B. Tech.

IN

ENGINEERING PHYSICS

CURRICULUM AND SYLLABI

(Applicable from 2023 Admission onwards)

तमसो मा ज्योतिर्गमय

Department of Physics

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of B. Tech. in Engineering Physics

PEO1	The graduates will develop appreciation for fundamental Physics and its applications to natural phenomena.
PEO2	The graduates will develop sound scientific and mathematical foundation and practical laboratory experience leading to a career of research in basic/applied Physics and related industry.
PEO3	The graduates will acquire competitive edge, communication skills and interpersonal team spirit necessary to take up challenging research projects in future advanced education and career.
PEO4	The graduates will develop technical and entrepreneur skills, and confidence necessary for contributing to the field of indigenous research and industry development.

Programme Outcomes (POs) and Programme Specific Outcomes (PSOs) of B.Tech. in Engineering Physics

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PSO1	Analyze and develop models of the physical world relevant to industry and society
PSO2	Formulate and investigate open ended problems in Physical Sciences and contribute to academic research

CURRICULUM

Total credits for completing B.Tech. in Engineering Physics is 150.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of B.Tech. programmes shall have the following Course Categories:

Sl. No.	Course Category	Number of Courses	Minimum Credits
1.	Institute Core (IC)	8	22
2.	Program Core (PC) and Program Electives (PE)	29-30	82
3.	Open Electives (OE)	8	24
4.	Institute Electives (IE) (Entrepreneurship Innovation (EI) + Digital / Automation Technologies (DA) + Humanities, Social Science, Management (HM))	6	18
5.	Activity Credits (AC)	--	4

COURSE REQUIREMENTS

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

1. INSTITUTE CORE (IC)

a) Mathematics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MA1002E	Mathematics I	3	1*	0	5	3
2.	MA1012E	Mathematics II	3	1*	0	5	3
3.	MA2002E	Mathematics III	3	1*	0	5	3
4.	MA2012E	Mathematics IV	3	1*	0	5	3
		Total	**12**	**4***	**0**	**20**	**12**

*Optional for Students (can be replaced by self-study)

b) Basic Sciences and Drawing

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	CY1004E	Chemical Structure and Bonding	3	0	0	6	3
2.	ME1011E	Engineering Graphics	2	0	2	5	3
		Total	**5**	**0**	**2**	**11**	**6**

c) Professional Communication and Professional Ethics

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MS1001E	Professional Communication	3	1*	0	6	3
2.	PH2101E	Professional Ethics	1	0	0	2	1
		Total	**4**	**1***	**0**	**8**	**4**

2A. PROGRAMME CORE (PC)

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	PH1101E	Mechanics	3	0	0	6	3
2.	PH1102E	Thermodynamics	3	0	0	6	3
3.	PH1191E	General Physics Lab	0	0	3	3	2
4.	ME1391E	Mechanical Workshop	0	0	2	1	1
5.	PH1111E	Classical Mechanics	3	0	0	6	3
6.	PH1112E	Analog Electronics	3	0	0	6	3
7.	PH1113E	Electromagnetics	3	1*	0	5	3
8.	PH1192E	Electronics Lab-I	0	0	3	3	2
9.	PH1193E	Electromagnetics Simulation lab	0	0	3	3	2
10.	PH2102E	Quantum Physics-I	3	1*	0	5	3
11.	PH2103E	Digital Electronics	3	0	0	6	3
12.	PH2191E	Microwave lab	1	0	3	5	3
13.	PH2192E	Electronics Lab-II	0	0	3	3	2
14.	PH2111E	Applied Optics	3	0	0	6	3
15.	PH2112E	Quantum Physics-II	3	1*	0	5	3
16.	PH2113E	Statistical Mechanics	3	0	0	6	3
17.	PH2193E	Optics Lab	0	0	3	3	2
18.	PH3101E	Atomic and Molecular Physics	3	0	0	6	3
19.	PH3102E	Computational Physics	2	0	3	7	4
20.	PH3103E	Condensed Matter Physics	3	0	0	6	3
21.	PH3191E	Solid State Physics Lab	0	0	3	3	2
22.	PH3111E	Lasers and Applications	3	0	0	6	3
23.	PH3112E	Nuclear Science and Engineering	3	0	0	6	3
24.	PH3192E	Project	0	0	0	9	3
25.	PH4192E	Summer Internship	0	0	0	6	2
		Tot	**45**	**3***	**26**	**127**	**67**

al					

2B. LIST OF ELECTIVES

Following courses may be credited under the categories mentioned in the table below, in addition to the Programme Electives.

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Additional Categories			
								PE	EI	DA	HM
Entrepreneurship and Innovation											
1.	IE2001E	Innovation and Entrepreneurship	3	0	0	6	3	N	Y	N	N
Condensed Matter Physics											
2.	PH3123E	Topics in Condensed Matter Physics	3	0	0	6	3	Y	N	N	N
3.	PH3128E	Thin Film Technology	3	0	0	6	3	Y	N	N	N
4.	PH3131E	Experimental Techniques in Physics	3	0	0	6	3	Y	N	N	N
5.	PH4127E	Solid State Devices	3	0	0	6	3	Y	N	N	N
6.	PH4128E	Physics of Nanostructures and Nanoscale Devices	3	0	0	6	3	Y	N	N	N
7.	PH4129E	Lithography Techniques	3	0	0	6	3	Y	N	N	N
8.	PH4131E	Semiconductor Physics	3	0	0	6	3	Y	N	N	N
9.	PH4133E	Soft Matter	3	0	0	6	3	Y	N	N	N
Optics and Photonics											
10.	PH3125E	Fiber Optic Communication and Sensors	2	0	2	5	3	Y	N	N	N
11.	PH3127E	Optical Instrumentation and Metrology	3	0	0	6	3	Y	N	N	N
12.	PH3130E	Laser Technology and Quantum Optics	3	0	0	6	3	Y	N	N	N
13.	PH4123E	Light-Matter Interaction in Resonators	3	0	0	6	3	Y	N	N	N
14.	PH4134E	Optics and Photonics Workshop	2	0	2	5	3	Y	N	N	N
15.	PH4137E	Lightwave Technology with Metamaterials	3	0	0	6	3	Y	N	N	N
16.	PH4138E	Plasmonics and Graphene Photonics	3	0	0	6	3	Y	N	N	N
17.	PH4139E	Speckle Phenomena and Imaging	3	0	0	6	3	Y	N	N	N

18.	PH4140E	Fourier Optics and Holography	3	0	0	6	3	Y	N	N	N
Theoretical and High Energy Physics											
19.	PH3122E	Electrodynamics	3	0	0	6	3	Y	N	N	N
20.	PH3124E	Physics of Elementary Particles	3	0	0	6	3	Y	N	N	N
21.	PH4122E	Relativity and Gravitation	3	0	0	6	3	Y	N	N	N
22.	PH4124E	Critical Phenomena	3	0	0	6	3	Y	N	N	N
23.	PH4126E	Advanced Quantum Mechanics	3	0	0	6	3	Y	N	N	N
24.	PH4130E	Weak Interactions and Standard Model	3	0	0	6	3	Y	N	N	N
25.	PH4132E	Quantum Mechanics for Quantum Computing	3	0	0	6	3	Y	N	N	N
26.	PH4136E	Advanced Statistical Mechanics	3	0	0	6	3	Y	N	N	N
27.	PH4141E	Differential Geometry and Group Theory for Physicists	3	0	0	6	3	Y	N	N	N
28.	PH4142E	Advanced Topics in Analytical Mechanics	3	0	0	6	3	Y	N	N	N
Astronomy, Astrophysics and Planetary Sciences											
29.	PH3126E	Atmospheric and Environmental Physics	3	0	0	6	3	Y	N	N	N
30.	PH4135E	Astronomy and Astrophysics	3	0	0	6	3	Y	N	N	N
Electronics, Instrumentation and Simulations											
31.	PH2121E	Computer Programming	2	0	2	5	3	N	N	Y	N
32.	PH3121E	Interfacing and Simulation	2	0	2	5	3	N	N	Y	N
33.	PH3133E	Signal Theory and Systems Analysis	3	0	0	6	3	Y	N	N	N

3. OPEN ELECTIVES (OE)

Courses offered by Other Departments/Schools/Centres or Approved Online Platforms, with a limit on the maximum number of courses from such platforms specified as per BTech Ordinances and Regulations. In addition, PE courses offered by the Parent department shall be included in this category for students of the Parent department.

4. INSTITUTE ELECTIVES (IE)

In case of the Institute Electives, courses in the appropriate categories offered by other departments/schools/centres also can be credited instead of the courses offered by the Department of Physics, subject to the approval from the Course Faculty and Faculty Advisor.

a) Entrepreneurship / Innovation Basket (EI):

Courses proposed by the Departments/Schools/Centres and approved by Institute Innovation Council. Total credits required is 3.

b) Digital Automation Technologies (DA):

Courses related to programming / automation tools & techniques / Industry 4.0. Total credits required is 6.

c) Humanities, Social Science, Management (HM):

Courses such as Indian and Foreign languages, Economics, Engineering Management, Financial Management and Design Thinking. Total credits required is 9.

5. ACTIVITY CREDITS (AC)

A minimum of 80 Activity Points are to be acquired for obtaining the 4 Activity Credits required in the curriculum.

Activity points acquired should be a minimum of 20 at the end of S4.
Activity points acquired should be a minimum of 40 at the end of S6.

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1002E	Mathematics I	3	1*	0	5	3	IC
2.	CY1004E	Chemical Structure and Bonding	3	0	0	6	3	IC
3.	ME1011E	Engineering Graphics	2	0	2	5	3	IC
4.	PH1101E	Mechanics	3	0	0	6	3	PC
5.	PH1102E	Thermodynamics	3	0	0	6	3	PC
6.	PH1191E	General Physics Lab	0	0	3	3	2	PC
7.	ME1391E	Mechanical Workshop	0	0	2	1	1	PC
		Total	**14**	**1***	**7**	**32**	**18**	

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA1012E	Mathematics II	3	1*	0	5	3	IC
2.	MS1001E	Professional Communication	3	1*	0	6	3	IC
3.	PH1111E	Classical Mechanics	3	0	0	6	3	PC
4.	PH1112E	Analog Electronics	3	0	0	6	3	PC
5.	PH1113E	Electromagnetics	3	1*	0	5	3	PC
6.	PH1192E	Electronics Lab-I	0	0	3	3	2	PC
7.	PH1193E	Electromagnetics Simulation Lab	0	0	3	3	2	PC
		Total	**15**	**3***	**6**	**34**	**19**	

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2002E	Mathematics III	3	1*	0	5	3	IC
2.	PH2101E	Professional Ethics	1	0	0	2	1	IC
3.		DA Elective-I	3	0	0	6	3	DA
4.		Open Elective-I	3	0	0	6	3	OE
5.	PH2102E	Quantum Physics-I	3	1*	0	5	3	PC
6.	PH2103E	Digital Electronics	3	0	0	6	3	PC
7.	PH2191E	Microwave Lab	1	0	3	5	3	PC
8.	PH2192E	Electronics Lab-II	0	0	3	3	2	PC
		Total	**17**	**2***	**6**	**38**	**21**	

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA2012E	Mathematics IV	3	1*	0	5	3	IC
2.		Entrepreneurship Innovation Elective	3	0	0	6	3	EI
3.		Open Elective-II	3	0	0	6	3	OE
4.	PH2111E	Applied Optics	3	0	0	6	3	PC
5.	PH2112E	Quantum Physics-II	3	1*	0	5	3	PC
6.	PH2113E	Statistical Mechanics	3	0	0	6	3	PC
7.	PH2193E	Optics Lab	0	0	3	3	2	PC
8.		Minor Course – 1	3	0	0	6	3#	MC
Total (Excluding the Minor Courses)			**18**	**2***	**3**	**37**	**20(+3#)**	

Semester V

Sl. No	Course Code	Course Title	L	T	P	O	Credits	Category
1.		Humanities Elective-I	3	0	0	6	3	HM
2.		Open Elective-III	3	0	0	6	3	OE
3.		DA Elective-II	3	0	0	6	3	DA
4.	PH3101E	Atomic and Molecular Physics	3	0	0	6	3	PC
5.	PH3102E	Computational Physics	2	0	3	7	4	PC
6.	PH3103E	Condensed Matter Physics	3	0	0	6	3	PC
7.	PH3191E	Solid State Physics Lab	0	0	3	3	2	PC
8.	--	Minor Course – 2	3	0	0	6	3#	MC
Total (Excluding the Minor Courses)			**17**	**0**	**6**	**40**	**21(+3#)**	

Semester VI

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.		Humanities Elective-II	3	0	0	6	3	HM
2.		Open Elective-IV	3	0	0	6	3	OE
3.		Open Elective-V	3	0	0	6	3	OE
4.		Program Elective-I	3	0	0	6	3	PE
5.	PH3111E	Lasers and Applications	3	0	0	6	3	PC
6.	PH3112E	Nuclear Science and Engineering	3	0	0	6	3	PC
7.	PH3192E	Project	0	0	0	9	3	PC
8.		Minor Course – 3	3	0	0	6	3#	MC
Total (Excluding the Minor Courses)			**18**	**0**	**0**	**45**	**21(+3#)**	

Semester VII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.		Humanities Elective-III	3	0	0	6	3	HM
2.		Open Elective-VI	3	0	0	6	3	OE
3.		Open Elective-VII	3	0	0	6	3	OE
4.		Open Elective-VIII	3	0	0	6	3	OE
5.		Program Elective-II	3	0	0	6	3	PE
6.	PH4191E	Project/Internship/ Programme Elective III	0 / 3	0	0	9/6	3	PE
7.	PH4192E	Summer Internship	0	0	0	*	2	PC
8.	..	Minor Course - 4	3	0	0	6	3#	MC
Total (Excluding the Minor Courses)			**15/18**	**0**	**0**	**39/36**	**20(+3#)**	**--**

***** Decided by the organization in which the internship is done.

Semester VIII

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	PH4193E	Project / Internship / Programme Electives – IV & V	0 / 6	0	0	18/12	6	PE
2.	PH4199E	Activity Credits (minimum of 80 points)					4	AC
Total			**0/6**	**0**	**0**	**18/12**	**10**	**--**

MA1002E MATHEMATICS I
(Common to CSE/EP branches)

Pre-requisites: Nil

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Find the limits, check for continuity and differentiability of real valued functions of one variable.
CO2: Find the limits, check for continuity and differentiability of real valued functions of two variables.
CO3: Find the maxima and minima of real valued functions of one variable or two variables.
CO4: Find the parametric representation of curves and surfaces in space and evaluate integrals over curves and surfaces.

Functions of one variable: limit, continuity - differentiability - local maxima and local minima - mean value theorems - Taylor's theorem - L'hôpital's rule - integration - fundamental theorem of calculus - volume - area - improper integrals - Gamma and Beta functions. Parameterised curves in space - arc length - tangent and normal vectors - curvature and torsion.

Functions of several variables: limit - continuity - partial derivatives - partial differentiation of composite functions - directional derivatives - gradient - local maxima and local minima of functions of two variables - critical point - saddle point - Taylor's formula for two variables - Hessian - second derivative test - method of Lagrange multipliers - Evaluation of double integrals - improper integrals - change of variables - Jacobian - polar coordinates - triple integral - cylindrical and spherical coordinates - mass of a lamina - center of gravity - moments of inertia.

Vector field: divergence - curl - identities involving divergence and curl - scalar potential - Line integral - independence of path - irrotational and solenoidal vector fields - Green's theorem for plane - parameterized surface - surface area and surface integral - flux - Gauss' divergence theorem - Stokes' theorem.

References:

1. H. Anton, I. Bivens and S. Davis, *Calculus* (10th edition), John Wiley & Sons, New York, 2015.
2. G. B. Thomas, M.D. Weirand J. Hass, *Thomas' Calculus* (12th edition), Pearson Education, New Delhi, India, 2015.
3. E. Kreyszig, *Advanced Engineering Mathematics* (10th edition), John Wiley & Sons, New York 2015.
4. Apostol, *Calculus Vol 1* (1st edition), Wiley, New Delhi, 2014.

CY1004E CHEMICAL STRUCTURE AND BONDING

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Demonstrate the application of fundamental laws of quantum mechanics to solve chemical problems
CO2: Calculate eigenvalues and wave functions of quantum systems
CO3: Apply the theories and models of chemical bonding to molecules and materials

Dual nature of light and matter – de Broglie's relation – Electron diffraction by crystals – Double slit experiments with light and matter – Schrödinger equation – Operators – Postulates of quantum mechanics – Solutions of Schrödinger equation for a free particle.

Particle-in-a-box – applications of particle-in-a-box solutions for describing electronic levels and spectra in conjugated molecules – Schrödinger equation for the hydrogen atom (qualitative description of solutions) – concepts of orbitals and quantum numbers – Qualitative description of many-electron systems.

Chemical Bonding – Valence bond and molecular orbital descriptions of bonding – Linear com- bination of atomic orbitals (LCAO) approach – Hybridization – Bonding in homonuclear diatomic molecules of the second period – Bond orders – Bond lengths and Bond strengths - Bonding in heteronuclear diatomic molecules - Concepts of g and u symmetries of molecular orbitals – Polarity and electronegativity – Bonding in boron halides, PF_5, SF_6, interhalogens, and xenon fluorides – Bent's rule – Berry pseudorotation.

References:

1. D. A. McQuarrie, *Quantum Chemistry*, Viva Student Edition, Viva, 2011.
2. P. Atkins, J. de Paula and J. Keeler, *Atkins' Physical Chemistry* (International Eleventh edition), Oxford University Press, 2018.
3. J. Barrett, *Structure and Bonding*, Wiley-Royal Society of Chemistry, 2002.
4. T. Engel and P. Reid, *Physical Chemistry* (3rd Edition), Pearson, 2013.
5. R. J. Silbey, R. A. Alberty and M. G. Bawendi, *Physical Chemistr, (*4th Edition), Wiley, 2006.
6. P. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong and M. Hagerman, *Shriver and Atkins' Inorganic Chemistry* (5th Edition), New York: W. H. Freeman and Company, 2010.

ME1011E ENGINEERING GRAPHICS

Pre-requisites: Nil

L	T	P	O	C
2	0	2	5	3

Total Sessions: 26L + 26P

Course Outcomes:

CO1: Use Indian Standard Code of Practice in Engineering Drawing.
CO2: Represent engineering objects by orthographic views.
CO3: Convert orthographic views of an engineering object into the isometric view.
CO4: Use software for drawing and visualizing engineering objects.

Introduction to Engineering Graphics and Scales

Drawing instruments and their uses, lines, lettering and dimensioning, Engineering drawing using software - Geometrical construction – Importance of Scales in engineering graphics.

Orthographic Projections

First and third angle projections (using software) - Orthographic projection of points on principal, profile, and auxiliary planes - Orthographic projection of straight line in simple and oblique positions - Application of orthographic projection of line - Orthographic projection of planes in simple and oblique position on principal and profile planes - Orthographic projection of lines and planes on auxiliary planes - Orthographic projection of solids in simple and oblique positions on principal and profile planes - Orthographic projections of solids in oblique position using auxiliary plane method

Section, Development and Isometric view

Orthographic projection of solids in section - Development of surfaces of solids - Method of isometric projection (Using software).

References:

1. N. D. Bhatt, *Engineering Drawing* (54^{th} edition), Charotar Publishing House, 2023.
2. B. Agrawal and C. M. Agrawal, *Engineering Drawing* (3^{rd} edition), McGraw Hill Education, 2019.
3. K. Venugopal and V Prabhu Raja, Engineering Drawing + Auto CAD (6^{th} Edition), New Age Intl. Pvt Ltd., 2022.

PH1101E MECHANICS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Solve problems in Mechanics and Oscillations using Newton’s equations of motion.
CO2: Describe oscillatory behavior under different conditions.
CO3: Formulate the dynamics of rigid bodies using Euler angles.
CO4: Interpret the dynamics of fluids by treating it as a continuous medium.

Newtons Equations
Review of Newtonian Mechanics: Force, Newton’s II law and equations of motion, examples – Conservative and non-conservative systems – system of particles, Center of Mass – Central Forces, Kepler’s Law, trajectories in Gravitational systems

Oscillations and Waves
Oscillations, Simple Harmonic Oscillations, Forced oscillations, damping, resonance – Waves, sound waves, elastic waves

Non inertial frames and rigid body motion
Motion in non-inertial frames, Coriolis and Centrifugal forces, Foucault pendulum – Independent Coordinates for a Rigid body, Euler angles – The Inertia tensor and Moment of Inertia – Principal Axis transformation

Fluid Mechanics
Fluid as a continuum – Velocity Field – Stress field – Viscosity, Newtonian and non-Newtonian fluids – Surface tension – Continuity equation – Dimensionless numbers in fluid mechanics – Laminar and Turbulent flow

References:

1. D. Kleppner and R. J. Kolenkow, *An Introduction to Mechanics* (1st Edition), McGraw Hill, 2017.
2. D. J. Morin, *Introduction to Classical Mechanics: With Problems and Solutions*, Cambridge University Press, 2008.
3. K. R. Symon, *Mechanics* (3rd Edition), Pearson, 2016.
4. M. R. Spiegel, *Theoretical Mechanics* (Schaum Series), McGraw Hill, 2017.
5. R. W. Fox, A. T. McDonald, P. J. Pritchare and A. W. Mitchel, *Fluid Mechanics* (9th Edition), John Wiley & Sons, 2011.

PH1102E THERMODYNAMICS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Identify thermodynamically relevant variables for macroscopic systems and set up equations of state.
CO2: Apply the first and second law of thermodynamics to thermodynamic systems in practice.
CO3: Analyze thermodynamic properties of a system using appropriate thermodynamic potentials.
CO4: Apply the conditions of phase equilibrium and thermodynamic stability to analyze phase transitions.

Equations of State and First Law

Spatial and temporal nature of macroscopic measurements - thermodynamic equilibrium - measurability of energy - quantitative definition of heat - equation of state: ideal gas - real gas - non-PVT systems – PVT surfaces - expansivity and compressibility – first law of thermodynamics - configuration and dissipative work - mechanical equivalent of heat - heat capacity - enthalpy – consequences of the first law of thermodynamics - energy equation - Gay-Lussac-Joule experiment - Joule-Thomson experiment of free expansion - reversible adiabatic processes - Carnot cycle.

Entropy and Second law

Entropy and second law of thermodynamics - thermodynamic temperature - entropy changes in reversible and irreversible processes - temperature-entropy diagrams - principle of increase of entropy - Clausius and Kelvin-Planck statement of second law – Combined first and second laws - TdS equations - properties of pure substances - ideal gas and van der Waals gas - liquids or solids under hydrostatic pressure - Joule and Joule-Thomson experiments - Euler Equation - Gibbs-Duhem relation.

Thermodynamic potentials)

Thermodynamic potentials - Helmholtz and Gibbs Function - Maxwell relations - stable and unstable equilibrium - third law of thermodynamics - chemical potential - conditions of equilibrium - maximum work theorem - energy minimum principle - Legendre transformations - minimum principle for thermodynamic potentials.

Stability and Phases

Intrinsic stability of thermodynamic systems - stability conditions for thermodynamic potentials - physical consequences of stability - Le Chatelier's principle – First-order phase transitions in single component systems - phase-coexistence - Clausius-Clapeyron equation - unstable isotherms - general attributes of first-order transitions - first-order phase transitions in multi-component systems - phase equilibrium and Gibbs phase rule - critical constants for van der Waal's gas – qualitative discussion on second-order phase transitions.

References:

1. M. W. Zemansky and R. H. Dittman, *Heat and Thermodynamics* (8th Edition), McGraw-Hill, 2017.
2. F. W. Sears and G. L. Sallinger, *Thermodynamics, Kinetic theory and Statistical Thermodynamics*, Narosa, New Delhi, 1995.
3. H. B. Callen, *Thermodynamics and an Introduction to Thermostatics* (2nd Edition), Wiley, 1985.
4. E. Fermi, *Thermodynamics*, Dover Publications, 2000.
5. A. Y. Cengel and A. M. Boles, *Thermodynamics: an engineering approach (5th Edition)*, TMH, 2006.

PH1191E GENERAL PHYSICS LAB

Pre-requisites: Nil

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Apply principles of mechanics, quantum and atomic theory for experimentation.
CO2: Develop skills for data analysis and interpretation.
CO3: Set up experiments, take observations and relate it with a suitable theory.
CO4: Build ability for group discussion and critical thinking for collaborative work.

List of Experiments:

1. To determine the moment of inertia of a flywheel.

2. To determine the charge to mass ratio of the electron.

3. To determine the moment of inertia of the disc of the torsion pendulum and the rigidity modulus of the material of the given metallic wire using torsional oscillations and a uniform ring.

4. To determine the acceleration due to gravity using a symmetric compound pendulum, the radius of gyration about the center of gravity (CG) and the moment of inertia of the bar about the CG.

5. To study the splitting of spectral lines of atoms in the presence of magnetic field.

6. To determine the threshold frequency for photo electric emission, work function of the photo emissive material and to evaluate the Planck’s constant.

7. To study the existence of discrete atomic energy levels using Franck-Hertz experiment.

8. To determine the ultrasonic velocity in the given liquid.

9. To determine Young’s modulus and Poisson ratio of a transparent material (glass) by Cornu’s method.

10. To study the variation of the magnetic field along the axis of a current carrying circular coil using a deflection magnetometer and to determine the value of B_h at the place.

References:

1. A. C. Melissinos and J. Napolitano, *Experiments in Modern Physics (2nd Edition)*, Academic Press, 2003.
2. R. A. Dunlop, *Experimental Physics*, Oxford Univ. Press, 1988.

ME1391E MECHANICAL WORKSHOP

Pre-requisites: Nil

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Identify and use various tools used in a machine shop and perform the basic lathe operations such as turning, facing, chamfering, knurling etc.
CO2: Identify and use various tools used in fitting and welding and perform operations such as chipping, filing, cutting, drilling, etc., and prepare multiple joints and welds
CO3: Identify and use various tools in carpentry & sheet metal work and perform multiple operations for the preparation of joints using wood and fabrication using sheet metal
CO4: Identify and use various tools in smithy & foundry and to practice forging, moulding and casting

The course is intended to expose the student to various manufacturing processes through hands on training in different sections of Central Workshop. During the course, the student learns the properties and selection of different materials and acquires the skill in using various tools and measuring devices.

1. **Machine Shop**: Study of the basic lathe operations. Turning, step turning, facing, chamfering, thread cutting, grooving, knurling etc.
2. **Fitting**: Study of tools- chipping, filing, cutting, drilling, tapping, about male and female joints, stepped joints. Cutting and edge preparation for lap and butt joints.
3. **Welding**: Study of arc and gas welding, accessories, joint preparation. Welding of lap and butt joints, Single V and Double V.
4. **Carpentry**: Study of tools and joints – planing, chiseling, marking and sawing practice, one typical joint- Tee halving/cross halving/Mortise and Tenon/ Dovetail.
5. **Sheet Metal**: Study of tools, selection of different gauge sheets, types of joints. Fabrication of a tray or a funnel.
6. **Smithy**: Study of tools. Forging of square or hexagonal prism/chisel/bolt.
7. **Foundry**: Study of tools, sand preparation. Moulding practice using the given pattern and demonstration on casting

References:

1. W. A. J. Chapman, *Workshop Technology - Parts 1 & 2* (4th Edition), New Delhi, India, CBS Publishers & Distributors Pvt. Ltd., 2007.
2. *Welding Handbook (9th Edition),* American Welding Society, 2001.
3. J. Anderson, *Shop Theory*, New Delhi, India, Tata McGraw Hill, 2002.
4. J. H. Douglass, *Wood Working with Machines*, Illinois, McKnight & McKnight Pub. Co., 1995.
5. W. A. Tuplin, *Modern Engineering Workshop Practice,* Odhams Press, 1996.
6. P. L. Jain, *Principles of Foundry Technology* (5th Edition), New Delhi, India, Tata McGraw Hill, 2009.

MA1012E MATHEMATICS II
(Common to CSE/EP branches)

Pre-requisites: Nil

L	T	P	O	C
3	1*	0	5	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Acquire sufficient knowledge about convergence of sequences and series and various methods of testing for convergence.
CO2: Solve linear ODEs with constant coefficients.
CO3: Test the consistency of the system of linear equations and solve it.
CO4: Acquire sufficient knowledge about vector spaces, linear transformation and theory of matrices.
CO5: Diagonalise symmetric matrices and use it to find the nature of quadratic forms.

Numerical sequences - Cauchy sequence - convergence of sequences - series - convergence of series - tests for convergence - absolute convergence. Sequence of functions - power series - radius of convergence - Taylor series. Periodic functions and Fourier series expansions - half-range expansions.

Existence and uniqueness of solution of first order ordinary differential equations (ODEs) - methods of solutions of first order ODE - linear ODE - linear homogeneous second order ODEs with constant coefficients - fundamental system of solutions - Wronskian - linear independence of solutions - method of undetermined coefficients - solution by variation of parameters.

System of linear equations: Gauss elimination method - row echelon form - row space - row rank - existence and uniqueness - homogeneous system - solution space - rank-nullity relation for homogeneous linear system. Abstract vector space - subspace - linear independence and span - basis - dimension - linear transformation - kernel - range - rank-nullity theorem.

Coordinates - matrix representation of linear transformation - base changing rule - eigenspace - diagonalisation of linear operator. Eigenvalues and eigenvectors of a matrix - Cayley-Hamilton theorem - diagonalisation of symmetric matrices - quadratic forms - transformation into principal axes - eigenvalue method of solving system of first order linear ODEs with constant coefficients.

References:

1. H. Anton, I. Bivens and S. Davis, *Calculus* (10th edition), John Wiley & Sons, 2015.
2. Apostol, *Calculus Vol 1* (1st edition), Wiley New Delhi, 2014.
3. E. Kreyszig, *Advanced Engineering Mathematics* (10th edition), Wiley, 2015.
4. Gilbert Strang, *Differential Equations and Linear Algebra*, Cambridge Press, 2014.
5. Stephen W. Goode and Scott Annin, *Differential Equations and Linear Algebra*, Pearson Prentice Hall, 2007.
6. O. Bretscher, *Linear algebra with applications*, New Delhi, Prentice Hall, 1997.

MS1001E PROFESSIONAL COMMUNICATION

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	1*	0	6	3

Course Outcomes:

CO1: Distinguish the role and purpose of communication at the workplace and for academic purposes.
CO2: Decide strategies and modes for effective communication in a dynamic workplace.
CO3: Combine multiple approaches for successful and ethical information exchange.
CO4: Estimate best communication practices to assist productivity and congeniality at the workplace.

Listening and Reading Comprehension

Conversation starters: introductions and small talk - Seek and provide information, clarification, polite enquiries, requests, congratulate people, apologise, give and respond to feedback - Describe graphs, tables, and charts - Words often confused: Lexicon and Meaning - Sense Groups - Listening for specific purposes: Listening to lectures, Summarise academic lectures for note-taking - Appropriate Language to Request and Respond - Public Speaking

Vocabulary and Speaking

Developing professional vocabulary - Basic Sentence Structures from Reading Texts - Concord - Functions of Auxiliary Verbs and Modals - Strategies for Effective Reading - Skimming and Scanning, Determine themes and main ideas, Predicting content using photos, images and titles - Critical Reading: Discussing and Summarising text points - Understanding Text Structures: sequencing, comparing and contrasting, relating cause and effect, problems and problem-solving - Discussing Rhetorical and Cultural Aspects in Texts - Text Appreciation: Drawing inferences, Framing Opinions and Judgments on Reading Text

Effective Writing

Note Making and Summarising: Prepare notes from reading texts, Paraphrasing - Use of Multimedia for Assistive Purposes - Paragraph Writing: cohesive devices to connect sentences in a paragraph - transitional devices - Use Text Structures in Paragraphs: sequencing, comparing and contrasting, relating cause and effect, problems and problem-solving - Avoiding Ambiguity and Cleft Sentences - Applications- Writing Instructions, Descriptions and Explanations - Official Letters of Request and Denial - Official E-mails - Abstract Writing - Digital Resources for Effective Communication

Communication at Workplace

Communication Theory - Process of Communication - Modes of Communication - Verbal and Non-Verbal Communication - Tone in Communication - Formal and Informal Communication at Workplace - Passive, Assertive and Aggressive Styles of Communication - Positive Body Language - Group Discussions - Presentation - Workplace Communication - Active Listening - Giving Feedback - Communication Etiquette - Persuasion - Negotiation - Tone and Voice - Telephone etiquette - Establishing Credibility in Conversations - Digital Communication and Netiquette: Conducting Oneself in Virtual Interactions, Constructive use of Social media - Ethical and Culturally Sensitive Communication: Ethical considerations in professional communication, Addressing diversity, Inclusive Communication Practices

References:

1. N. Bhatnagar and M. Bhatnagar, *Communicative English for engineers and professionals*, Dorling Kindersley, 2010.
2. M. Foley and D. Hall, *Longman advanced learners' grammar: A self-study reference & practice book with answers*, Pearson Education, 2018.
3. B. A. Garner, *HBR Guide to better business writing: Engage readers, tighten and Brighten, make your case*, Harvard Business Review Press, 2012.
4. M. Hewings, *Advanced grammar in use: A reference and practice book for Advanced learners of English*, Cambridge University Press, 2013.

5. M. Ibbotson, *Cambridge English for Engineering*, Cambridge University Press, 2015.
6. S. Kumar and P. Lata, *Communication Skills,* Oxford University Press, 2015.
7. N. Sudarshana and C. Savitha, *English for Technical Communication*, Cambridge English, 2016.

PH1111E CLASSICAL MECHANICS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply Calculus of Variations and Lagrangian method for problems in Classical Mechanics.
CO2: Utilize the symmetry properties of systems to simplify the description of a system.
CO3: Describe oscillatory behavior under different conditions.
CO4: Implement special relativity and identify the discerning features.

Lagrangian method
Constraints - Generalized Coordinates - Virtual Displacements - D'Alembert's Principle - Calculus of Variations, examples - Lagrangian, Euler-Lagrange Equations, examples - Central force motion - Orbits and Scattering.

Hamilton's equations and Canonical Transformations
Legendre transformations - Hamilton's equations and examples - Cyclic coordinates – Symmetry - Conservation principles and Noether's theorem - Canonical transformations - Poisson bracket formulation

Normal Modes of Oscillation
System of oscillators - eigenvalue problem and normal modes - damping - forced oscillations and resonance - Dynamical stability.

Special Relativity
Special theory of relativity - Lorentz transformation - Consequences of Special Relativity - Relativistic mechanics and dynamics - Four-vectors, tensors, metric - Space-time diagrams.

References:

1. H. Goldstein, C. P. Poole and J. Safko, *Classical Mechanics* (3rd Edition), Pearson, 2011.
2. Landau and Lifshitz, *Mechanics: Course of Theoretical Physics Vol-I* (3rd Edition), Butterworth-Heinemann, 2010.
3. D. Kleppner and R. J. Kolenkow, *An Introduction to Mechanics* (1st Edition), McGraw Hill, 2017.
4. M. R. Spiegel, *Theoretical Mechanics* (Schaum Series), McGraw Hill, 2017.
5. D. A. Wells, *Lagrangian Dynamics* (Schaum Outlines Series), McGraw-Hill, 1967.

PH1112E ANALOG ELECTRONICS

L	T	P	O	C
3	0	0	6	3

Pre-requisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply circuit theorems and solve physics problems in terms of equivalent circuits.
CO2: Explore the fundamentals of operational amplifiers and design wave-shaping circuits, oscillators, mathematical operations, voltage regulators, current sources, and instrumentation amplifiers.
CO3: Apply the fundamentals of the 555 timers and realize various timing and clock circuits.
CO4: Realize various active filters through transfer function formalism and Design band-pass, band-reject (Notch) filters.
CO5: Employ the concepts of special purpose diodes and FET, MOSFET transistors in physical measurement systems.

Voltage and current sources – circuit theorems- superposition theorem – Thevenin's theorem – Norton's theorem – Thevenin-Norton conversions – maximum power transfer theorem – star-delta transformations – Equivalent circuit and its applications in physics.

Open-loop operational amplifier configurations – feedback configurations- voltage series and voltage shunt feedback amplifiers – differential amplifiers- differential amplifier with one op-amp and two op-amps – current to voltage converter – input offset voltage – input bias current – input offset current – total output offset voltage – common mode rejection ratio – compensating networks – slew rate- causes of slew rate – slew rate equation – the effect of slew rate in applications.

Summing – scaling – and averaging amplifiers – subtractor – integrator – differentiator – instrumentation amplifier – voltage to current converter – Oscillators- basic principle of the sinusoidal oscillator – phase shift – and Wein bridge oscillators – Comparators – Schmidt trigger – the 555 timer – the 555 as a monostable – and as an astable multivibrator – applications – Phase Locked Loop (PLL)- operating principles and applications – voltage regulators.

Filter theory – transfer function – poles and zero-filter responses –design of low-pass, high-pass, band-pass and band-stop (Notch) active filters using Op-amps, Special diodes: Schottky diode, LED, varactor diode, Photo diode, tunnel diode, FET, MOSFET, Diac, Triac and SCR.

References:

1. A. Malvino, D. Bates and P. Hoppe, *Electronic principles* (9th Edition), McGraw-Hill, 2020.
2. T. L. Floyd and D. M. Buchla, *Basic operational Amplifiers and Linear Integrated Circuits*, Pearson Education Asia, 2003.
3. R. A. Gayakwad, *Op-amps and Linear Integrated Circuits*, Prentice Hall of India, 2009.
4. W. D. Stanley, *Operational amplifiers with linear integrated circuits*, Pearson, 2004.
5. R. F. Coughlin and F. F. Driscoll, *Op- Amps and Linear Integrated Circuits* (4th Edition), Prentice Hall of India, 2003.
6. A. S. Sedra and K. C. Smith, *Microelectronic Circuits* (6th Edition), Oxford University Press, 2011.

PH1113E ELECTROMAGNETICS

Pre-requisites: Nil

L	T	P	O	C
3	1*	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply concepts of vector calculus to describe Electric and Magnetic fields.
CO2: Identify simplifying principles like symmetry to compute Electric and Magnetic fields.
CO3: Formulate and solve problems involving time dependent electromagnetic fields using Maxwell's equations.
CO4: Analyze propagation of electromagnetic waves in vacuum and dielectric media

Electrostatics

Electrostatic force and field: scalar and vector fields - Coulomb's law - flux of the electric field and Gauss law - divergence of electric field - electric potential - line integral of the field - curl of the electric field - Poisson and Laplace equation - electrostatic work and energy - conductors and electric fields - field and potential of dipoles - electric polarization vector - Gauss law for a dielectric medium - electrostatic boundary conditions.

Magnetostatics

Electric current - current density - surface and volume currents - continuity equation - magnetic field - Biot-Savart law - divergence and curl of magnetic field - Ampere's law - field due to a magnetic dipole - magnetic dipole in external magnetic field - magnetostatic energy - magnetized materials - magnetostatic boundary conditions.

Time dependent Electric and Magnetic fields

Electromotive force - Faraday's law - Lenz law - electromagnetic induction - mutual and self- inductance - Maxwell's equations - Maxwell's correction to Ampere's law - displacement current - electromagnetic field – energy density - Poynting's theorem.

Maxwell's equations in free space - wave equation - plane wave solution - structure of the electro- magnetic wave - spherical waves - propagation in dielectric medium and refractive index.

References:

1. D. J. Griffiths, *Introduction to Electrodynamics* (4th Edition), PHI Learning - New Delhi, 2012.
2. E. Purcell and D. Morin, *Electricity and Magnetism* (3rd Edition), Cambridge University Press, 2013.
3. M. O. Sadiku, *Elements of Electromagnetics* (4th Edition), Oxford, 2009.
4. D. J. Cheng, *Field and Wave Electromagnetics* (2nd Edition), Pearson, 2014.
5. R. P. Feynman, R. Leighton and M. Sands, *Feynman Lectures on Physics Vol.-II* (Millenium Edition), Pearson, 2012.
6. J. Edminister, *Schaum's Outline: Theory and Problems in Electromagnetics* (2nd Edition), McGraw-Hill, 1979.

PH1192E ELECTRONICS LAB - I

Pre-requisites: Nil

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:
CO1: Design inverting and non-inverting operational amplifiers.
CO2: Perform mathematical operations (differentiation and integration) using operational amplifier.
CO3: Construct various (low-pass, high-pass, band-stop) active filter circuits using operational amplifier.
CO4: Realize waveform generators and wave-shaping rectifier circuits.
CO5: Apply the fundamentals of 555 timer circuits and realize various timing and clock pulse circuits.

List of Experiments:

1. Inverting, non-inverting amplifiers, and voltage follower circuits using IC741
2. Voltage to the current converting amplifier
3. Differentiator and integrator using IC741
4. Half and Full-wave active rectifiers using IC741
5. Instrumentation amplifier using IC741
6. Wein bridge oscillator using IC741/Waveform generators (sine, square and triangular)
7. First order low-pass, high-pass Butterworth filters and Notch Filter
8. Astable multivibrator using IC741
9. Astable and monostable multivibrators using 555 timer
10. Voltage comparators and Schmidt Trigger

References:

1. T. L. Floyd and D. M. Buchla, *Basic operational Amplifiers and Linear Integrated Circuits*, Pearson Education Asia, 2003.
2. R. A. Gayakwad, *Op-amps and Linear Integrated Circuits*, Prentice Hall of India, 2009.
3. W. D. Stanley, *Operational amplifiers with linear integrated circuits*, Pearson, 2004.
4. R. F. Coughlin and F. F. Driscoll, *Op- Amps and Linear Integrated Circuits* (4th Edition), Prentice Hall of India, 2003.
5. A. S. Sedra and K. C. Smith, *Microelectronic Circuits* (6th Edition), Oxford University Press, 2011.
6. Virtual lab resources: https://www.vlab.co.in/broad-area-electronics-and-communications

PH1193E ELECTROMAGNETICS SIMULATIONS LAB

Pre-requisites: Nil

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Employ finite-element method (FEM) and finite-difference-time-domain method (FDTD) to solve electromagnetic problems.

CO2: Simulate electrostatic and magnetostatic problems associated with capacitors and inductors, respectively.

CO3: Design electric dipole antenna, magnetic lens, and wire-grid polarizers and explore its functionalities numerically.

CO4: Perform complex electromagnetic computations and solve electromagnetic wave propagation problems numerically.

List of Experiments:

1. Solve the electrostatic boundary value problem for a given set of boundary conditions numerically and plot electric potential and electric field distributions (2-D, 3-D problems)
2. Simulate (i) capacitor fringing fields and (ii) Eddy current distributions when different kinds of metallic plates are placed near a 50 Hz AC conductor
3. Compute and plot the magnetostatic force between an iron rod and a permanent magnet
4. Design an electric dipole antenna and plot its electric field and radiation pattern
5. Design the Helmholtz coil and plot the magnetic field distribution associated with it
6. Study the Mie scattering of a lossless dielectric sphere and plot the differential radar cross-section
7. Find the eigenmode and quality factors of a dielectric ring resonator
8. Simulate Gaussian wave propagation in a nonlinear medium
9. Animate the electromagnetic mode of rectangular and slab waveguides
10. Compute Fresnel’s coefficients for transverse electric (TE) and transverse magnetic (TM) wave incident on a dielectric slab from the air and compare them with analytical results
11. Design wire grid polarizers and verify cross-polarization conversion
12. Design a magnetic lens and plot the electron beam trajectories in a spatially varying magnetic field

References:

1. R. C. Rumpf, *Electromagnetic and Photonic Simulation for the beginner*, Artec Press, 2022.
2. A. Taflove, A. Oskooi and S.G. Johnson, *Advances in FDTD Computational Electrodynamics: Photonics and Nanotechnology*, Artech: Norwood, MA, 2013.
3. MEEP (Open source FDTD electromagnetic solver): https://meep.readthedocs.io/en/latest/
4. Comsol RF Module: www.comsol.com

MA2002E MATHEMATICS III

L	T	P	O	C
3	1*	0	5	3

Pre-requisites: Nil

Total: 39 Lecture Sessions

Course Outcomes

CO1: Analyse different types of linear operators on inner-product-spaces and their spectral decomposition.

CO2: Find the singular value decomposition of linear transformations and matrices and use it to obtain low rank approximations.

CO3: Use the Cauchy-Riemann equations to check the complex differentiability of functions.

CO4: Classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.

Linear Algebra

Review of vector spaces, linear transformations, minimal polynomial, eigenvalues, diagonalizability, inner product spaces, norm, orthogonality of the subspaces associated to a linear transformation, orthonormal basis, Schur's theorem, linear functional, Riesz representation theorem, orthogonal complement, direct sum, orthogonal projection, best approximation, least square approximation, pseudoinverse, Adjoint of a linear operator, null-space and range of adjoint, self-adjoint and normal operators, minimal polynomial of self-adjoint operator, spectral theorem for self-adjoint operators, spectral theorem for normal operators, singular value decomposition, low-rank approximation, Eckart-Young Theorem.

Complex Analysis

Complex functions, derivative, holomorphic function, Cauchy-Riemann equations, harmonic functions, harmonic conjugate, Line integral in the complex plane, Cauchy's integral Theorem, Cauchy's integral formula, Derivatives of analytic functions, power series, zeros of holomorphic functions, isolated singularities, Laurent's series, residue integration method, evaluation of real improper integral.

References:

1. S. Axler, *Linear Algebra Done Right* (4th Edition), Springer, 2023.
2. G. Strang, *Introduction to Linear Algebra* (5th Edition), Wellesley Cambridge Press, 2016.
3. J W Brown and R V. Churchill, *Complex Variables and Applications* (9th Edition), McGraw-Hill Education, 2009.
4. S. Ponnusamy andH Silverman, *Complex Variables with Applications*, Birkhauser, 2006.
5. E. Kreyszig, H. Kreyszig and E. J. Norminton, *Advanced Engineering Mathematics* (10th Edition), Wiley, New Delhi, 2015.
6. C. R. Wylie and L. C. Barrett, *Advanced Engineering Mathematics* (6th Edition), McGraw-Hill, New Delhi, 1995.

PH2101E PROFESSIONAL ETHICS

Pre-requisites: Nil

Total Lecture Sessions: 13

L	T	P	O	C
1	0	0	2	1

Course Outcomes:
CO1: Inculcate human values and use it as the basis for all activities.
CO2: Demonstrate ethical practices in professional research and development activities
CO3: Demonstrate scientific integrity in recording and reporting research results.
CO4: Assimilate the elements of Academic Integrity and Honour Codes as lifelong practice.

Human Values
Morals, values and ethics – Integrity – Work ethic – Service learning – Civic virtue – Sharing – Honesty – Courage – Valuing time – Cooperation – Commitment – Empathy – Self-confidence – Character.

Ethics in Professional Practice
Ethics in professional context – Ethical basis of engineering activities – Ethical responsibilities to consumers and customers – Safety and risk – Ethics in management of intellectual property – Environmental matters and sustainability.

Professional ethics in academics and research
APS guidelines on ethics – case studies, Redundant publication, plagiarism, explicit, systemic and implicit bias, integrity of research results, publications and authorship issues, conflicts of interest, responsible conduct in the work place, fabrication of data, deception, theft of others data.

References:

1. R.S. Naagarazan, *A Textbook on Professional Ethics and Human Values* (3rd Edition), New Age International Pvt. Ltd., 2022.
2. A. F. Bainbridge, *Ethics for Engineers*: *A Brief Introduction*, CRC Press, 2021.
3. E. G. Seebauer and R. L. Barry, *Fundamentals of Ethics for Scientists and Engineers*, Oxford University Press, 2001.
4. American Physical Society, *Guidelines on Ethics* (https://www.aps.org/policy/statements/guidlinesethics.cfm)
5. International Centre for Academic Integrity – available at ‘https://academicintegrity.org/’.
6. Paul Oliver, *Students Guide to Research Ethics* – Open University Press, Maidenhead, Philadelphia, 2003.
7. CSIR *Guidelines for Ethics in Research and in Governance, 2019*.

PH2102E QUANTUM PHYSICS – I

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	1*	0	5	3

Course Outcomes:
CO1: Compute probability distribution for observables of a system in a given quantum state.
CO2: Solve Schrodinger equation for simple one dimensional problems.
CO3: Analyze three dimensional central field problems and compute eigenvalues and eigenstates.
CO4: Investigate symmetries of a quantum system.
CO5: Apply density matrix formalism and idea of entanglement to study simple systems.

Basic Formalism
Postulates of Quantum Mechanics, Dirac formalism – bra-ket notation, states and observables, measurement theory, Born interpretation - Translation operator and momentum, canonical commutation relations - expectation values - uncertainty principle - matrix representation of operators, change of basis, position and momentum representation - time evolution, Hamiltonian operator, Time dependent Schrödinger equation, Time independent Schrödinger equation - Schrödinger, Heisenberg and interaction pictures.

One Dimensional Systems
One dimensional time independent potential problems, general properties, bound and scattering solutions- Free particle - potential wells and barriers, tunneling - Simple harmonic oscillator: operator method and algebraic method - periodic potential, Bloch’s theorem, band structure - symmetry, conservation laws- parity.

Three Dimensional Systems
Rotations, angular momentum operators, commutation relations, eigenvalues and eigenfunctions, orbital and spin angular momentum- three dimensional time independent potential problems: central field problems, hydrogen atom.

Composite and Incompletely Known Systems
Composite systems, quantum entanglement - incompletely known systems and density matrix, pure and mixed states - entropy, connection to partition functions.

References:

1. R. L. Liboff, *Introductory Quantum Mechanics* (4th Edition.), Pearson education, 2003.
2. J. J. Sakurai, *Modern Quantum Mechanics* (3rd Edition), Addison Wesley, 1999.
3. R. Shankar, *Principles of Quantum Mechanics* (2nd Edition), Springer, 1994.
4. D. J. Griffiths, *Introduction to Quantum Mechanics* (2nd Edition), Pearson Education, 2005.
5. N. Zettili, *Quantum Mechanics: Concepts and Applications* (2nd Edition), John Wiley, 2009.
6. L. I. Schiff, *Quantum Mechanics* (3rd Edition), McGraw Hill, 1968.

PH2103E DIGITAL ELECTRONICS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Express proficiency in Number Systems, IEEE 754 number format, Boolean algebra, reduction, and simplification of circuits using Karnaugh maps and digital logic electronic circuits using diodes and transistors.

CO2: Design combinational logic Circuits, Binary to Grey and Grey to Binary converters, Parity generators and parity checkers, Multiplexer, Demultiplexer, Encoder and Decoder circuits.

CO3: Describe the fundamentals of various flip-flops and construct sequential circuits such as shift registers and counters.

CO4: Realize various digital-to-analog and analog-to-digital conversion methods and apply them in physical measurement circuits.

CO5: Construct Read Only Memory and demonstrate its applications. Practice interfacing techniques using Arduino/Labview for physical measurements.

Number systems-Conversion Techniques-Negative and Fraction Representations-IEEE 754 Number Format. Logic gates and Boolean algebra, Boolean laws, De Morgan’s theorems, Simplification and Reduction of circuits using Karnaugh maps-Don’t care conditions, Construction of fundamental digital Electronic Logic circuits using Diode-Resistor, Transistor-Transistor Families. CMOS-based basic logic gates.

Combinational logic circuits - adders- half and full adders, subtractor- half and full subtractors, encoders and decoders, seven segment decoders, parity generators and checkers, multiplexers, demultiplexers and their applications. Fundamentals of flip flops: R-S, J-K, T, and D, master-slave flip flops, characteristic equations and excitation tables for R-S, J-K, T and D flip flops, and conversion of flip flops.

Sequential logic circuits: shift registers, types of registers- serial in serial out, serial in parallel out, parallel in-serial out, parallel in- parallel out, applications of shift registers, counters - asynchronous counters, decoding gates, synchronous counters, digital-to-analog converters with binary weighted-resistors and R-2R resistors, analog- to- digital converter- successive approximation A/D converters.

Construction of Read Only Memory (ROM), EPROM, flash, static and dynamic random-access memories, memory and I/O interfacing – Basics of Arduino/Labview and demonstration of interfacing applications.

References:

1. Malvino, Leach and Saha, *Digital Principles and applications*, Tata Mc. Graw Hill, 2014.
2. T. L. Floyd, *Digital Fundamentals* (8th Edition), Pearson Education Asia, 2011.
3. Morris Mano M., *Digital Logic and Computer Design*, Pearson Education India, 2016.
4. Anil K. Maini, *Digital Electronics, Principles, Devices and Applications*, John Wiley and Sons, 2007.
5. John F. Wakerley, *Digital Design Principles, and Practices* (4th Edition), Prentice Hall, 2006.
6. W. H. Gothmann, *Digital Electronics: An introduction to theory and practice*, Prentice Hall, 2000.
7. Simon Bales, *Arduino Measurement Projects for Beginners*, 2018.

PH2191E MICROWAVE LAB

Pre-requisites: Nil

L	T	P	O	C
1	0	3	5	3

Total 13 Lecture Sessions + 39 Practical Sessions

Course Outcomes:

CO1: Apply principles electromagnetic theory and characterize rectangular wave guides

CO2: Measure unknown impedance and characterize microwave devices such as multihole directional coupler, magic-T, attenuators and horn-antenna

CO3: Measure dielectric constant of low-loss dielectric materials.

CO4: Simulate electromagnetic phenomena and design advanced electromagnetic wave components

CO5: Analyze experimental data, draw inferences and prepare reports; develop soft skills necessary for working effectively in a team environment.

Theory and Experiments related to:

1. Study of Klystron Characteristics (AM & FM Mode) & Measurement of Frequency and Wavelength in a Rectangular Waveguide.
2. Measurement of VSWR and Reflection Coefficient
3. Impedance Measurement and Smith Chart
4. Study of Fixed and Variable Attenuators
5. Characteristics of Multihole-Directional Coupler
6. Study of Magic-T
7. Horn Antenna (obtain the radiation pattern both numerically and experimentally)
8. Measurement of Dielectric Constant (Solid)
9. Measurement of Dielectric Constant (Liquid)
10. Design metallic and dielectric microwave cavities and compute their eigenmodes and quality factor numerically
11. Simulate negative refraction in metamaterials
12. Compute the transmission/reflection coefficients of 1-D and 2-D photonic crystals and compute their electromagnetic bandgap
13. Demonstrate the formation of Surface-Plasmon-Polariton Resonances using Kretschmann-Raether and Otto configurations.

References:

1. R. S. Rao, *Microwave Engineering*, Prentice Hall India, 2012.
2. *Comsol RF Module* (www.comsol.com)
3. Raymond C. Rumbpf, *Electromagnetic and Photonic Simulation for the beginner*, Artech House, 2022.

PH2192E ELECTRONICS LAB-II

Pre-requisites: Nil

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Apply basic logic gates (NAND, NOR) for the design of combinational circuits (half-adder, full-adder, half subtractor, full-subtractor, Parallel adder), code converters, and parity checkers

CO2: Verify the truth table of Flip-flops (RS, JK, JK Master-Slave, D and T) and construct latch circuits.

CO3: Design asynchronous and synchronous mod-counters and employ them for time measurements.

CO4: Realize multiplexer/demultiplexer and encoder/decoder circuits experimentally.

List of Experiments

1. Verify the truth table of fundamental logic gates and verify the universality of NAND and NOR gates
2. Design combinatorial circuits (Half-adder, full-adder, half-subtractor and full-subtractor)
3. Design Parallel adder/subtractor circuits using IC7483
4. Construct code converters (Binary to Grey and Grey to Binary), Parity generators and parity checkers using simplified logic circuits
5. Construct and verify 4-to-1 multiplexer and 1-to-4 demultiplexer using basic logic gates
6. Construct and verify 2-to-4 decoder and 4-to-2 encoder circuits using basic logic gates
7. Verify the truth table of RS, JK, JK master-slave, D, and T flip flops and demonstrate the RS latching.
8. Construct and verify 4-bit synchronous and asynchronous counters

References:

1. Malvino, Leach and Saha, *Digital Principles and applications*, Tata Mc. Graw Hill, 2014.
2. T. L. Floyd, *Digital Fundamentals* (8^{th} Edition), Pearson Education Asia, 2011.
3. Morris Mano M., *Digital Logic and Computer Design*, Pearson Education India, 2016.
4. Anil K. Maini, *Digital Electronics, Principles, Devices and Applications*, John Wiley and Sons, 2007.
5. John F. Wakerley, *Digital Design Principles, and Practices*, Ed. 4, Prentice Hall, 2006.
6. W. H. Gothmann, *Digital Electronics: An introduction to theory and practice*, Prentice Hall, 2000.
7. Virtual lab resources: https://www.vlab.co.in/broad-area-electronics-and-communications

MA2012E MATHEMATICS IV

L	T	P	O	C
3	1*	0	5	3

Pre-requisites: Nil
Total Lecture Sessions: 39

Course Outcomes
CO1: Solve problems involving random variables and functions of random variables.
CO2: Perform de-correlation of random vectors using PCA.
CO3: Apply regression and correlation analysis for studying relationship between variables.
CO4: Use probabilistic and statistical analysis in various applications of engineering.

Probability
Sample space, probability, conditional probability, independence, random variable, probability distributions, binomial distribution, Poisson distribution, geometric distribution, continuous random variable, probability density function, normal distribution, uniform distribution, Markov’s inequality, Chebyshev’s inequality, moments and moment generating function, normal approximation of binomial distribution, functions of random variables.

Jointly distributed random variables, marginal and conditional distributions, covariance, correlation coefficient and independence, joint probability distribution of functions of random variables, bi-variate normal distribution, random vectors, expectation vectors and covariance matrices, autocorrelation matrix, properties of covariance matrices, decorrelation of random vectors, multidimensional gaussian, transforming to independence, principal components analysis.

Statistical Inference
Population, sample and statistic, central limit theorem, sampling distribution of the mean, point estimation, unbiased estimator, sample variance, Chi square distribution, distribution of sample mean and sample variance, interval estimation of population mean and variance, Student’s t-distribution, interval estimation of mean when variance is unknown, maximum likelihood estimator, testing of hypothesis, testing hypothesis concerning mean, hypotheses tests concerning variance, F distribution, Chi square test for goodness of fit, analysis of contingency tables, simple linear regression, method of least squares, sampling distribution of regression coefficients, inference concerning regression parameters sample correlation coefficient of paired data, regression to the mean,

References:

1. F. Dekking, C. Kraaikamp, H. Lopuhaä and L. Meester, *A Modern Introduction to Probability and Statistics: Understanding Why and How*, Springer London, 2005.
2. H. Stark and J. W. Woods, *Probability, Statistics, and Random Processes for Engineers*. Pearson, 2012.
3. N. S. Matloff, *Probability and Statistics for Data Science: Math + R + Data, CRC Press*, 2020.
4. N. T. Kottegoda and R. Rosso, *Statistics, Probability, and Reliability for Civil and Environmental Engineers*. Colombia: McGraw-Hill, 1998.
5. S. M. Ross, *Introduction to Probability and Statistics for Engineers and Scientists*, Elsevier Science, 2009.

PH2111E APPLIED OPTICS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Analyze the ray paths and aberrations in different optical systems using the principles of ray optics.

CO2: Apply the electromagnetic theory to analyse light propagation at different interfaces and light-matter interactions in different materials.

CO3: Employ the principles of interference, diffraction and polarization, for modulating the optical fields in different systems.

CO4: Apply the concepts of ray optics, electromagnetic theory, interference, diffraction and polarization to design basic optical instruments.

Ray optics

Geometrical and physical optics – Fermat’s principle and applications – Principle of reversibility – Image formation – Beam expanders - Design considerations – Ray equation and solution in inhomogeneous media – Mirage and ray paths in optical fibers – Matrix methods in paraxial optics – Aberrations – Classifications and correction methods.

Electromagnetic theory

Propagation of EM waves dielectric medium – Refractive index – Reflection and refraction at dielectric interfaces – Normal and oblique angles – Fresnel equations – Reflection - external and internal – Phase changes on reflection – Absorption and dispersion in materials.

Interference and diffraction

Principle of superposition – Young’s double slit experiment – Michelson, Fabry-Perot and Mach-Zehnder interferometers – Coherence – Fourier analysis – Spectral bandwidth of source and coherence time – Diffraction – Fresnel and Fraunhofer diffraction effects – Single slit diffraction – Beam spreading – Rectangular and circular apertures – Rayleigh’s criterion of resolution of optical instruments – Spatial frequency filtering – Diffraction from multiple slits – Diffraction grating.

Polarization

Polarized and unpolarised light – plane, circularly and elliptically polarized light – Stokes parameters – Matrix representation of polarized light and polarizers – Production of polarized light – Dichroism – Birefringence – Quarter wave plate and half wave plate – Brewster’s law – Optical activity.

References

1. F. L. Pedrotti, and L. S. Pedrotti, *Introduction to Optics* (3rd Edition), Cambridge University Press, 2017.
2. E, Hecht, *Optics*, Pearson Education, 2003.
3. A. Ghatak, *Optics*, Tata-McGraw-Hill, 2010.
4. D. J. Griffiths, *Introduction to Electrodynamics*, (4th Edition), PHI Learning, New Delhi, 2012.

PH2112E QUANTUM PHYSICS – II

Pre-requisites: PH2102E

Total Lecture Sessions: 39

L	T	P	O	C
3	1*	0	5	3

Course Outcomes:
CO1: Investigate quantum mechanical systems using approximation methods.
CO2: Apply basic group theoretic techniques to simplify quantum mechanical problems.
CO3: Analyze non-relativistic scattering problems using Born series and partial wave method.
CO4: Solve free Dirac and Klein - Gordon equation and interpret their solutions.

Approximation Methods
Time independent perturbation theory, degenerate perturbation theory- charged particle in electromagnetic fields- Time dependent perturbation theory, method of variation of constants, transition rate, sudden and adiabatic approximations, Fermi's golden rule- variational method, application to ground state of He-atom-WKB method.

Group Theoretic Techniques and Many Particle Systems
SU(2) and angular momenta - Addition of angular momenta, Clebsch-Gordon coefficients – tensor operators, Wigner-Eckart theorem - identical particles, distinguishable and indistinguishable particles, symmetric and anti-symmetric wave functions, exchange degeneracy, bosons and fermions, Slater determinant, Pauli's exclusion principle- locality principle and Bell's inequalities.

Scattering
Scattering theory, scattering cross section - Born approximation - partial wave analysis, hard sphere scattering.

Relativistic Quantum Mechanics
Relativistic effects - Klein-Gordon equation - Dirac equation, Dirac matrices, spinors, positive and negative energy solutions, physical interpretation - nonrelativistic limit of the Dirac equation.

References:

1. J. J. Sakurai, *Modern Quantum Mechanics* (3rd Edition), Addison Wesley, 1999.
2. R. Shankar, *Principles of Quantum Mechanics* (2nd Edition), Springer, 1994.
3. D. J. Griffiths, *Introduction to Quantum Mechanics* (2nd Edition), Pearson Education, 2005.
4. N. Zettili, *Quantum Mechanics: Concepts and Applications* (2nd Edition), John Wiley, 2009.
5. L. I. Schiff, *Quantum Mechanics* (3rd Edition), McGraw-Hill, 1968.
6. J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics,* McGraw-Hill, 1964.
7. A. Messiah, *Quantum Mechanics* (2nd Edition, Vol 1 and 2 combined edition), Dover publishers, 1995.

PH2113E STATISTICAL MECHANICS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Use concepts of statistical ensemble theory to connect thermodynamic properties of systems to the statistical distribution of the microstates of the system.

CO2: Analyse properties of thermodynamic systems using microcanonical, canonical, and grand canonical ensembles.

CO3: Apply concepts of quantum statistical physics to various problems such as free electrons, photon gas, specific heat of solids, Bose-Einstein condensate

Need for statistical physics, macro states and micro states, phase space, Liouville's theorem, fundamental postulate of equilibrium statistical mechanics, microcanonical ensemble, Gibbs paradox, enumeration of microstates, entropy, canonical ensemble – partition function, free energy, calculation of thermodynamic quantities, fluctuations, grand canonical ensemble.

Classical ideal gas, Maxwell-Boltzmann distribution, equipartition theorem, virial theorem, specific heat of gases, real gases, paramagnetism, Langevin and Brillouin functions, Curie's law, negative temperature concept, system of harmonic oscillators.

Systems of identical, indistinguishable particles, spin, symmetry of wavefunctions, bosons, fermions, Pauli's exclusion principle, Bose-Einstein and Fermi-Dirac distributions, degeneracy, ideal Fermi gas and ideal Bose gas, Bose-Einstein condensation, applications – free electron gas, radiation, specific heat of crystalline materials – Einstein and Debye theories, electronic contribution to specific heat of metals.

References:

1. R. K. Pathria, *Statistical Mechanics* (2nd edition), Butterworth-Heinemann, 1996.
2. K. Huang, *Statistical Mechanics* (2nd edition), John Wiley, 1987.
3. F. Reif, *Fundamentals of Statistical and Thermal Physics*, McGraw-Hill, 1985.
4. M. Kardar, *Statistical Physics of Particles*, Cambridge University Press, 2007.
5. E. A. Jackson, *Equilibrium Statistical Mechanics*, Prentice-Hall, 1968.
6. H. B. Callen, *Thermodynamics* (2nd edition), Wiley, 2005.

PH2193E OPTICS LAB

Pre-requisites: Nil

Total Practical Sessions: 39

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Apply the concepts of ray optics, electromagnetic theory, interference, diffraction and polarization to design
basic optical instruments.
CO2: Apply the concepts of interference and diffraction to gain the basics of optical instrumentations.
CO3: Apply the principles of polarization to develop different instruments based on polarizers.

List of Experiments:

1. Reflection, Refraction and Fresnel coefficients
2. Double refraction
3. Newtons rings
4. Michelson Interferometer
5. Mach–Zehnder interferometer
6. Fabrey-Perot interferometer
7. Diffraction experiments – Gratings, slits and apertures
8. Production and characterization of polarized light
9. Electro-Optic effect
10. Faraday Effect

References

1. F. L. Pedrotti and L. S. Pedrotti, *Introduction to Optics, Thrid Edition*, Cambridge University Press, 2017.
2. E. Hecht, *Optics*, Pearson Education, 2003.
3. A. Ghatak, *Optics*, Tata-McGraw-Hill, 2010.

PH3101E ATOMIC AND MOLECULAR PHYSICS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze one-electron atoms quantum mechanically in increasing levels of complexity starting from the coarse structure to fine and hyperfine structure.
CO2: Interpret the spectrum of one-electron atoms in static magnetic and electric fields.
CO3: Compute quantum mechanically the rates of absorption, stimulated emission, and spontaneous emission in one-electron atoms interacting with electromagnetic waves.
CO4: Compute the spectrum of simple many-electron atoms using central field approximation.
CO5: Analyze spectral properties of diatomic molecules using quantum mechanical treatment.

Single electron atoms - Spectrum and interaction with static electromagnetic fields
Schrodinger equation for one-electron atoms, eigenfunctions of bound states, expectation values and virial theorem - Fine structure of hydrogenic atoms, fine structure splitting - Lamb shift - hyperfine structure and isotope shifts, magnetic dipole and electric quadrupole hyperfine structure - Interaction of one-electron atoms with external electric and magnetic fields: linear and quadratic stark effect, Zeeman effect, Paschen-Back effect, anomalous Zeeman effect, quadratic Zeeman effect

Light-Matter Interactions
Charged particles in electromagnetic field - transition rates: absorption, stimulated emission, spontaneous emission, Dipole approximation, Einstein coefficients - selection rules - spin of photon, Beth’s experiment - line intensities and lifetimes of excited states - line shapes and width, pressure and Doppler broadening.

Multi-electron atoms
Two-electron atoms - spin wave functions - level scheme - independent particle model - many electron atoms - central field approximation - spin orbitals, slater determinants - Thomas Fermimodel of an atom

Molecular Physics
Molecular symmetry, rotational spectroscopy - vibrational spectroscopy - Raman spectroscopy - electronic spectroscopy of molecules - Frank-Condon principle - spin resonance spectroscopy.

References:

1. B. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules* (2^{nd} Edition), Pearson Education , 2004.

2. R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles* (2nd Edition), Wiley, 2006.

3. C. J. Foot, *Atomic Physics*, Oxford University Press, 2005.

4. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw Hill, 1994.

5. P. W. Atkins and R. S. Friedman, *Molecular Quantum Mechanics* (3rd Edition), Oxford University Press, 1997.

PH3102E COMPUTATIONAL PHYSICS

Pre-requisites: Nil

Total 26 Lecture Sessions + 39 Practical Sessions

L	T	P	O	C
2	0	3	7	4

Course Outcomes:

CO1: Acquire basic programming skills for solving complex physics and engineering problems.
CO2: Apply numerical methods for solving systems of linear, and non-linear equations relevant to physics and engineering.
CO3: Apply interpolation and curve fitting methods for analyzing and interpreting scientific data.
CO4**:** Implement numerical methods for evaluating integrals and solving ordinary differential equations relevant to physics and engineering problems.

Programming with Python/Matlab – basics, operators, controls – if-else, loops – for and while, arrays and matrices, functions, plotting and graphics, good programming practices, testing and debugging.

Roots of non-linear functions – bisection method, Newton-Raphson and secant method, convergence, applications to quantum mechanics - finite potential well, double well, etc.; Systems of linear equations – Gauss and Gauss-Jordan elimination, matrix inversion; Simultaneous non-linear equations – Newton-Raphson method, applications – nonlinear dynamics, electrical networks, etc.

Interpolation – Newton's interpolation, Lagrange interpolation; Regressions and curve fitting – general (weighted) least square fitting - linear and non-linear, continuous functions, and orthogonal polynomials.

Numerical integration – trapezoidal, Simpson's methods, errors and corrections, Romberg integration, adaptive step sizes; Ordinary differential equations – Euler's methods, Runge-Kutta methods, convergence, applications to classical and quantum mechanics.

List of Numerical experiments

1. Finding roots of non-linear equations – bisection, Newton-Raphson method, secant method
2. Linear Algebra and matrix methods – Solving linear equations (Gaussian elimination, Gauss-Jordan method etc.) and matrix eigenvalue problems.
3. Integration and methods – Trapezoidal rule and Simpsons' rule.
4. Solving ODE – Euler's method, Modified Eulers method, Runge-Kutta method.
5. Interpolation – Newton interpolation and Lagrange interpolation.
6. Least squares curve fitting.

References:

1. Paul DeVries and Javier Hasbun, *A First Course in Computational Physics* (2nd edition), Jones and Bartlett, 2010.
2. Tao Pang, *An Introduction to Computational Physics* (2nd edition), Cambridge University Press, 2006.
3. S. S. Shastry, *Introductory methods of numerical analysis* (3rd edition), Prentice-Hall of India, 2003.
4. Steven C. Chapra, *Applied Numerical Methods* (3rd edition), McGraw Hill, 2011.

PH3103E CONDENSED MATTER PHYSICS

Prerequisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	**0**	**0**	**6**	**3**

Course Outcomes:

CO1: Differentiate between different lattice types and explain the concepts of reciprocal lattice and crystal diffraction.
CO2: Distinguish different excitations in crystals and explain the specific heat.
CO3: Apply free electron model and interpret the properties of metals.
CO4: Explain the concept of energy bands and use it to find electrical properties of materials.

Crystal Physics-Classification of condensed matter-crystalline and noncrystalline solids. Bonding in solids - Ionic, covalent and metallic solids, the van der Waals interaction, hydrogen bonding. Crystal symmetry, point groups, space groups, lattices and basis, typical crystal structures, reciprocal lattice, Bragg's law of diffraction, X-ray, neutron, and electron diffraction.

Lattice Vibrations and Thermal Properties - Monoatomic and diatomic lattices, normal modes of lattice vibration, phonons and density of states, dispersion curves. Specific heat – classical, Einstein and Debye models. Thermal conductivity, normal and Umklapp processes.

Free Electron theory- Dependence of electron energy on the wave vector, E-k diagram. Free electron theory of metals- Thermal and Electrical transport properties, Electronic specific heat, Fermi surface. Failures of free electron theory.

Energy Band Theory- Energy spectra of atoms, molecules and solids, Bloch theorem. Nearly free electron model and origin of energy band. Construction of Brillouin zones, extended, reduced and periodic zone schemes. Kronig-Penny model, tight binding approximation. Motion of electrons in bands and effective mass.

References:

1. C. Kittel, *Introduction to Solid State Physics*, Wiley, 2007.
2. Ashcroft and Mermin, *Solid State Physics*, Thomson, 2007.
3. HaraldIbach and Hans Luth, *Solid State Physics*, Springer, 2009.
4. Ali Omar, *Elementary Solid State Physics*, Addison-Wesley, 2005.
5. Stephen Elliott, *The Physics and Chemistry of Solids*, John Wiley & Sons, 1998.

PH3191E SOLID STATE PHYSICS LAB

Pre-requisites: Nil

Total Practical Sessions: 39

L	T	P	O	C
0	0	3	3	2

Course Outcomes:
CO1: Apply principles of solid state physics to characterize materials
CO2: Set up experiments and measure physical quantities
CO3: Analyze experimental data, draw inferences and relate them with a suitable theory
CO4: Develop skills for group discussion and critical thinking for collaborative work

List of Experiments:

1. Measurement of specific heat capacity
2. Measurement of temperature coefficient of resistance
3. Study the variation of dielectric constant with temperature and determine the Curie temperature
4. Study the variation of junction voltage of a diode with temperature and determine the forbidden energy gap
5. Measurement of magnetic susceptibility by Quinck's tube method
6. Measurement of magnetic susceptibility by Gouy's balance method
7. Determine the Curie temperature of a given ferrite sample using magnetic hysteresis loop tracer experiment
8. Measurement of dielectric constant as a function of frequency
9. Hall effect at various temperatures
10. Study of magneto-resistance
11. Thin film deposition and characterization

A total of eight experiments to be done.

References:
1. Dieter K. Schroder, *Semiconductor Material and Device Characterization* (3rd Edition), Wiley, 2008.
2. C. Kittel, *Introduction to Solid State Physics*, Wiley, 2007.
3. Milton Ohring, *The Materials Science of Thin Films*, Academic Press, 1992.

PH3111E LASER PHYSICS AND APPLICATIONS

L	T	P	O	C
3	0	0	6	3

Pre-requisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Appreciate the multidisciplinary applications of lasers in science and engineering
CO2: Explain the operation principle of laser and distinguish between different line broadening mechanisms
CO3: Design stable optical laser cavities and predict performance
CO4: Develop continuous and pulsed laser system with various gain media and assess their appropriate uses

Light-matter interaction

Einstein's coefficients -- Optical gain-- Electron oscillator model-- Line broadening mechanisms and line shapes-- Homogeneous and inhomogeneous broadening-- Natural-- Doppler and collision broadening-- Pumping schemes- Laser rate equations: Two-level, Three-level, Four-level laser systems

Laser resonators

Plane mirror resonator -- Resonance frequencies, Cavity loss, Cavity lifetime-- Quality factor-- Spherical mirror resonators -- Ray paths in the resonator -- ABCD Matrices-- Cavity Stability criteria-- Optical cavity containing amplifying media-- Threshold population inversion-- Variation of laser power around threshold-- Optimum output coupling-- Continuous wave and transient laser operations: Q-switching, Techniques for Q-switching -- Mode-locking mechanism, Active and passive mode locking

Laser systems

Solid state Lasers: Ruby laser-- Nd-YAG and Nd-glass laser-- Titanium-Sapphire laser-- Atomic gas lasers: He-Ne laser-- Argon-ion laser-- Molecular gas laser-- CO_2 laser-- Liquid lasers-- Semiconductor laser-- Fiber laser-- Excimer laser-- Free electron laser-- Laser Safety: Safety standards and safety procedures

Applications of Lasers

Applications of lasers in Science and Industry-- Spatial frequency filtering-- Holography-- Laser induced fusion-- Laser energy requirements-- Energy confinement-- Pump-probe spectroscopy-- Laser isotope separation-- Harmonic generation-- Stimulated Raman emission-- Self-focusing -- Laser tracking – LiDAR -- Lasers in industries -- Application in material processing and electronics industry.

References:

1. K. Thyagarajan and A. Ghatak, *Lasers: Fundamentals and Applications* (2nd Edition), Springer, 2011.
2. W. T. Silfvast, *Laser Fundamentals*, Cambridge University press, (2nd Edition), 2004.
3. A. E. Siegman, *Lasers*, University Science Books Mill Valley, C. A., 1986.
4. A. Yariv, *Quantum Electronics* (2nd Edition), John Wiley and Sons, New York, 1989.

PH3112E NUCLEAR SCIENCE AND ENGINEERING

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Explain the properties of various nuclei and elementary particles by using various models
CO2: Apply ideas of quantum mechanics to analyse the radioactive decay of nuclei
CO3: Acquire the fundamentals skills of reactor design and safety
CO4: Identify the fusion process and design of thermonuclear reactor

Properties of Nuclei and Sub-Nuclear Physics
Nuclear radius - mass and binding energy, spin, parity, magnetic and electric moments - Nuclear Forces and its characteristics - Properties of deuteron - Nuclear Models: Semi-empirical mass formula, stability, binding energy, magic numbers - Fermi gas model - Liquid drop model - Shell model. Constituents of nucleons-quarks, Particle classifications - Leptons, Mesons, Baryons - Fundamental interactions and their relative strengths - Symmetries and conservation laws - Eightfold way and Quark Model - concept of colour charge and gluons

Nuclear Decays
General nuclear radioactive decay - alpha decay and barrier penetration - beta decay - Fermi’s theory - Kurie plot - parity violation in beta decay - Gamma decay - energetic of gamma decay - angular momentum and parity selection rules - Detection of nuclear radiation - Interactions of radiation with matter - counters and detectors.

Nuclear Fission and Reactor Design
Introduction and Mechanism - Spontaneous and neutron induced fission - Energy release - Fission chain reaction - Controlled fission reaction - Neutron reproduction factor - The four-factor formula - Fission reactors: Basic design - Power reactors - Research reactors – Converters - Breeder reactors - Neutron energy requirement - Type of fuel – Moderator - Heterogeneous and Homogeneous assembly - Coolant.

Nuclear Fusion and Fusion Reactor
Basic fusion process - Energy release, Coulomb barrier, Cross section - Solar fusion - Controlled fusion reactors - Plasma confinements: Lawson criterion - Tokamak method - International Thermonuclear Experimental Reactor (ITER) project.

References:

1. K. S. Krane, *Introductory Nuclear Physics*, John Wiely & Sons, 1988.
2. K. Heyde, *Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach* (3rd Edition), IOP publishing, 2004.
3. W. N. Cottingham and D. A. Greenwood, *An Introduction to Nuclear Physics* (2nd Edition), Cambridge University Press, 2001.
4. S. Glasstone and A. Sesonske, *Nuclear Reactor Engineering - Reactor Design Basics* (4th Edition) Vol. I, Chapman and Hall, 1994.
5. F. Halzen and A. D. Martin, *Quarks and Leptons* (2nd Edition), Wiley, 2008.
6. D. Griffths, *Introduction to Elementary Particles* (2nd Edition), Wiley, 2008.

PH3192E PROJECT

Pre-requisites: Nil

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Carry out literature review and collate information from multiple sources
CO2: Identify research gaps
CO3: Explain research findings in written/oral modes

The ‘Project’ course aims at introducing the students to various areas of research in Pure and Applied Physics. The students shall choose a topic in consultation with their guide(s), carry out extensive literature survey from books, journals and other sources and identify research gaps. The students shall carry out research work on identified problems. For the course evaluation, the student shall submit a written report as well as an oral presentation to a duly constituted committee.

PH4191E PROJECT/INTERNSHIP

Pre-requisites: Nil

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Identify research problems and carry out literature review
CO2: Analyze and research problems
CO3: Explain research findings in written and oral modes

The students, in consultation with their guide(s), shall identify a problem and carry out research work on it. The evaluation will be based on the internal evaluation by the guide, a written report documenting the work they have carried out and an oral presentation to a duly constituted committee. This project can be substituted by a Programme Elective course of equivalent credits.

PH4192E SUMMER INTERNSHIP

Pre-requisites: Nil

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Identify research problems and carry out literature review
CO2: Analyze and research problems
CO3: Document research findings and explain them in presentations

The Summer Internship shall preferably be done outside the institute in an industry or academic institution during the summer vacation after the sixth semester. If a student is unable to find a suitable internship outside the institute, the student can carry out the same with a chosen guide within the institute. The internship is to be evaluated during the seventh semester.

PH4193E PROJECT/INTERNSHIP

Pre-requisites: Nil

L	T	P	O	C
0	0	0	18	6

Course Outcomes:

CO1: Identify research problems and carry out literature review
CO2: Analyze and research problems
CO3: Document research findings and explain them in presentations

This part of the Project shall preferably be done as an internship in Industry / own Entrepreneurial venture / R&D organizations / other academic institutions of repute in India or abroad. Otherwise, this Project may be done in the institute; or substituted by Programme Elective courses of equivalent credits.

ELECTIVE COURSES: ENTREPRENEURSHIP AND INNOVATION

IE2001E INNOVATION AND ENTREPRENEURSHIP

Pre-requisites: Nil

L	T	P	0	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Taking up innovative projects and identifying novelty
CO2: Starting innovative practices in their entrepreneurial activities.
CO3: Involve themselves in the business activities like startups scientifically.
CO4: Understanding linking procedure and methods with other Institutions

Introduction to innovation and idea development: Introduction to Innovation, managing innovation, types of innovation, creativity, concept of design thinking, measuring innovation, Novelty -definition, identification-Protection of innovation - Introduction to Intellectual Property Rights – IPR, Patents, Trademarks, Copy Rights, grassroots innovation, Issues and Challenges in Commercialization of Technology Innovations.

Entrepreneurship basics – scope of entrepreneurship, characteristics of an entrepreneur, building a business, business plan, concept of lean canvas model, Entrepreneurship and Innovations, Converting Innovation to Economic Value - Growth Strategies, value proposition, Market Segments, Revenue Model, Social Entrepreneurship, Intrapreneurship.

Case studies- based on the area of specialization
Technology product development, Technology Life Cycle, how to implement and manage a technological innovation, new product development, managing the resources, technology business incubation, Sources of Information and schemes to support technology entrepreneurship.
Demonstration - based on the area of specialization

Functional areas of entrepreneurship - marketing management, operations management, personnel management, financial management, procedure and formalities in setting up an Industrial unit, Problems for Small Scale Enterprises and Industrial Sickness.
Site visits to understand the Entrepreneurship activities of startups.

References:

1. R. D. Hisrich and M. P. Peters, *Entrepreneurship* (8th Edition), Tata McGraw-Hill, 2013.
2. Holt David H., *Entrepreneurship: New Venture Creation*, Pearson Education, 2016.
3. Debasish Biswas and Chanchal Dey, *Entrepreneurship Development in India*, Taylor & Francis, 2021.
4. Tarek Khalil, *Management of Technology*, Tata McGraw-Hill.
5. B. R. Barringer, *Entrepreneurship: Successfully launching new ventures*, Pearson Education India, 2015.
6. Vasant Desai, *Small-Scale Industries and Entrepreneurship,* Himalaya Publishing House, Delhi, 2008.
7. Donald F. Kuratko, *Entrepreneurship: Theory, Process, Practice*, Cengage Learning India, Delhi, 2017.
8. Cynthia L. Greene, *Entrepreneurship Ideas in Action,* Thomson Asia Pvt. Ltd., Singapore. 2004.

ELECTIVE COURSES: CONDENSED MATTER PHSICS

PH3123E TOPICS IN CONDENSED MATTER PHYSICS

Prerequisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply band theory to materials and analyze the properties of semiconductors.
CO2: Analyze the dielectric properties of materials and the physics of ferroelectricity.
CO3: Apply the quantum mechanical model to analyze the magnetic properties of materials.
CO4: Analyze the superconductivity in materials and evaluate its potential applications.

Semiconductors-Brief overview of band theory, Intrinsic and extrinsic semiconductors, Charge carrier density in intrinsic semiconductors, Doping, Carrier densities in doped semiconductors. Concept of effective mass. Effective mass of electron and hole in semiconductors, Hall effect measurement.

Dielectric properties- dielectric constant and polarizability, local electric field, Clausius-Mossotti equation, Classical theory of dipolar polarizability, ionic polarizability, electronic polarizability. Optical properties of solids. Ferroelectricity, ferroelectric domains, multiferroics.

Magnetism-exchange interaction, diamagnetism, paramagnetism, ferromagnetism and anti-ferromagnetism. Langevin's classical theory of diamagnetism, Quantum theory of diamagnetism and paramagnetism, Hund's rules. Pauli paramagnetism. Heisenberg model, mean field theory, spin waves, giant and colossal magnetoresistance.

Superconductivity- Basic properties of the superconducting state, Meissner effect, critical field. London equation – Type I and II superconductor. Isotope effect, Penetration depth, Coherence length, Thermodynamics of superconducting transition, superconducting band gap. concept of Ginzburg landau theory Cooper pairs, BCS theory (qualitative), flux quantization, Josephson effect, SQUID, High temperature superconductors. Applications- Magnetic Shielding, Power Transmission and Medical Applications.

References:

1. C. Kittel, *Introduction to Solid State Physics*, Wiley, 2007.
2. Ashcroft and Mermin, *Solid state Physics*, Thomson, 2007.
3. HaraldIbach and Hans Luth, *Solid State Physics*, Springer, 2009.
4. Michael Tinkham, *Introduction to superconductivity* (2^{nd} Edition), Dover Books, 2004.
5. J. Robert Schrieffer, *Theory of Superconductivity*, CRC Press, 1964.
6. T. V. Ramakrishnan and C. N. R. Rao, *Superconductivity Today*, Wiley, 1992.

PH3128E THIN FILM TECHNOLOGY

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Choose and apply appropriate vacuum techniques for thin film deposition and characterizations.

CO2: Analyze the merits and demerits of PVD and CVD techniques and motivate the selection of deposition techniques for various thin film applications.

CO3: Evaluate and use models for nucleation and growth of thin films.

CO4: Apply different characterization techniques to analyze the physical properties of thin films and assess the relationship between deposition techniques and film properties.

Vacuum Science and Technology

The necessity of vacuum, classification of vacuum ranges, gas transport and pumping in vacuum systems, conductance and pumping speed – Production of vacuum, rotary vane pumps, diffusion pump and turbo molecular pump, sorption pump, ion pump, cryopump, titanium sublimation pump – Operation of high vacuum and ultrahigh vacuum (UHV) system – Pressure measurement, capacitance gauge, thermocouple gauge, pirani gauge, cold cathode and hot cathode ionization gauges, Bayard-Alpert gauge, gauge calibration, pressure variation with respect to gauge location – Vacuum materials and components, leak detection.

Physical Vapor Deposition Techniques

Physical vapor deposition techniques – Thermal evaporation, theory of evaporation, cosine law, evaporation system, problems in evaporation of alloys/compounds, evaporation sources, resistance/induction heating sources, e-beam evaporation, molecular beam epitaxy (MBE) – Pulsed laser deposition (PLD), modeling of PLD process, large area PLD – Sputtering, physics of sputtering, classifications of sputtering, DC, RF, reactive, and magnetron – Hybrid PVD Processes, ion plating, activated reactive evaporation (ARE), ionized cluster beam deposition (ICB), ion beam assisted deposition (IBAD).

Chemical Vapor Deposition Techniques

Chemical vapor deposition techniques, mechanism, process, chemistry of CVD, reaction types – Thermodynamics of CVD, Gas transport and kinetics of CVD – Classifications of CVD, atmospheric pressure CVD (APCVD), low pressure CVD (LPCVD), plasma Enhanced CVD (PECVD), hot Filament CVD (HFCVD), metal organic CVD (MOCVD), atomic layer deposition (ALD) – Design of CVD reactors, uniform deposition on the interior surfaces and complex geometries, large area deposition.

Characterization of Thin Films

Capillarity theory, atomistic nucleation process, cluster coalescence and depletion, thin film nucleation and growth, grain structure of thin films – Characterizations, Thickness measurements, *in-situ* crystal thickness monitor, *ex-situ* surface profilometer, optical techniques, cross-sectional scanning electron microscopy – Electrical transport measurements, linear probe resistivity, Van-der-Pauw resistivity, Hall effect – Mechanical properties, hardness, adhesion, residual stresses, porosity – Compositional analysis, energy dispersive x-ray spectroscopy(EDXS), x-ray photoelectron spectroscopy (XPS).

References:

1. Milton Ohring, *The Materials Science of Thin Films,* Academic Press, 1992.
2. Donald L. Smith, *Thin Film Deposition: Principles and Practice,* McGraw Hill, 1995.
3. K. L. Chopra, *Thin Film Phenomena*, McGraw Hill, 1969.
4. V. V. Rao, T. B. Ghosh and K. L. Chopra, *Vacuum Science and Technology*, Allied Publishers Limited, 1998.
5. Leon I. Maissel and Reinhard Glang, *Handbook of Thin Film Technology*, McGraw Hill, 1969.

PH3131E EXPERIMENTAL TECHNIQUES IN PHYSICS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyses of IR and Raman data using the basic principle of vibrational spectroscopy.
CO2: Analyses of the resonance spectroscopy and photoelectron spectroscopy data.
CO3: Understand the basic operation principle of optical microscopy and its design.
CO4: Understand the principle of operation of electron microscopy and the interpretation of data.

Infrared and Raman Spectroscopy
Infra-red spectroscopy, vibrations of polyatomic molecules, normal modes of vibration in crystals, isotope effect, Fourier transform IR, IR spectrophotometer, analysis of IR spectrum – Raman Spectroscopy, theory of Raman scattering, rule of mutual exclusion principle, Resonance Raman scattering, major components of Raman spectrometer, sampling handling techniques, fluorescence problems, Raman microscopy, analysis of Raman data.

Electron Spectroscopy
Electronic spectroscopy of molecules, photoluminescence spectroscopy – Nuclear magnetic resonance spectroscopy, resonance condition, NMR instrumentation, relaxation systems – Electron spin resonance spectroscopy principle, ESR spectrometer, hyperfine structure, ENDOR – Surface spectroscopy, photoelectron spectroscopy, instrumentation, analysis of XPS/UPS data.

Optical Microscopy
Optical imaging and microscopy, basic optical microscope, finite tube length microscopes, infinity corrected microscopes, Kohler illumination, critical illumination – Bright field microscopy, dark field microscopy, phase-contrast microscopy, confocal microscopy.

Electron Microscopy
Scanning electron microscopy (SEM), BSE and SE image formation, SEM image interpretation, energy dispersive x-ray spectrum – Transmission electron microscopy (TEM), modes of operation of a TEM, SAED, z-contrast imaging – Scanning tunneling microscopy (STM), principle of operation – Atomic force microscopy (AFM), modes of operation of AFM.

References:

1. Colin Banwell and Elaine Mccash, *Fundamentals of Molecular Spectroscopy* (4^{th} Edition), McGraw Hill Education, 2017.
2. John Ferraro, *Introductory Raman Spectroscopy*, Academic Press, 1994.
3. Peter Larkin, *Infrared and Raman Spectroscopy Principles and Spectral Interpretation*, Elsevier, 2011.
4. Jan Toporski, Thomas Dieing and Olaf Hollricher, *Confocal Raman Microscopy*, Springer Cham, 2018.
5. Douglas B. Murphy and Michael W. Davidson, *Fundamentals of Light Microscopy and Electronic Imaging* (2^{nd} Edition), Wiley-Blackwell, 2013.
6. Tomasz S. Tkazyk, *Field Guide to Microscopy*, SPIE Press Bellingam, USA, 2010.
7. Joseph I. Goldstein, Dale E. Newbury, Joseph R. Michael, Nicholas W.M. Ritchie, John Henry J. Scott, and David C. Joy, *Scanning Electron Microscopy and X-Ray Microanalysis*, Springer, 2018.
8. Brent Fultz James and M. Howe, *Transmission Electron Microscopy and Diffractometry of Materials*, Springer Nature, 2013.

PH4127E SOLID STATE DEVICES

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Apply the principles of condensed matter physics to understand the structural and electrical properties of semiconductor materials.
CO2: Analyze the behavior of semiconductor-semiconductor and metal-semiconductor junctions under different bias conditions.
CO3: Describe the physics of various semiconductor devices such as BJT, JFET, MESFET and MOSFET.

Brief overview of semiconductor materials - charge carrier statistics, Basic structure of the p-n junction- thermal equilibrium condition - built in potential barrier - depletion region - the space charge width and electric field - DC forward and reverse characteristics - depletion capacitance and storage capacitance – current - voltage characteristics - junction breakdown mechanisms. Open circuited - step - graded junctions. Small-signal equivalent circuit. Metal semiconductor contacts- Ohmic contacts - Schottky barriers - rectifying contacts. Comparison of the Schottky barrier diode with p-n junction diode.

Fundamentals of bipolar junction transistor (BJT) operation - charge carrier distribution in each region - different modes of operation - transistor action and amplification - frequency response and switching of bipolar transistors.

Basic operation of p-n junction field-effect transistor (JFET) and metal-semiconductor field-effect transistor (MESFET) - fundamentals of metal oxide semiconductor field-effect transistor (MOSFET) -the two terminal MOS structure – energy band diagram - MOS capacitor - concept of accumulation - depletion and inversion - four terminal structure - MOSFET - I-V characteristics - brief introduction to MOS scaling - types of MOSFETS – depletion and enhancement type - NMOS and CMOS - power MOSFET construction - differences between a MOSFET and a BJT.

References:

1. S. M. Sze, *Semiconductor Devices: Physics and Technology*, John Wiley and Sons, 2002.
2. Ben G. Streetman and Sanjay Benerjee, *Solid State Electronic Devices***,** Pearson Education, 2002.
3. Donald A Neaman, *Semiconductor Physics and Devices*, McGraw Hill, 2003.
4. A. S. Sedra and K. C. Smith, *Microelectronic Circuits* (2nd Edition), Holt, Rinehart and Winston, 1987.

PH4128E PHYSICS OF NANOSTRUCTURES AND NANOSCALE DEVICES

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Analyze and correlate characteristic length and time scales of mesoscopic systems
CO2: Identify the principles of quantum confinement and calculate the energy levels for elementary quantum confined geometries
CO3: Identify the principles and design of epitaxial growth techniques
CO4: Analyze the physics and model the operation of different semiconductor heterojunction devices

Characteristic length scales
Review of basic quantum mechanics and solid state physics- bulk semiconductor physics- macroscopic-mesoscopic physics- classification based on characteristic length scales- size quantization- quantum confinement in solid-state systems- semiconductor homojunctions and heterojunctions- crystal growth techniques – Molecular Beam Epitaxy (MBE) and Metal-Organic Chemical Vapor Deposition (MOCVD)- characterization of semiconductor multilayers- semiconductor heterostructures- band engineering- layered structures- quantum wells and barriers—super lattices

Nanoscale Probes
Scanning electron microscopy (SEM) and transmission electron microscopy (TEM)- scanning probe microscopy – STM- AFM and NSOM- fabrication - lithography and pattern transfer- nanoimprint technologies- etching – wet and dry chemical etching. Ion implantation- metallization- dielectric deposition- selected area growth and overgrowth

Low-dimensional structures
Dimensionality – 2D- 1D and 0D structures- quantum wells – infinitely deep square well- square well of finite depth- parabolic well- occupation of sub-bands- modulation doping- optical properties of semiconductor quantum wells- semiconductor superlattices- formation of minibands- 1D and 0D structures (quantum wires and quantum dots)- practical realizations

Optoelectronic devices based on semiconductor nanostructures
Lasers- modulators- detectors and solar devices - basic principles of double-heterojunction semiconductor lasers- single and multiple quantum well lasers- Vertical Cavity Surface Emitting Lasers (VCSELs)- quantum wire and quantum-dot lasers- quantum well optical modulators- photodetectors- Quantum Well Infrared Photodetectors (QWIPs)

References:

1. M. J. Kelly, *Low-dimensional Semiconductors: Materials, Physics, Technology, Devices* (1st Edition), Oxford University Press, 1995.
2. J. H. Davies, *Physics of Low-Dimensional Semiconductors* (1st Edition), Cambridge University Press, 1998.
3. J. Singh, *Semiconductor Devices, Basic Principles* (1st Edition), John Wiley & Sons Inc., 2001.

4. M. Jaros, *Physics and Applications of Semiconductor Microstructures* (1st Edition), Oxford University Press, 1989.

PH4129E LITHOGRAPHY TECHNIQUES

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Choose and apply appropriate lithography techniques for micro/nano fabrication.
CO2: Analyze the merits and demerits of masked lithography techniques.
CO3: Analyze the merits and demerits of direct lithography techniques.
CO4: Evaluate different lithography techniques and their process flow for specific device applications.

Lithography Techniques
Micro/nano fabrication, top-down approach, bottom-up approach – Clean room, necessity, types of clean room, construction and maintenance of clean room, clean room standards, protocols – Lithography, process steps, photoresists, spin coating, exposure, chemical development, optimization, etching methods, dry and wet methods – Types of lithography, differences, replication tools, next generation lithography tools.

Masked lithography
Optical (photo) lithography, optical lithography mask, different light sources, contact and proximity exposures, diffraction limit and resolutions enhancement methods, projection lithography – EUV lithography, dose calculation, interferometric and holographic tools, lithography masks, laser writer, synchrotron radiation for lithography processes, x-ray lithography mask, merits and demerits – Comparison of all masked lithography tools and various applications.

Direct lithography- Electron beam lithography
Maskless lithography, differences between masked and maskless, advantages and disadvantages – Principles of electron beam lithography system, electron properties, design of electron beam lithography system, operation of electron beam lithography system – e-beam resists, resist properties, comparison with optical lithography resists, dose calculation, beam scanning – Nanofabrication with EBL for NEMS applications, nanofabrication with EBL for nanofluidics applications.

Direct lithography- using ion beams
Ion beam lithography (IBL) types, focused ion beam properties, beam scanning, resists for ion beam lithography, process flow – Focused ion beam lithography, incident ion properties, principle, design and operation, masked ion beam structuring, broad beam patterning, atom lithography, applications of ion beam lithography, nanofabrication with IBL for nanofluidics applications – Micro/nano replications tools, necessity, MEMS/NEMS, micro/nano fluidics, soft lithography, PDMS casting, hot embossing, micro injection and nano imprinting, replication tools, principles, process flow and requirements, polymers for imprinting, characteristics and performance, master mold preparation for replication tools

References:

1. Stefan Landis, *Nano Lithography*, Wiley, 2011.
2. David G. Bucknail, *Nanolithography and Patterning Techniques in Microelectronics*, CRC Press, 2005.
3. Chris A. Mack, *Fundamental Principles of Optical Lithography: The Science of Microfabrication*, John Wiley & Sons, London 2007.
4. P. Rai Choudhary, *Handbook of Microlithography, Micromachining and Microfabrication*, SPIE Press, Technology & Engineering, 1997.

5. Cabrini and Satoshi Kawata, *Nanofabrication Handbook*, CRC Press, Taylor and Francis, 2012.
6. Harry. J. Levinson and W.R. Fahrner, *Principles of Lithography*, International Society for Optical Engineering, 2005.
7. Stefan Landis, *Lithography and Nanolithography*, Wiley – ISTE, 2010.

PH4131E SEMICONDUCTOR PHYSICS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Choose and apply the knowledge of basic semiconductor physics for device fabrication.
CO2: Evaluate the carrier statistics in intrinsic and extrinsic semiconductor materials.
CO3: Analyze the carrier transport mechanism in semiconductor devices.
CO4: Assess the technological challenges in nanostructured devices.

Semiconductor Materials and their Properties
Crystalline and amorphous, inorganic and organic, elemental and compound semiconductors – Preparation and characteristics. band structural aspects, effects of temperature and electric field on the band structure, Franz Keldysh effect – Localized states of impurities, theoretical models and experimental probes, capacitive and spectroscopic techniques – Optical properties, allowed and forbidden, phonon-assisted transitions and their spectral shapes – Burstein Moss effect, excitons, free and bound excitons.

Carrier Statistics
Statistical thermodynamics of carriers, Fermi level in intrinsic and doped materials, Non-stoichiometric semiconductors, role of structural defects, heavy doping and degeneracy, electrical conductivity, rally effect, two-band model – Mobility of carriers, mechanisms of scattering, measurement of mobility, recombination processes, Boltzmann equation for electron transport, equilibrium and non-equilibrium processes – Effective masses and their measurement, cyclotron resonance – Thermoelectric power, magneto resistivity, hot electron effects, microwave generation.

Carrier Transport
Metal-semiconductor contacts, Schottky barrier – p-n junctions, theory of carrier transport in p-n junctions, characteristics of practical junctions and deviations from ideality, capacitance effects, space charge and diffusion capacitances, impurity profiling through capacitance measurements – Tunnel diode and applications, photoconductivity, role of traps and recombination, photovoltaic devices for solar cells and radiation detection, luminescence, light emitting diodes and laser action in p-n junction diodes.

Nanostructures
Surface states, band bending and effect on bulk properties – Thin film structures, low-dimensional semiconductors, quantum wells, multiple quantum well structures, quantum dot structures – Methods of preparation, special characteristics and devices based on quantum wells, quantum Hall effect, high electron mobility transistor.

References:

1. R. A. Smith, *Semiconductors*, Academic Publishers, Calcutta, 1989.
2. R. F. Pierret. *Advanced Semiconductor Fundamentals*, Addison-Wesley, 1989.
3. M. Shur, *Physics of Semiconductor Devices*, Prentice Hall, 1990.
4. S. M. Sze, *Physics of Semiconductor Devices* (2^{nd} Edition), Wiley Eastern, 1991.
5. G. C. Jain and W. B. Berry, *Transport Properties of Solids and Energy Conversion*, Tata McGraw-Hill, 1972.
6. W. C. Dunlop, *An Introduction to Semiconductors*, Wiley, 1957.
7. W. Shockley, *Electrons and Holes in Semiconductors*, D. Van Nostrand, 1950.

PH4133E SOFT MATTER

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Evaluate molecular level interactions in soft matter systems and characterize macroscopic behavior in confined/unconfined space.
CO2: Apply colloidal physics to analyze self-assembly in colloids and their applications in practice
CO3: Design suitable interfaces/surfaces for specific soft matter applications
CO4: Analyze the structure and dynamics of polymers, and various biological soft matter systems.

Introduction to soft matter systems

Intermolecular interactions – Structural parameters – Free energy of solutions - Phase transitions – Viscous, elastic and viscoelastic behavior – Rheology and micro rheology – Methods and Instruments

Colloids

Colloidal particle in a liquid – Stokes-Einstein equation – Forces between colloidal particles – Colloidal stability – Characterization of colloids – Self-assembly - Different types of colloids and their applications – Sols – Gels – Foams – Emulsions – Food colloids

Interfaces and surfactants

Types of interfaces – Surface tension – Laplace pressure - Wetting phenomena – Three-phase contact line and spreading factor – Droplets and bubbles – Capillary interactions - Characteristics of surfactants – Adsorption of surfactants at the interfaces – Aggregation behavior of surfactants - Applications of surfactants – Wetting at soft interfaces

Polymers and biological soft matter

Structure and conformation of polymers – Lattice models – Dynamics of polymer solutions – Viscoelastic properties – Bio soft matter – Cells – Nucleic acids – Proteins – Vesicles – Membranes

References:

1. Masao Doi, *Soft Matter Physics*, Oxford University Press, 2013.
2. Richard AL Johns, *Soft Condensed Matter*, Oxford University Press, 2002.
3. Pierre-Gilles Gennes, Françoise Brochard-Wyart, David Quéré and Pierre-Gilles Gennes, *Capillarity and Wetting Phenomena*, Springer, 2004.
4. Milton J. Rosen, *Surfactants and Interfacial Phenomena*, John Wiley & Sons, 2004.

ELECTIVE COURSES: OPTICS AND PHOTONICS

PH3125E FIBER OPTIC COMMUNICATION AND SENSORS

Pre-requisites: Nil

Total 26 Lecture Sessions + 26 Practical Sessions

L	T	P	O	C
2	0	2	5	3

Course outcomes:

CO1: Demonstrate and apply the concepts of ray optics and wave optics for transmission properties of an optical fiber.

CO2: Apply the principles of optical sources, detectors and power launching-coupling methods for designing fiber networks.

CO3: Analyze the propagation characteristics and estimate the losses in different types of optical fiber communication systems.

CO4: Design of fiber optic measurement systems and sensors.

Optical Fiber Waveguides

Optical fiber wave guide – Ray theory of transmission – Electromagnetic mode theory – Modes – Step index fibers and graded index fibers – Cut off wavelength – Effective refractive index – Bandwidth – Power flow – Mode Coupling – Fiber materials – Fabrication of optical fibers – Optical fiber cables design.

Transmission characteristics and applications

Transmission loss of fiber (attenuation) – Material absorption loss – Linear and nonlinear scattering losses – Dispersion – Intramodal and intermodal dispersion – Dispersion modified single mode fibers – Optical fiber connection –Different types of semiconductor detectors — Light Sources – Multiplexers and Amplifiers – Fiber optics communication systems – Fiber optics sensors – Distributed sensors in gas and oil industry – Biomechanical and Chemical Sensors.

Fiber optics experiments

1. Measurement of Numerical Aperture
2. Optical fiber coupling
3. Optical fiber transmission loss
4. Optical fiber temperature sensing
5. Optical fiber pressure sensing

References:

1. Gerd Kaiser, *Fiber Optic Communication*, Springer, 2021.
2. Ajoy Ghatak and K. Thygarajan, *An introduction to fiber optics*, Cambridge University Press, 2017.
3. John M. Senior, *Optical fiber communication- Principles and practice*, Prentice Hall of India Pvt. Limited, 2009.
4. Igantio Del Villar and Igantio Del Matias, *Optical Fibre Sensors*, Wiley-IEEE Press, 2020.

PH3127E OPTICAL INSTRUMENTATION AND METROLOGY

Pre-requisite: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course outcomes:
CO1: Apply the concepts of ray optics, wave optics and polarization to develop optical devices.
CO2: Apply the concepts of optoelectronic devices to select various optoelectronic components for optical devices.
CO3: Design various optical measurement techniques and optomechanical systems.
CO4: Apply signal processing tools for various optical systems.

Foundations of optics
Geometrical optics – Aberrations – Dispersion – Interference – Coherence and its measurement – Optical thin film – Diffraction – Resolution of optical instruments – Spatial frequency filtering – Point spread function engineering – Grating – Polarizers

Optoelectronic components
Principles and operations of light sources – LEDs and lasers – Principles and operation of detectors – Photoconductors – PN, PIN and Avalanche detectors – Photomultipliers – IR detectors – CCD and CMOS cameras – Noise and sensitivity of detectors – Spatial light modulators – Acousto-optic modulators – Pockel's readout optical modulators – Liquid crystal light valves

Optomechanical and Optical instrumentation
Opto-Mechanical Characteristics of Materials – Design and mounting of lenses, mirrors, prisms and gratings – Mounting of multiple lenses – Designing optical instruments – Telescopes and microscopes – Different types of microscopes: Design, working and applications - Design of Spectrometers – Design and applications of interferometers – Michelson and Mach-Zehnder interferometers – Applications in Fiber optics

Measurement techniques and Signal processing
Ellipsometry – Profilometry – Straightness and Alignment – Moiré Metrology – Flow visualization – Particle Image Velocimetry – Signal processing – Optical system under coherent and incoherent illumination – Spatial filter – Joint transform correlator – White-light optical signal processing – Hybrid optical signal processing

References:

1. Stephen Rolt, *Optical Engineering Science*, John Wiley and Sons LTD, 2020.
2. Lukas Novotny and bert Hecht, *Principles of Nano-Optics*, *Cambridge University Press*, 2012.
3. Robert E. Fischer, Biljana Tadic-Galeb and Paul R. Yoder, *Optical System Design*, The McGraw-Hill Companies, 2008.
4. FTS Yu and X. Yang, *Introduction to Optical Engineering*, Cambridge Uni. Press, 1997.
5. Toru Yoshizawa, *Handbook of Optical Metrology* (2^{nd} Edition), CRC Press, 2017.

PH3130E LASER TECHNOLOGY AND QUANTUM OPTICS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Explore the emerging laser technologies and nonlinear optical effects with lasers
CO2: Analyze light propagation in periodic structures.
CO3: Realize and Design photonic crystal-based optical elements
CO4: Develop a quantum picture of light and explore quantum optical phenomena.

Lasers

Einstein's theory of light-matter interaction -- Laser rate equations – Stable resonators for laser – Controlling lasing modes -- Ultrafast pulse generation -- Fiber laser -- Free electron laser – Quantum cascade laser – Laser micromachining – Laser based LiDAR technology for self-driving cars -- Laser communication in space science.

Nonlinear Optics

Interaction of intense laser with matter-nonlinear optics–Nonlinear medium–Wave equation for nonlinear optical
media–Second and third harmonic generation–Phase matching–Frequency mixing–Electrooptic effects, Pockels effect, Kerr effect, Faraday effect, and Acousto optic effect–Optical phase conjugation.

Light in Periodic Structures and Photonic Crystals

Theory of multilayer films–Propagation of electromagnetic waves through periodic structure–Transfer matrix methods–Reflectance at the normal incidence–Two and three-layer antireflection films–High reflectance layer, Bragg reflectors–Photonic Crystals, one-dimensional photonic crystals, the physical origin of the photonic band gap, Two and three-dimensional photonic crystal–Defect in photonic crystals–localization of light–point defect and linear defect–Cavities and waveguides–Beam splitters and other applications.

Quantum Optics

Quantization of free electromagnetic field–Fock States–Vacuum fluctuations–Quantum Beats–Quantum eraser–Bell's theorem–Coherent States and their properties– Squeezed states–Highlights of photon-photon interferometry and photon detection.

References:

1. F. Légaré, *Emerging Laser Technologies for High-power and Ultrafast Science*, IOP Publishing, 2021.
2. O. Svelto, *Principles of Lasers* (5th Edition), Springer US, 2016.
3. P. W. Milonni and J. H. Eberly, *Laser Physics*, John Wiley & Sons Inc. NJ, 2010.
4. Dipankar Bhattacharyya and Jyotirmoy Guha, *Quantum optics and quantum computation,* IOP Publishing Ltd., 2022.
5. R. W. Boyd, *Nonlinear Optics* (3rd Edition), Academic Press Inc., 2008.
6. Amnon Yariv and Pochi Yen, *Photonics*, Oxford University Press New York, 2007.
7. John D Joannapoulos, Steven G Johnson, Joshua N Winn and Robert D Meade., *Photonic crystals Molding the flow of light*, Princeton University Press, 2008.
8. M. O. Scully and M. S. Zubairy, *Quantum Optics*, Cambridge University Press, Cambridge,1997.

PH4123E LIGHT-MATTER INTERACTION IN RESONATORS

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply quantum mechanical perturbation theory to estimate the Einstein's coefficients
CO2: Apply Maxwell's equations to design optical resonators
CO3: Design optical resonators to realize weak/strong light-matter coupling
CO4: Implementation of ultrastrong coupling using intersubband transitions in quantum wells

Resonant light-atom interactions
Atoms in free-space-- the two-level atom approximation-- the weak-field limit – Einstein's coefficients-- The strong-field limit – Rabi oscillations-- Basic concepts-- Damping-- Experimental observations of Rabi oscillations.

Atoms in cavities
Optical cavities- Atom-cavity coupling- Weak-coupling- Free space spontaneous emission- Spontaneous emission in a single-mode cavity - the Purcell effect- Experimental demonstrations of the Purcell effect- Strong coupling- Cavity quantum electrodynamics- Experimental observations of strong coupling- Applications of cavity effects.

Light-matter interactions in solid-state systems
Semiconductors- excitons in bulk and quantum wells- Molecular Beam Epitaxy- semiconductor microcavities- Photonic crystal nanocavities- Weak coupling regime in excitonic systems- Strong coupling regime and formation of cavity polaritons. Experimental demonstration of Rabi oscillations and Rabi splitting.

Intersubband cavity polaritonics
Intersubband transitions in quantum wells- intersubband excitations- Dipole selection rule- intersubband resonators- intersubband cavity polaritons- External control of intersubband polaritons- the ultra-strong coupling regime of light-matter interaction- Experimental demonstration of the ultrastrong coupling regime.

References:

1. Mark Fox, *Low-dimensional Semiconductors: Materials, Physics, Technology, Devices* (1st Edition), Oxford University Press, 2006.
2. Benoit Deveaud, *Physics of Low-Dimensional Semiconductors* (1st Edition), Wiley-VCH GmbH & Co, 2007.
3. A. V. Kavokin, and J. J. Baumberg, *Microcavities* (1st Edition), Oxford University Press, 2007.
4. R. Paiella, *Intersubband Transitions in Quantum Structures* (1st Edition), McGraw-Hill Companies, 2006.

PH4134E OPTICS AND PHOTONICS WORKSHOP

Pre-requisites: Nil

L	T	P	O	C
2	0	2	5	3

Total 26 Lectures Sessions + 26 Practical Sessions

Course Outcomes:
CO1: Apply the principles of optics and lasers to develop optical measurement techniques.
CO2: Apply the concept of signal communication to develop fibre optic based optical communication systems.
CO3: Employ different fibre optic components for light manipulation and amplification.
CO4: Apply the concept of spectroscopy to analyse some real systems.

Gaussian beams – Beam expanders and collimators – Spatial filtering with pinhole – Gaussian beam profile measurement – Dual beam interferometers (circular and wedge fringes) – Fringe projection – Thickness measurement and Surface profiling – Optical Tweezers – Imaging.
Light launching to an optical fibre – Fibre coupler based devices for light manipulation – Fibre connectors – Fibre optic amplifier – Amplifier properties – advantages – applications – Optical signal transmission and reception – Signal distortions in an optical communication system -- Effects of noise in optical communication.
UV-Vis Spectroscopy-Nature of Electronic Transitions-Principles of Absorption Spectroscopy- Spectral Measurements- Brief Instrumentations-Applications-Raman Spectroscopy-Principle-Classical and Quantum Theory-Selection Rules-Spectral Measurements- Brief Instrumentations-Applications

Practical session:
1. Profiling of a magnified, collimated and spatially filtered Gaussian beam.
   Aim: Design and implement Gaussian beam collimator with frequency filtering for a specific magnification, and record the intensity profile using photodetectors. Study the effect of the spatial filter diameter on the output profile.
2. Surface topography of a sample using fringe projection technique
   Aim: Extract surface topography of the given sample using the line fringes from the suitable designed Mach-Zehnder interferometer. Compare the experimentally obtained data with ray optics simulation.
3. Optical communication
   Aim: Establish a free-space analogue audio frequency signal communication system. Develop a fibre optic based video transmission system. Estimate the range of these optical communication systems and the effect of ambient noise.
4. Optical fiber amplifier
   Aim: Employ a fiber optic based amplifier for optical signal amplification. Evaluate the amplification factor and small signal gain of the amplifier.
5. Manipulation of light propagation in optical fiber
   Aim: Manipulate light using different fiber optic components: Light splitter, Wavelength division multiplexer, Variable intensity attenuator, Optical switch, and Optical isolator.
6. UV-Vis absorption spectra of dye and its pH dependence.
7. Raman spectra of benzene and its derivatives.

References:

1. F. L. Pedrotti and L. S. Pedrotti, *Introduction to Optics* (3rd Edition), Cambridge University Press, 2017.
2. Gerd Kaiser, *Fiber Optic Communication*, Springer, 2021.
3. Igantio Del Villar and Igantio Del Matias, *Optical Fiber Sensors*, Wiley-IEEE Press, 2020.
4. A. Ghatak and K. *Thyagarajan, Introduction to Fiber Optics*, Cambridge University Press, New Delhi, 2011.
5. Colin N. Banwell and Elaine M. McCash, *Fundamentals of molecular spectroscopy*, Tata McGraw-Hill, 1994.

PH4137E LIGHTWAVE TECHNOLOGY WITH METAMATERIALS

Prerequisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explore electrodynamics of negative index medium.
CO2: Design metamaterials starting from permittivity and permeability negative media and realize double negative metamaterials for microwave, terahertz, and optical regimes.
CO3: Apply parameter retrieval methods to extract constitutive parameters of metamaterials.
CO4: Realize various kinds of lightwave technology metasurfaces including chiral metasurfaces, spatially modulated digital metasurfaces, and time-modulated metasurfaces.
CO5: Design cloaking-invisibility devices, electromagnetic wave transformers, and energy concentrators using the coordinate transformation method.

Electrodynamics of Negative Index Medium

Negative index medium: Veselago’s proposals–Wave propagation in left-handed media–Energy density and group velocity–Negative refraction–Modified Snell’s law–Double Focusing–Flat lens–Inverse Doppler Shift–Backward Cerenkov radiation–Negative Goos-Hänchen shift–Losses and dispersion-Indefinite media and their examples.

Realization of Metamaterials

Realization of bulk metamaterials–negative permittivity medium, thin wire structure, and electric plasmas–negative permeability medium, Split Ring Resonators (SRR) and magnetic plasmas–Types of SRRs–Realization of negative index medium–Parameters Retrieval Procedure and Effective parameters–Homogenization procedure–3-D metamaterials.

Lightwave Technology with Metasurfaces

Metasurfaces–Electric and magnetic dipole interactions–Chiral metasurface–Optical activity and circular dichroism–Bianisotropy in metasurfaces and various new polarization phenomena–Perfect absorber–Flat lens design–Zero-refractive index Metasurface–Dielectric metasurfaces–Concepts of spatial and time-modulated metasurfaces.

Transformation Optics

Coordinate transformation method and transformation optics–Cloaking and invisibility devices–Electromagnetic energy concentrators and illusion optics techniques using metamaterials.

References:

1. S. Kar, *Metamaterials and Metasurfaces, Basics and Trends*, IOP Publishing Ltd., 2023.
2. W. Zhu, and A.-Q. Liu, *Metasurfaces: Towards Tunable and Reconfigurable Meta-devices*, Springer, 2023.
3. S. Anantha Ramakrishna and Tomasz M. Grzegorczyk, *Physics and Applications of Negative Refractive Index Materials*, SPIE and CRC Press, Taylor and Francis Group, Bellingham, Washington USA, 2009.
4. Ricardo Marques, Ferran Martin and Mario Sorolla, *Metamaterials with Negative Parameters*, John Wiley and Sons, 2008.

5. M. A. Noginov and V. A. Podolskiy, *Tutorials in Metamaterials,* CRC Press, Taylor and Francis Group, Boca Raton, 2012.
6. A. B. Shvartsburg and A. A. Maradudin, *Waves in Gradient Metamaterials,* World Scientific Publishing Singapore, 2013.

PH4138E PLASMONICS AND GRAPHENE PHOTONICS

Prerequisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explore the fundamentals of plasmonics and surface plasmon polariton resonances
CO2: Identify 2-D plasmonic materials such as graphene and Dirac semimetal structures and their nonlinear optical properties.
CO3: Design plasmonic devices and explore graphene photonic applications
CO4: Highlight the role of plasmon-assisted microscopy and sub-wavelength imaging.

Plasmonics and Surface Plasmon Polaritons

Introduction of Plasmons –Bulk Plasmons-Drude Model –Surface electromagnetic modes –Electromagnetic fields of surface plasmons –Excitations of surface plasmon by electron and by light –Surface Plasmon Polariton (SPP) on a slab, dispersion relation and field distributions –metal-dielectric-metal and periodic structures –Kretschmann-Raether and Otto Configurations of SPP excitations.

2-D Plasmonic Materials

Susceptibility and permittivity of 2-D materials such as graphene and bulk Dirac Semimetals –Plasmonic properties of graphene–Kubo formalism –Permittivity of monolayer and multilayer graphene –nonlinear optical properties of graphene-II and III harmonic generation and frequency mixing using graphene.

Plasmonic Devices and Graphene Photonic Applications

Plasmonic waveguides (Graphene strip and slot waveguides) –Optical and Terahertz modulators –Saturable absorbers – Cerenkov radiation light source –Polarizers, Photodetectors and Plasmonic sensors –Sub-wavelength imaging with plasmonic nanoparticles –Plasmonic structured illumination microscopy (PSIM).

References:

1. O. Pluchery and J. F. Bryche, *Introduction to Plasmonics*, World Scientific, 2023.
2. B. D. Gupta, A. K. Sharma and J. Li, *Plasmonics-Based Optical Sensors and Detectors*, Routledge, Taylor and Francis, 2024.
3. J. M. Liu, and I. T. Lin, *Graphene Photonics*, Cambridge University Press, Singapore, 2019.
4. L. Solymar and E. Shamonina, *Waves in metamaterials,* Oxford University Press, New York, 2009.
5. H. Raether, *Surface Plasmons on smooth and rough surfaces and on gratings*, Springer-Verlag Berlin, 1986
6. Q. Bao, H. Y. Hoh and Y. Zhang, *Graphene Photonics, Optoelectronics and Plasmonics,* Taylor and Francis, Pan Standford Publishing, Singapore, 2017.
7. Z. Liu, *Plasmonics and Super-Resolution Imaging,* Pan Stanford Publishing Pte. Ltd, Singapore, 2017.

PH4139E SPECKLE PHENOMENA AND IMAGING

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Evaluate the statistics of speckle patterns formed by coherent and partially coherent light.
CO2: Estimate the speckle size and speckle contrast and their dependence on scattering microstructure
CO3: Assess the effects of speckle on different imaging systems and apply different speckle suppression techniques.
CO4: Utilize the laser speckle in metrology to measure different physical parameters.

First order statistics of speckle

Origin of speckle – Subjective and objective speckle - Random phasor representation – Rayleigh density function – First order statistics of intensity and phase – Density function of fully developed speckle – Speckle contrast – Speckle pattern with coherent background – Sum of independent speckles – Sum of correlated speckles – Partially polarized and partially developed speckles – Statistics of Compound speckle.

Higher order statistics of speckle

Joint density functions of amplitudes, phases, and intensities – Second order statistics of speckle – Autocorrelation and power spectral density in free space and imaging geometries – Cittert-Zernike theorem – Speckle size – Statistics of integrated and blurred speckle patterns - Dependence of speckle on scattering microstructure – Speckle contrast on surface roughness – Integration of partially polarized speckles.

Speckle with partially coherent light

Speckle with polychromatic light – Spectral correlation – First order and second order statistics of polychromatic speckle patterns – Speckle with Quasi-monochromatic light – Imaging approach – Propagation of mutual coherence – Effects of the spatial coherence on the image of a rough surface – Speckle patterns by light of arbitrary coherence.

Speckle interferometry and applications

Speckle and speckle suppression in holographic image and Optical coherence tomography - Speckle in multimode fibers – Effects of speckle on Radar – Electronic and phase shifting speckle interferometry – Speckle shearing interferometry - Displacement, rotation, vibration and surface roughness measurements using speckle.

References:

1. J. W. Goodman, *Speckle Phenomena in Optics* (2^{nd} Edition), SPIE Press, 2020.
2. J. C. Dainty, *Laser Speckle and Related Phenomena*, Springer Berlin Heidelberg, 2014.
3. J. W. Goodman, *Statistical Optics* (2^{nd} Edition), John Wiley & Sons, New York, 2015.

PH4140E FOURIER OPTICS AND HOLOGRAPHY

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Evaluate the Fourier spectrum of an arbitrary optical field in image plane and employ the spatial frequency filtering in image processing.
CO2: Develop and optimize an optical imaging system by assessing its optical transfer function and spatial frequency response.
CO3: Estimate the effect of diffraction and aberrations in optical imaging systems and holography.
CO4: Apply different holography techniques in microscopy and interferometry by assessing their employability and tolerance.

Fourier analysis of signals and scalar diffraction theory

Fourier analysis of two-dimensional signals – Theorems of Fourier transform - Convolution and correlation - Linear systems and Superposition – Impulse response and Point-spread function (PSF) - Scalar diffraction theory: Fresnel-Kirchhoff formulation – Rayleigh-Sommerfeld formula – Angular spectrum and its propagation – Huygens-Fresnel principle – Paraxial approximation and Fresnel diffraction – Fraunhofer diffraction at far field.

Frequency analysis of optical imaging systems

Phase transformation by lenses – Fourier transform by a converging lens – Image formation by a positive lens with monochromatic illumination - Fourier analysis of general imaging systems – Entrance and Exit pupils - Abbe theory of image formation - Effects of coherent and incoherent illuminations – Amplitude transfer function (ATF) – Optical transfer function (OTF) and its properties - OTF of an Aberration-free system – Effects of aberrations on ATF and OTF – Apodization.

Optical information processing and holography

Optical filtering – Abbe-Porter experiments – Spatial filtering – Low pass and high pass filters – Phase contrast and Maréchal techniques – Image processing with spatially incoherent light – Wavefront reconstruction by Holography – Gabor hologram and its limitations – Image formation and Magnifications in holography – Holograms of different types: transmission and reflection.

Holograms and their applications

Recording of a hologram – Thick and thin holograms - Volume holographic grating and Wavefront reconstruction – Coupled mode theory for diffraction efficiency and tolerance – Digital holograms - Holographic materials – Effect of noise on holography – Holography with incoherent light – Applications of holography: Microscopy – Interferometry – Artificial neural networks.

References:

1. K. Khare, M. Butola and S. Rajora, *Fourier Optics and Computational imaging* (2nd Edition), Ane Books Pvt. Ltd., Switzerland, 2023.
2. J. W. Goodman, *Introduction to Fourier Optics* (4th Edition), W. H. Freeman, 2017.
3. B. E. A. Saleh and M. C. Teich, *Fundamentals of Photonics* (3rd Edition), John Wiley & Sons, New Jersy, 2019.

4. J. Rosen, *Holography: Recent Advances and Applications*, IntechOpen, 2023.
5. P. Hariharan, *Basics of Holography*, Cambridge University Press, NY, 2002.

ELECTIVE COURSES: THEORITICAL AND HIGH ENERGY PHYSICS

PH3122E ELECTRODYNAMICS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Formulate and solve problems involving time dependent electromagnetic fields using potential formalism.

CO2: Compute radiation fields and energy transfer for time varying charge and current distributions or accelerated charges.

CO3: Apply principles of relativity to electromagnetic fields and formulate these in a relativistically covariant manner.

Potentials and Fields

Potentials and fields - Scalar and vector potentials – gauge transformation - Coulomb and Lorentz gauge – Gauge fixing and degrees of freedom – Field Equations in terms of potentials

Fields of dynamics sources

Retarded potentials – Jefimenko's equations – Lienard-Wiechert potentials – field of a moving point charge – Radiation from moving point charge, electric and magnetic dipole radiation – radiation from an arbitrary source – multipole expansion of radiation – radiation reaction and damping

Relativity and Electrodynamics

Lorentz transformation – relativistic mechanics and dynamics – four-vectors in electrodynamics – electromagnetic field tensor and Maxwell's equations – transformation of fields – fields of uniformly moving particles.

References:

1. D. J. Griffiths, *Introduction to Electrodynamics* (4th Edition), PHI Learning - New Delhi, 2012.
2. E. Purcell and D. Morin, *Electricity and Magnetism* (3rd Edition), Cambridge University Press, 2013.
3. M. O. Sadiku, *Elements of Electromagnetics* (4th Edition), Oxford, 2009.
4. J. D. Jackson, *Classical Electrodynamics* (3rd Edition), Wiley, 2007.

PH3124E PHYSICS OF ELEMENTARY PARTICLES

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the properties of fundamental particles and their interactions
CO2: Analyse the symmetries of particle physics
CO3: Compute the scattering amplitude for various processes using Feynman diagrams
CO4: Analyse two body decay and scattering processes

Elementary Particles and Symmetries
Particle interactions: families, relative strengths - Symmetries and conservation laws - Quantum numbers - Gell-Mann-Nishijima formula - Eightfold way and Quark Model - colored quarks and gluons - Symmetries and groups – Isospin - Flavor symmetries and Discrete symmetries - Neutral Kaons and CP violation.

Relativistic Kinematics
Four-vectors - Lorentz transformations - Energy and momentum - Collisions: Classical and Relativistic – Cross section in CM and Lab frame - Mandelstam variables.

Feynman Calculus
Decays and scattering: decay rate, cross sections - the golden rule: decays and scattering - two particle decays and two-body scattering - Feynman rules for a toy theory.

Quantum Electrodynamics
The Dirac equation: solutions, antiparticles, Bilinear covariants - The photon - Feynman rules for QED - Examples: Bhabha, Moller and Compton scattering.

References:

1. D. Griffths, *Introduction to Elementary Particles* (2nd Edition), Wiley, 2008.
2. W. E. Burcham and M. Jobes, *Nuclear and Particle Physics* (2nd Edition), Pearson, 1994.
3. F. Halzen and A. D. Martin, *Quarks and Leptons* (2nd Edition), Wiley, 2008.
4. D. H. Perkins, *Introduction to High Energy Physics* (4th Edition), Cambridge, 2000.

PH4122E RELATIVITY AND GRAVITATION

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Perform calculations compatible with special relativity and examine classical field theories.
CO2: Analyse manifolds using the techniques of Riemannian geometry.
CO3: Obtain Einstein Field Equations or generalizations thereof.
CO4: Solve simple systems of relevance in Gravitational physics.

Flat space time
Review of Special Relativity (SR) – Global inertial frames, four-vectors and tensors in SR, covariant vectors and tensors – Covariance of equations under Lorentz transformations

Classical field theory
Classical field theory of a real scalar field: action, Lagrangian density, Euler-Lagrange field equation – The massless vector field: Lagrangian – Conserved currents and Noether's theorem– Stress energy tensor – Perfect fluids.

Curved space time
General coordinate invariance, Principle of Equivalence – Tensors in curved space-time, connection, parallel transport, geodesics, covariant derivative, Curvature tensors, Lie Derivatives – Bianchi identities – Einstein's field equations.

Solutions of Einstein's Field Equations
Schwarzschild solution, Birkoff theorem – Precession of the planetary orbits, bending of light, the gravitational red shift – Gravitational waves and their signatures.

References:

1. B. Schutz, *A first course in General Relativity*, Cambridge University Press, 1985.
2. S. M. Carroll, *Spacetime and Geometry*, Cambridge University Press, 2019.
3. S. Weinberg, *Gravitation and Cosmology*, John Wiley & Sons, 1972.
4. R. Wald, *General Relativity*, The Unviersity of Chicago Press, 1984.
5. C. W. Misner, K. Thorne and J. A. Wheeler, *Gravitation*, Princeton University Press, 2017

PH4124E CRITICAL PHENOMENA

Pre-requisite: Nil

Total Lecture Hours: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes

CO1: Apply the concept of thermodynamic potential and determine stability/instability of a thermodynamic Phase.
CO2: Identify first-ordered and higher-ordered phase transitions based on phase transition characteristics.
CO3: Differentiate universality classes of phase transition by performing scaling analysis.
CO4: Apply mean-field theory and elucidate qualitative features of phase diagram in continuous phase transitions.
CO5: Apply renormalization group theory and characterize phenomena in the vicinity of critical point.

Intrinsic stability of thermodynamic systems - stability conditions for thermodynamic potentials, physical consequences, Le Chatelier and Le Chatelier-Braun principles, First-order phase transitions - general attributes of first-order phase transitions, Gibbs phase rule

Second-order phase transitions - Thermodynamics and statistical mechanics of phase transition, order parameter, Critical point exponents and exponent inequalities, Ising model, equivalence of Ising model to lattice gas model and binary alloys, magnetization, Bragg-Williams approximation, Bethe-Peierls approximation, one-dimensional Ising model

Correlation function and fluctuation-dissipation theorem - critical exponents - Scaling hypothesis - dimensional analysis, Scaling forms, Widom's scaling form, Scale invariance, Goldstone excitations, importance of dimensionality, dimensional reduction

Landau approach - model Hamiltonian, Ising Model, XY-Model, Mean-field theory - van der Waals equation of state, tricritical point, Gaussian model, Ginzburg criterion, Renormalization group theory- block spins, 1D-Ising model, Renormalization group transformation - fixed points and scaling fields, momentum space formulation, Gaussian model, renormalization of partition function, Landau-Wilson model, Fixed points and trajectories.

References:

1. H. E. Stanley, *Introduction to Phase Transitions and Critical Phenomena,* Oxford, 1971.
2. J. M. Yeomans, *Statistical Mechanics of Phase transitions,* Oxford, 1992.
3. K. Huang, *Statistical Mechanics,* John Wiley, 2000.

PH4126E ADVANCED QUANTUM MECHANICS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Analyze quantum phenomena using Path Integrals
CO2: Apply ideas of group theory to simplify and solve problems in quantum physics
CO3: Describe and interpret relativistic quantum mechanics

Path Integrals in Quantum Mechanics
Review of time evolution in Quantum Mechanics – Path integral definition and properties – Path integral for free particle and harmonic oscillator – Path integral as a propagator – equivalence to Schrodinger equation – Applications of path integrals in perturbation theory.

Review of Group Theory and Representations
Finite groups – representations, irreducible representations – Introduction to Lie groups – Generators, Lie algebras – Representations – Examples: SO(2), SO(3), SU(2) and SO(3,1) groups – Applications: SU(2) in Angular momentum algebra, particle spectrum from SO(3,1) representations.

Relativistic Quantum Mechanics
Klein Gordon and Dirac equations – Plane wave solutions, properties and interpretations – non-relativistic correspondence - Spin and helicity – massless Dirac particle, chirality – relativistic hydrogen atom – Parity, Charge conjugation, Time reversal and other symmetries.

References:
1. H. Georgi, *Lie Algebras in particle physics,* Levent, 2009.
2. R. P. Feynman and A. R. Hibbs, *Quantum Mechanics and Path Integrals*, Dover Publications, 2005.
3. H. Kleinert, *Path Integrals* (3rd Edition), World Scientific, 2004.
4. P. M. Mathews and K. Venkatesan, *A Textbook of Quantum Mechanics* (2nd Edition), McGraw Hill, 2017.

PH4130E WEAK INTERACTIONS AND STANDARD MODEL

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Identify fundamental particles and their interactions
CO2: Develop the idea of mathematical formulation of various symmetries of nature
CO3: Analyze the basic ingredients of the standard model of particle physics
CO4: Interpret spontaneous symmetry breaking and Higgs mechanism

Fundamental Interactions and Quark Model
Fundamental interactions in nature – particle classification – concept of isospin and SU(2) – quarks and colors, quark model, the eightfold way, hadron structure – proton form-factors, parton model – Gell-Mann-Okubo mass formula – bound states and resonance states.

P and CP violation
Discrete symmetries – parity violation, cobalt-60 experiment – Fermi theory, V-A interaction, current-current hypothesis of weak interaction – CP violation in Kaon system, the CPT theorem.

(Non-)Abelian Gauge Theories
Lagrangians and single particle wave equations – symmetries and conservation laws, Noether's theorem – U(1) gauge theory and QED – non-Abelian gauge theories: SU(2) and SU(3) gauge theories – weak isospin and hypercharge – Feynman rules and diagrams.

Basic Ingredients of Standard Model
Spontaneous symmetry-breaking, Goldstones theorem, Higgs mechanism – Glashow-Weinberg-Salam model – choice of Higgs field, masses of the gauge bosons and fermions – quantum chromodynamics and the standard model – experimental tests of the standard model: magnetic moment of the electron and the muon, weak neutral currents, quark mixing, flavor oscillations.

References:
1. W. E. Burcham and M. Jobes, *Nuclear and Particle Physics* (2nd Edition), Pearson, 1994.
2. F. Halzen and A. D. Martin, *Quarks and Leptons* (2nd Edition), Wiley, 2008.
3. D. H. Perkins, *Introduction to High Energy Physics* (4th Edition), Cambridge, 2000.
4. D. Griffths, *Introduction to Elementary Particles* (2nd Edition), Wiley, 2008.

PH4132E QUANTUM MECHANICS FOR QUANTUM COMPUTING

Pre-requisites: Nil

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply Dirac bra-ket formalism to quantum mechanical problems and solve these.
CO2: Formulate one dimensional potential problems in terms of Schrodinger equation and analyse solutions.
CO3: Analyze and identify symmetries in quantum systems to simplify solutions to problems.
CO4: Apply density matrix formalism and idea of entanglement to problems in quantum computing and information.
CO5: Apply ideas of decoherence to analyze quantum to classical transition in simple quantum systems.

Quantum kinematics
Postulates of Quantum mechanics - bra-ket notation, states and observables - measurement - probabilities - commutators and uncertainty relations - matrix representations of observables - change of basis - translation and momentum operator – Qubits, spin half systems, photon polarization.

Quantum dynamics
Time evolution of states and time dependent Schrodinger equation - time independent Schrodinger equation - one dimensional potential problems: infinite and finite square well potentials, tunnelling – harmonic oscillator - Symmetries and conserved quantities.

Composite systems and incompletely known systems
Rotations, Angular momentum, spin - spin correlation measurements and Bell's inequality – Composite systems and entanglement, Einstein Podolsky Rosen (EPR) paradox - Density matrices, Pure and mixed states, time evolution of density matrices - Bloch sphere - partial trace and entanglement entropy.

Measurements and open quantum systems
Projective measurements- generalized measurements and Positive Operator Valued Measures (POVM), Neumarks theorem, Kraus representation - quantum zeno effect - Quantum decoherence and quantum to classical transition, Einselection.

References:

1. J. J Sakurai and Jim Napolitano, *Modern Quantum Mechanics* (3rd Edition), Cambridge university Press, 2021.
2. R. Shankar, *Principles of Quantum Mechanics* (2nd Edition), Springer New York, 2014.
3. Asher Peres, *Quantum theory: concepts and methods*, Kluwer academic publishers, 2002.
4. Maximilian Schlosshauer, *Decoherence and the Quantum to classical transition*, Springer-Verlag, 2007.
5. W. H. Zurek, *Decoherence, einselection and the quantum origins of the classical*, Rev. Mod. Phys. 75, 715, 2003.

L	T	P	O	C
3	0	0	6	3

PH4136E ADVANCED STATISTICAL MECHANICS

Pre-requisites: Nil

Total Lecture Sessions: 39

Course Outcomes:
CO1: Apply the concept of mean-field theory for qualitative description of phase transitions.
CO2: Analyze critical behaviour of model systems using exact calculations and approximation methods.
CO3: Apply Monte-Carlo methods for studying properties of physical models near phase transitions.

Mean-field theory for continuous phase transition: Ising model, Bragg-Williams approximation, Bethe approximation, critical behaviour, Landau theory of phase transitions, Landau-Ginzburg theory for fluctuations – Exactly solvable models: one dimensional and two-dimensional Ising model – Series expansions: high-temperature expansion, low-temperature expansion – Numerical simulations: thermal averages, importance sampling, Monte-Carlo method - Metropolis method, critical slowing down.

Scaling hypothesis: The homogeneity assumption, dimensional analysis, scaling form, universality – Real space renormalization: Kadanoff block spins, fixed points - general discussion, critical exponents, application of real space renormalization - one dimensional and two-dimensional Ising model, Monte-Carlo renormalization group.

Momentum space renormalization: formal discussion, Gaussian model - direct solution and renormalization group approach – Perturbative renormalization group: Expectation values in the Gaussian model, expectation values in perturbative theory, diagrammatic representation of perturbation theory, susceptibility, first order perturbative RG, second order perturbative RG, ϵ-expansion.

References:
1. M. Plischke and B. Bergersen, *Equilibrium Statistical Physics* (3rd Edition), World Scientific, 2006.
2. M. Kardar, *Statistical Physics of Fields*, Cambridge University Press, 2007
3. R. K. Pathria, *Statistical Mechanics* (2nd Edition), Elsevier, 1996.
4. J. J. Binney, N. J. Dowrick, A. J. Fisher and M. E. J. Newman, *The Theory of Critical Phenomena*, Oxford Science Publications, 1992.
5. K. Huang, *Statistical Mechanics* (2nd Edition), Wiley, 2000.

PH4141E DIFFERENTIAL GEOMETRY AND GROUP THEORY FOR PHYSICISTS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Describe characteristics of manifolds and calculate their attributes using the tools of differential geometry.
CO2: Calculate curvature and geodesics of a general Riemannian manifold.
CO3: Analyze properties of discrete and continuous groups.
CO4: Construct irreducible representations of groups using tensor methods.

Topological spaces and manifolds
Topological spaces, compactness, connectedness, homeomorphism, topological invariants – paths and loops, homotopy: definition and examples – Manifolds – differentiable maps – vectors, one-forms, tensors – flows and lie derivatives – differential forms – exterior derivative – integration of forms – Physical examples.

Riemannian manifolds
Riemannian geometry: Riemannian and pseudo Riemannian manifolds – metric tensor – connections, parallel transport and geodesics – covariant Derivative – curvature and torsion tensors and its geometrical meaning – Ricci tensor and scalar curvature.

Discrete groups
Definition of a group – subgroup – class – Lagrange's theorem – invariant subgroup –Homomorphism and isomorphism between two groups – Representation of a group– Schur's lemmas – orthogonality theorem – character table – reduction of Kronecker product of representations.

Continuous groups
Infinitesimal generators, Lie algebra – SO(3) – Definition of SU(2) and SU(3) groups – Lie algebra of SU(2) – Relation between SU(2) and SO(3) – Lie algebra of SU(3)- Gellmann's matrices, – Representation theory of SU(2), Lorentz and Poincare groups, tensor methods.

References:

1. Michio Nakahara, *Geometry, topology and physics* (2nd Edition), IoP publishing, 2003.
2. Bernard F. Schutz, *Geometrical methods of mathematical physics*, Cambridge university press, 1980.
3. Sunil Mukhi and N Mukunda, *Lectures on advanced mathematical methods for physicists,* Hindustan book agency, World Scientific publishing, 2010.
4. Theodore Frankel, *The geometry of Physics*, Cambridge University Press, 1997.
5. Howard Georgi, *Lie algebras in particle physics*, Westview Press, 1999.
6. J. Fuchs and C. Schweigert, *Symmetries, Lie Algebras and Representations: A Graduate Course for Physicists,* Cambridge University Press, 2003.

PH4142E ADVANCED TOPICS IN ANALYTICAL MECHANICS

Pre-requisites: Nil

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:
CO1: Identify symmetries of a classical system and utilize them to simplify their description.
CO2: Analyze classical systems with constraints and local symmetries.
CO3: Distinguish between integrable and Chaotic systems.

Canonical Transformations

Canonical Transformations and the Symplectic group – Time evolution as a Canonical Transformation – Hamilton-Jacobi Equation – Poincaré-Cartan Integral Invariants – Universal Integral Invariants of Poincaré – Generalized Conservative Systems – Marpetuis-Lagrange Principle of Least Action.

Constraint Analysis and Symmetries

Classification of Constraints – Physical Interpretation of Singular theories – Theories with Second-Class constraints, examples of system with kinematic constraints – Dirac brackets – Theories with First-Class constraints, examples of Electrodynamics and Non-Relativistic Spin – Local symmetries and constraints, conserved charges – Extended Lagrangians.

Non-linear Dynamics

Periodic motion – Perturbations and Kolmogrov-Arnold-Moser Theorem – Attractors – Chaotic Trajectories and Lyapunov exponents – Poincaré maps – Hénon-Heiles Hamiltonian – Bifurcation, Driven damped Harmonic Oscillators – Parametric Resonance.

References:

1. E. C. G. Sudarshan and N. Mukunda, *Classical Dynamics: A Modern Perspective*, John Wiley & Sons, 1974.
2. A. Deriglazov, *Classical Mechanics: Hamiltonian and Lagrangian Formalism*, Springer-Verlag, 2010.
3. L. D. Landau and E. M. Lifshitz, *Mechanics* (3rd Edition), Pergamon press, 2009.
4. H. Goldstein, C. Poole and J. Safko, *Classical Mechanics* (3rd Edition), Narosa Publishers, 2001.

ELECTIVE COURSES: ASTRONOMY, ASTROPHYSICS AND PLANETARY SCIENCES

PH3126E ATMOSPHERIC AND ENVIRONMENTAL PHYSICS

L	T	P	O	C
3	0	0	6	3

Pre requisite: Nil

Total Lecture Sessions: 39

Course Outcomes:
CO1: Determine relevant components of Climate system.
CO2: Apply laws of Physics to Atmospheric and Environmental system.
CO3: Analyze atmospheric and oceanic circulation.
CO4: Recognize basic instrumentation and models for Atmospheric dynamics.

Components of climate system – Structure and composition of the atmosphere; the hydrosphere: properties of water, the hydrologic cycle, measuring the water content of the atmosphere; cryosphere; biosphere; Radiation – Sun as primary source of energy for the earth, black body radiation and solar radiation spectrum, albedo, radiation balance at the earth's surface and determination of surface temperature, UV radiation; ozone layers and depletion; greenhouse effect; the carbon cycle; atmospheric aerosols and their effect on radiation balance.

Laws of thermodynamics; energy transfers – conduction, convection, radiation, evaporation; ideal gas model, exponential variation of pressure with height, temperature structure and lapse rate; Stability; Atmospheric dynamics – Navier Stokes theorem, continuity equation, general idea about synoptic and meso-scale disturbances; Entropy in the climate system.

Winds in the atmosphere – measuring wind, origin of winds – the atmosphere as a heat engine; the principal forces acting on an air parcel; cyclones and anticyclones; thermal gradients and winds; global convection and global circulation; Angular momentum cycle; Energetics – energy equations, observed energy balance, polar energetic; divergence, vorticity and momentum balance; The Ocean structure and the thermohaline circulation.

Modeling of climate – global climate circulation models and predictions; nature of climate system; climate state and climate variability – inter annual and inter decadal variability; climate cycles – El Nino, North Atlantic Oscillation; climate observation – instrumentations and techniques for measuring climate variables; discussions on climate change.

References:

1. J. P. Peixoto and A. H. Oort, *Physics of Climate*, AIP & Springer Verlag, 1992.
2. N. Mason and P. Hughes, *Introduction to Environmental Physics: Planet Earth, Life and Climate*, Taylor and Francis, 2001.
3. J. R. Holton, *An Introduction to Dynamic Meteorology*, Academic Press, 1992.
4. Boeker and van Grondelle, *Environmental Science: Physical Principles and Applications*, Wiley, 2001.

PH4135E ASTRONOMY AND ASTROPHYSICS

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:
CO1: Identify the celestial objects such as planets, stars in the night sky.
CO2: Apply the physical principles for the classification of stars.
CO3: Explore the physics of structures and evolution of the Sun and other stars.
CO4: Describe the distribution of stars in the Milly Way and other galaxies.
CO5: Understand the formation and expansion of universe.

Celestial Objects and Our Universe
Overview of the universe: celestial objects and celestial sphere, constellations – Solar system and exoplanets – Basic astronomical motions: two-body problem, planetary motions – Stellar distances: Trigonometric parallaxes of stars – Astronomical instruments: telescopes and their usages.

Classification of Stars
Apparent and absolute magnitudes, luminosity, distance modulus – Blackbody radiation, temperatures and colours of stars - Masses and radii of stars - Spectral classification of stars - Hertzsprung-Russell diagram – Spectral lines: Boltzmann excitation equation, Saha's theory of thermal ionization.

Stellar Structure and Evolution
Basics of radiative transfer, line strength and source function - Stellar atmosphere – Equations for stellar structure: energy of stars, PP and CNO cycles; hydrostatic equilibrium, stability conditions for convective and radiative equilibrium - Stellar models: polytrophic model, Lane-Emden equation - Stellar evolution: main sequence stars, supernovae, neutron stars, dwarfs and black holes.

Galaxies and Cosmology
Milky Way: distribution of stars, interstellar gases and dusts, luminosity function, star counts - External galaxies: Hubble classification of galaxies, spiral galaxies, elliptical galaxies, irregular galaxies - Active galaxies - Cosmology: Theoretical foundation, specific cosmological models (big-bang model, steady state theory), big bang nucleosynthesis, cosmic microwave background.

References:

1. B. W. Carrol and D. A. Ostlie, *An Introduction to Modern Astrophysics* (2nd Edition), Pearson Addison Wesley, 2006.
2. W. M. Smart and R. M. Green, *Textbook on Spherical Astronomy* (6th Edition), Cambridge University Press, 1977.
3. K. D. Abhyankar, *Astrophysics - Stars and Galaxies*, Universities Press, 2001.
4. F. H. Shu, *The Physical Universe – An Introduction to Astronomy*, University Science Books, 1982.
5. S. Chandrasekhar, *An Introduction to the study of the stellar structure*, Dover Publications Inc., 2003.
6. R. Kippenhahn, A. Weigert and A. Weiss, *Stellar Structure and Evolution* (2nd Edition), Springer, 2012.

ELECTIVE COURSES: ELECTRONICS, INSTRUMENTATION AND SIMULATIONS

PH2121E COMPUTER PROGRAMMING

Pre-requisites: Nil

Total 26 Lectures Sessions + 26 Practical Sessions

L	T	P	O	C
2	0	2	5	3

Course Outcomes:

CO1: Acquire basic Python programming skills relevant to science and engineering problems.
CO2: Understand and apply the concepts of object oriented programming for complex scientific problems.
CO3: Uses of powerful python libraries for data analysis and visualizations.

Introduction to Python, IDLE, variables, data types, operators, precedence, conversions, string operations, inbuilt functions, math library. Console input/output - input and print function, formatted printing.

Decision control instructions – if-else statements, logical operators, conditional expressions, nested conditions; Iteration – while and for statements, range function, break, continue and pass statements; Functions – defining functions, parameters and arguments, lambda expression.

Lists – accessing elements, list operations, list methods, list comprehensions, del statement, arrays; Dictionary – accessing and manipulating elements, dictionary methods; Tuples and Sets.

File handling – create, read, write and delete files.

Classes – class definition, class variables and methods, objects, inheritance. numpy and matplotlib libraries.

References:

1. Y. Kanetkar, *Let Us Python* (4^{th} Edition), BPB Publications, 2022.
2. Official python documentation: https://docs.python.org/3/
3. Charles R. Severance, *Python for Everybody: Exploring Data Using Python 3* (1^{st} Edition), CreateSpace Independent Publishing Platform, 2016. (http://do1.dr-chuck.com/pythonlearn/EN_us/pythonlearn.pdf).
4. Allen B. Downey, *Think Python: How to Think Like a Computer Scientist* (2^{nd} edition), Shroff/O‘Reilly Publishers, 2016.

PH3121E INTERFACING AND SIMULATION

Pre-requisite: Nil

L	T	P	O	C
2	0	2	5	3

Total 26 Lectures Sessions + 26 Practical Sessions

Course Outcomes:

CO 1: Understand and demonstrate data acquisition fundamentals
CO 2: Apply signal conditioning techniques
CO 3: Build data acquisition hardware and interfacing code
CO 4: Build data analysis and simulation modules
CO 5: Apply data acquisition/automatization in real-world scenarios

Communication protocols

Communications technologies and protocols for engineers: designing, specifying, using instrumentation and control systems; knowledge required to analyse, specify and debug data communication systems, introducing the latest digital technologies; Data transmission using wired and wireless protocols of IoT, IIoT; Standards and Protocols of RS-232, RS422, RS-485, GPIB, TCP/IP, USB, SPI, I2C etc.; smart instrumentation.

Programming basics for interfacing

Instrument interfacing using different programming environments such as Python/LabVIEW – basic interfacing fundamentals; instrument drivers and libraries; hands-on training to develop interface for instrument communication, automation and control

Data acquisition practicals

Elements of data acquisition systems (DAQ) - Sensor, Signal Conditioning, and Analog-to-Digital Converter (ADC); DAQ(Hardware)- DAQ modules, boards, Hardware design and hands-on experience; data types; using a specific programming environment for data acquisition, analysis, display and storage; practical examples of interfacing and automation – temperature sensor, digital oscilloscopes, image acquisition and analysis; Data security and encryption

References:

1. Travis and Jeffrey, *LabVIEW for everyone*, Pearson Education India, 2009.
2. Forouzan and Behrouz A., *Data communications and networking*, Huga Media, 2007.
3. Di Paolo Emilio, Maurizio and Maurizio Di Paolo Emilio, *Design of Data Acquisition Systems*, Data Acquisition Systems: From Fundamentals to Applied Design, 2013, 99-113.
4. Norris and Donald, *Python for Microcontrollers: Getting Started with MicroPython*, McGraw Hill Education, 2017.

PH3133E SIGNAL THEORY AND SYSTEMS ANALYSIS

L	T	P	O	C
3	0	0	6	3

Prerequisites: Nil

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply fundamental concepts of signals and systems to comprehend physical systems.
CO2: Analyze and manipulate signals and systems.
CO3: Analyze signals and systems in the frequency domain.
CO4: Design and model the physical systems mathematically.

Introduction to Signals and Systems Signals: Basic signals (Sinusoidal, exponential, unit step, unit impulse, ramp, triangular), Classification of signals (Continuous-time vs. discrete-time, analog vs. digital), Basic signal operations (Amplitude scaling, time shifting, time reversal), Systems: Properties of systems (Linearity, time-invariance, causality, stability).

Linear Time-Invariant System Representation of Signals in terms of Impulses, Discrete-Time LTI Systems: The Convolution Sum, Continuous-Time LTI Systems: The Convolution Integral, Properties of LTI Systems, LTI System response to different input signals (Impulse, step, sinusoidal), Evaluating impulse response from the step response.

Fourier analysis of Continuous Time Signals and Systems Representation of Periodic Signals: The Continuous-Time Fourier Series, Representation of Aperiodic Signal: Continuous Time Fourier Transform. Periodic Signals and the Continuous Time Fourier Transform, Properties of the Continuous-Time Fourier Transform, Continuous-Time Fourier Transform of Basic Continuous Signals.

Fourier analysis of Discrete Time Signals and Systems Representation of Periodic Signals: The Discrete-Time Fourier Series, Representation of Aperiodic Signal: Discrete Time Fourier Transform. Periodic Signals and the Discrete Time Fourier Transform, Properties of Discrete-Time Fourier Transform, Discrete-Time Fourier Transform of Basic Discrete Signals.

Laplace Transform Concept of Laplace Transform of a continuous signal, Unilateral and Bilateral Laplace Transform, Region of Convergence of Laplace Transform, Relation between Fourier Transform and Laplace Transform, Properties of Laplace Transform, Some Laplace transform Pairs, Inverse Laplace Transform, Analysis and Characterization of LTI Systems Using Laplace Transform.

Z-Transform Concept of Z- Transform of a Discrete Sequence, Region of Convergence for the Z-Transform, Properties of Z-Transform, Some common Z-Transform Pairs, Analysis and Characterization of LTI Systems using Z-Transform, Inverse Z-Transform.

References:

1. A. V. Oppenheim, A. S. Willsky and S. H. Nawab, *Signals and Systems* (2nd Edition), PHI Learning Private Limited/Pearson Education, 2011.
2. S. Haykin and B. V. Veen, *Signals and Systems*, John Wiley, 1999.
3. B. P. Lathi, *Linear Systems and Signals*, Oxford University Press, 2004
4. S. S. Soliman and M. D. Srinath, *Continuous and discrete signals and systems*, Englewood Cliffs, 1990.