004.
18. Dr. P Jayakumar, Solar Energy: Resource Assesment Handbook, 2009
19. J.Balfour, M.Shaw and S. Jarosek, Photovoltaics, Lawrence J Goodrich (USA).

Course Outcomes		Level
CO-1	Gain knowledge on traditional energy sources and the issues of using them and materials limitation for implementing renewable energy technologies. Give detail insight into hydroelectric power.	Understand/Analyse
CO-2	Understand the solar irradiance and their availability in earth. Gain knowledge on solar thermal and solar PV technologies.	Understand/analyse Apply
CO-3	Get detail insight into the wind energy and the bioenergy.	Understand/Analyze
CO-4	Understand how to harness geothermal energy, wave energy and tide energy and their availability.	Understand/analyse Apply
CO-5	Gain knowledge on various energy storage technologies with special focus on hydrogen storage and rechargeable batteries.	Understand/ Apply

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	3	3	2	2	1
CO-2	3	2	2	3	1
CO-3	3	2	2	2	1
CO-4	3	3	2	2	1
CO-5	3	3	1	3	1

Course Code: PHYSE06
Course Title: Computational Modelling of Materials
Course Type: SEC
Credits: 03 (45 Hours)

Computational Modelling of Materials

Unit 1

Introduction to Computational Materials Science: Definitions and Terms-Force Field Methods-Molecular Mechanics - Quantum Mechanical Methods: Ab initio methods-Semi empirical methods - Density functional theory methods.

Unit 2

Ground-state calculations of condensed matter: The Hohenberg-Kohn Theorems – Self-consistent total energies, forces, stresses, Kohn-Sham orbitals - Separable norm-conserving and ultrasoft pseudo-potentials, Projector Augmented Waves - exchange-correlation functionals from LDA to generalized-gradient corrections.

Unit 3

Tutorial: Modeling of periodic solids: Visualization of crystal types – Miller Indices – Crystal planes – Optimization of energy, lattice parameters, volume – Finding optimum k-point grid – Electronic band structure and density of states plotting –Finding band-gap and identifying origin of bands – Electronic charge density visualization – Bonding analysis.

Unit 4

Tutorial: Modeling of Molecules: Optimization of molecular structure - Effect of different exchange-correlation functionals – Bonding and conformation analysis – HOMO-LUMO gaps – Visualization of electrostatic potential surface – Excited-state properties – Identification of functional groups.

Unit 5

Tutorial : Analysis of Band structure: Semiconductor's band gap – direct, indirect. Metal, semi metal, semiconductor and insulator, Hole and electron carriers and effective mass, Physical interpretation of the effective mass Application to solar cells, transparent conductor and photocatalysts.

Reference Books:

1. Richard M. Martin. Electronic structure Basic theory and prtical methods. Cambridge University press, 2016.
2. N.W. Ashcroft and N.D. Mermin, Solid State Physics. Saunders, 2004.
3. H.L. Skriver, The LMTO method. Springier, Berlin, 1984.
4. G.C. Fletcher. Electron theory of solids. North Holland Pub. Co. 1980.
5. Density Functional Theory – D. S. Sholl and J.A. Steckel, Wiley, 2009.

6. Jensen, Frank (2017). Introduction to Quantum Chemistry. 3rd ed. Wiley.
7. N.W. Ashcroft and N.D.Mermin, Solid State Physics.Cengage Learning Asia,2016.
8. Richard Dronskowski, Computational Chemistry of Solid State Materials, WILEY-VCH(2005).
9. Gaussian16, Crystal17, LMTO Manuals.

Course Outcomes		Level
CO-1	Introduce various aspects of computational modelling of materials	**Understand/analyse**
CO-2	Give basis of ab initio plane wave basis set methods used to study ground state properties of materials.	**Understand/analyse Apply**
CO-3	Give theory and hands-on experience on analyzing electronic structure and chemical bonding in solids.	**Apply**
CO-4	Give theory and hand-on experience on analyzing molecular structure and excited state properties.	**Apply**
CO-5	Apply the computational tools to verify experimental studies.	**Apply**

Mapping of Program Outcomes with Course Outcomes

Course Outcomes	Program Outcomes				
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**
CO-1	2	3	2	2	1
CO-2	3	2	2	3	1
CO-3	3	2	2	2	1
CO-4	3	3	2	2	1
CO-5	3	3	1	3	1