MASTER OF SCIENCE

IN

PHYSICS

(Regulations 2018)

CURRICULUM AND SYLLABUS

(For students admitted from academic year 2018-2019 onwards)

UNDER CHOICE BASED CREDIT SYSTEM

SRM

INSTITUTE OF SCIENCE & TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

DEPARTMENT OF PHYSICS

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

SRM NAGAR, KATTANKULATHUR – 603 203

M.Sc. Physics

CURRICULUM AND SYLLABUS

(For students admitted from the academic year 2018-2019 onwards)

Objectives:

1. To develop the critical analysis and problem solving skills required in the application of principles of Physics.
2. To prepare the students with a working knowledge of experimental/computational techniques and instrumentation required to work independently in research or industrial environments.
3. To strengthen students' capability in organizing and presenting the acquired knowledge coherently both in oral and written discourse.
4. To prepare the students to successfully compete for current employment opportunities.

Eligibility:

B. Sc. with Physics as a major subject (or) B. Sc. Triple Major with Physics as one of the major subjects.

Duration:

2 Years (4 semesters)

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

1. Postgraduates will pursue higher studies in related fields including management and carry out research.
2. Postgraduates will perform as employees in private/government institutions rising up to top positions.
3. Postgraduates will become entrepreneurs.

STUDENT OUTCOMES

The curriculum and syllabus for the Master degree in Physics (2018) conform to outcome based teaching learning process. In general, TWELVE STUDENT OUTCOMES (a-l) have been identified and the curriculum and syllabus have been structured in such a way that each of the courses meets one or more of these outcomes. Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program. Further each course in the program spells out clear instructional objectives which are mapped on to the student outcomes.

On successful completion of this Program, students will have the ability to

a) Acquire knowledge and understanding of fundamental concepts, principles and theories related to the identified subject areas.
b) Acquire advanced knowledge in some areas of interest in physics and is familiar with contemporary research within various fields of physics.
c) Develop skills of critical thinking, hypothesis building, and to apply the scientific method to physics concepts, theoretical models and laboratory experiments.
d) Develop problem solving skill to, independently and creatively, identify and formulate problems and to plan and, use theoretical and/or experimental methods, carry out advanced tasks within specified time limits.
e) Develop the skill to combine and use knowledge from several disciplines to enter/propose novel ideas that require an analytic and innovative approach, and disseminate subject matter and results to both specialists and a broader audience.
f) Use computers effectively to solve problems through numerical methods and simulations and to analyze the data through available software.
g) Handle standard and advanced laboratory equipment, modern instrumentation and classical techniques to carry out experiments.
h) Develop skills to interpret and explain the limits of accuracy of experimental data in terms of significance and underlying theory.
i) Collaborate and to lead collaborative work to accomplish a common goal.
j) Understands the role of physics in the society and have the background to consider ethical, legal and security issues and responsibilities.
k) Demonstrate written and oral communication skills for dissemination of scientific results in report, article, or oral presentation formats.
l) Develop an adequate background for pursuing pedagogic education and international perspective on her/his discipline, and a commitment to life-long learning and professional development.

Contents

Particulars **Page No.**

CURRICULUM

M.Sc. (Physics) **Total Credits: 82**

As per UGC Regulation 2016 (Credit Framework for Online Learning Courses through **SWAYAM**), SRMIST strongly encourages the use of SWAYAM (Study Web of Active Learning by Young and Aspiring Minds) platform.

1. Students shall be allowed to choose one SWAYAM course per semester on the recommendation of the faculty advisor and the credits will be transferred.
2. Based on the curriculum, students shall be allowed to choose one major core course from SWAYAM.
3. Suitable courses available on SWAYAM can also be chosen as an elective (major/non-major).

SEMESTER I

Category	Course Code	Course	L	T	P	O	L+T+P	C
Major Core	18PPH101	Mathematical Physics-I	3	1	-	1	4	4
	18PPH102	Classical Mechanics	3	1	-	1	4	4
	18PPH103	Electrodynamics	3	1	-	1	4	4
	18PPH104	Electronic Devices and Applications	3	1	-	1	4	4
	18PPH105	General Physics Laboratory	-	-	6	-	6	3
		Total	**12**	**4**	**6**	**4**	**22**	**19**

SEMESTER II

Category	Course Code	Course	L	T	P	O	L+T+P	C
Major Core	18PPH201	Mathematical Physics-II	3	1	-	1	4	4
	18PPH202	Quantum Mechanics-I	3	1	-	1	4	4
	18PPH203	Condensed Matter Physics-I	3	1	-	1	4	4
	18PPH204	Statistical Mechanics and Thermodynamics	3	1	-	1	4	4
	18PPH205	Electronics & Computer Laboratory	-	-	6	-	6	3
	18PPH206	Seminar*#	-	-	2	-	2	1
Non-Major Elective-I		Open Elective-I	2	-	-	-	2	2
		Total	**14**	**4**	**8**	**4**	**26**	**22**

L – Lecture, T – Tutorial, P – Practical, O – Outside Class, C– Credits

Note:* Continuous assessment [Fully Internal]

 # Based on recent research articles

SEMESTER III

Category	Course Code	Course	L	T	P	O	L+T+P	C
Major Core	18PPH301	Quantum Mechanics-II	3	1	-	1	4	4
	18PPH302	Condensed Matter Physics-II	3	1	-	1	4	4
	18PPH303	Atomic and Molecular Physics	3	1	-	1	4	4
	18PPH304	Project Phase I*$	-	-	8	-	8	4
Major Elective-I	18PPH3EA	Structure and Properties of Materials	3	1	-	1	4	4
	18PPH3EB	Photonics	3	1	-	1		
	18PPH3EC	Computational Physics	3	1	-	1		
	18PPH3ED	Sensors	3	1	-	1		
Non-Major Elective-II		Open Elective-II	2	-	-	-	2	2
Total			**14**	**4**	**8**	**4**	**26**	**22**

SEMESTER IV

Category	Course Code	Course	L	T	P	O	L+T+P	C
Major Core	18PPH401	Nuclear and Particle Physics	3	1	-	1	4	4
	18PPH402	Advanced Laboratory	-	-	6	-	6	3
	18PPH403	Project Phase II$	-	-	16	-	16	8
Major Elective-II	18PPH4EA	Nanoscience and Nanomaterials	3	1	-	1	4	4
	18PPH4EB	Thin Film Technology	3	1	-	1		
	18PPH4EC	Atmospheric Physics	3	1	-	1		
	18PPH4ED	High Energy Physics	3	1	-	1		
	18PPH4EE	Applied Optics	3	1	-	1		
	18PPH4EF	Soft Matter and Biological Physics	3	1	-	1		
	18PPH4EG	Quantum Field Theory	3	1	-	1		
Total			**6**	**2**	**22**	**2**	**30**	**19**

L – Lecture, T – Tutorial, P – Practical, O - Outside Class, C– Credits

Note:* Continuous assessment [Fully Internal]

$Research and Seminar

SUMMARY				
Category	**No. of Courses**			
	Semester I	**Semester II**	**Semester III**	**Semester IV**
Core Courses	5	5	3	3

Seminar	-	1	-	-
Major Elective(s)	-	-	1	1
Non-Major Elective(s)	-	1	1	-
Project Phase-I	-	-	1	-
Project Phase-II	-	-	-	1
Total number of credits				**82**

Non-Major Electives (offered to other departments)

1. 18PPH2NA Introduction to Nanotechnology
2. 18PPH2NB Laser Physics
3. 18PPH3NA Medical Physics
4. 18PPH3NB Energy Storage and Devices

SYLLABUS

SEMESTER I

Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH101	**Mathematical Physics-I**	**3**	**1**	**-**	**1**	**4**	**4**
Instructional Objectives **At the end of this course the learner is expected:**			**Student Outcomes**				

1	To develop knowledge in mathematical physics and its applications.	a	b	c	e	f
2	To develop expertise in mathematical techniques required in physics.	c	d	e	j	k
3	To enhance problem solving skills.	c	d	e	f	h
4	To enable students to formulate, interpret and draw inferences from mathematical solutions.	b	c	f	h	L

UNIT – I VECTOR ANALYSIS AND MATRICES

Dimensional analysis, vector algebra and vector calculus, gradient, divergence & curl, transformation of vectors, rotation of the coordinate axes, invariance of the scalar and vector products under rotations, vector analysis in curved coordinate, special coordinate system, circular, cylindrical and spherical polar coordinates, linear algebra matrices, Cayley-Hamilton theorem, eigenvalues and eigenvectors.

UNIT – II TENSORS ANALYSIS

Introduction, definitions, contraction, directs product, quotient rule, pseudo tensors, Levi-Civita symbol, irreducible tensors, non-Cartesian tensors, metric tensor. Christoffel symbols, covariant differentiation.

UNIT – III DIFFERENTIAL EQUATIONS

Partial differential equations of theoretical physics, ordinary differential equation, separation of variables, singular points, series solutions-Frobenius method, second solution, Bessel's equation, regular and irregular singularities.

Unit – IV COMPLEX VARIABLES

Introduction, Cauchy-Riemann conditions, Cauchy's integral theorem, Cauchy's integral formula, Taylor and Laurent series, singularities, calculus of residues, evaluation of definite integrals and contour integrals, dispersion relation.

UNIT-V DELTA AND GAMMA FUNCTIONS

Dirac delta function, delta sequences for one-dimensional function, properties of delta function, orthogonal function and integral representation of delta function, gamma function, Weierstrass form, factorial notation and applications, beta function, relation with gamma function.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. G. Arfken and H.J. Weber, *Mathematical Methods for Physicists*, 6th Ed., Academic Press, SanDiego, 2005.
2. P.K. Chattopadhyay, *Mathematical Physics*, Wiley Eastern, New Delhi, 2005.
3. C. Harper, *Introduction to Mathematical Physics*, Prentice Hall of India, New Delhi, 2004.
4. M.R. Spiegel, *Schaum's Outline of Advanced Mathematics for Engineers and Scientists*, 1st Ed., McGraw Hill, 2009.

Unit-I : Arfken and Weber, Harper, Spiegel, Chattopadhyay

Unit-II : Arfken and Weber
Unit-III : Arfken and Weber, Chattopadhyay
Unit-IV : Arfken and Weber, Spiegel
Unit-V : Arfken and Weber, Spiegel

References

1. L.A. Pipes, *Applied Mathematics for Engineers and Physicists*, McGraw-Hill, 1958.
2. M.L. Boas, *Mathematical Methods in the Physical Sciences*, 3rd Ed., John Wiley, 2005.
3. M.R. Spiegel, Seymour Lipschutz, John J. Schiller, and Dennis Spellman, *Schaum's outlineof Complex Variables*, 2nd Ed., McGraw Hill, 2009.
4. B.D.Gupta, *Mathematical Physics*, 4th Ed., Vikas Publishing House, 2009.
5. S.Hassani, *Mathematical Physics: A Modern Introduction to Its Foundations*, 2nd Ed., Springer, 2013.
6. P.K. Chattopadhyay, *Mathematical Physics*, 1st Ed., New Age International, 2009.

Course Nature : Theory							
Assessment Method (Max.Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH102	**Classical Mechanics**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To emphasize the mathematical formulation of mechanics problems and to physically interpret the solutions.	a	b	c	e	l
2	To apply the fundamental concepts of classical mechanics to the particle systems and rigid bodies.	a	b	l		
3	To lay the solid background of mathematical methods to employ in modern physics.	a	b	c	e	l
4	To develop problem solving and critical thinking skills.	c	d	e	f	j

UNIT – I INTRODUCTION

Review of Newtonian mechanics, principle of virtual work, Lagrange's equations of first kind, D'Alembert's principle, degrees of freedom, types of constraints, variational principle; generalised coordinates and velocities, Lagrangian and equations of motion, cyclic coordinates, Hamiltonian.

UNIT – II LAGRANGIAN AND HAMILTONIAN FORMALISM

Hamiltonian formalism, Hamilton's equations of motion, Hamilton's principle; Poisson brackets and canonical transformations, definition of canonical transformations, conditions for canonicality, Poisson brackets, Poisson's theorem, Jacobi-Poisson theorem, Hamilton Jacobi equation, symmetry, invariance and Noether's theorem.

UNIT – III RIGID BODY DYNAMICS

Frames of reference, rotating frames, centrifugal and Coriolis forces, rigid body dynamics, angular momentum and kinetic energy, moment of inertia and inertia tensor, Euler equations, torque free motion of rigid body, motion of heavy symmetric top.

UNIT – IV PERIODIC MOTION

Periodic motion, types of equilibrium and the potential at equilibrium, phase space dynamics, stability analysis; small oscillations, free vibrations, normal coordinates and its applications to chain molecules (triatomic).

UNIT – V SPECIAL RELATIVITY

Lorentz transformation, relativistic kinematics and dynamics, $E=mc^2$, four-vector notation, energy-momentum four-vector for a particle, relativistic invariance of physical laws.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. H. Goldstein, C. Poole and J. Fafko, *Classical Mechanics*, Pearson EducationInc., 2002.
2. K.C. Gupta, *Classical Mechanics of Particles and Rigid Bodies*, Wiley Eastern, 2006.
3. J.R. Taylor, *Classical Mechanics,* 1st Ed., University Science Books, 2005.
4. D. Morin, *Introduction to Classical Mechanics*, 1st Ed., Cambridge University Press, 2008.
5. R.G. Takwale, and P.S. Puranik, *Introduction to Classical Mechanics*, Tata McGraw-Hill Education, 1979.

References

1. Percival and D. Richards, *Introduction to Dynamics*, Cambridge University press, 1982.
2. Rana and Joag, *Classical Mechanics*, Tata McGraw-Hill, 1991.
3. Landau and Lifshitz, *Mechanics*, Butterworth-Heinemann, 1982.
4. J.W. Harald and Muller-Kirsten, *Classical Mechanics and Relativity*, 1st Ed., World scientific Publishing Ltd, 2008.
5. D.Strauch, *Classical Mechanics - An Introduction*, 5th Ed., Springer, 2009.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH103	Electrodynamics	3	1	-	1	4	4

Instructional Objectives At the end of this course the learner is expected:		Student Outcomes				
1	To develop theoretical knowledge in electrodynamics.	a	b	c	e	l
2	To develop skills on solving analytical problems in electrodynamics.	c	d	e	f	j
3	To understand the electrodynamics of radiating and relativistic systems.	a	b	c		
4	To give basics of defining the complete electromagnetic response of complex systems.	a	b	c	e	l

UNIT – I MAXWELL'S EQUATIONS

Electrodynamics before Maxwell: Gauss law, electric scalar potential, Laplace's and Poisson's equations, Biot-Savart's law, divergence and curl of magnetic field, magnetic vector potential, Ampere's law and Faraday's law.

Electrodynamics after Maxwell: Maxwell's modification to Ampere's law, Lorentz force, Maxwell's equations in matter, boundary conditions, continuity equation.

UNIT - II ELECTROMAGNETICWAVES

Poynting's theorem, Poynting vector, electromagnetic waves in vacuum, transverse nature of electromagnetic waves, energy and momentum in electromagnetic fields, electromagnetic waves in matter, reflection and transmission at oblique incidence, absorption and dispersion, electromagnetic waves in conductor, skin depth, reflection at a conducting surface, frequency dependence of permittivity.

UNIT - III POTENTIALS AND FIELDS

Scalar and vector potentials, gauge transformations: Coulomb gauge and Lorentz gauge, retarded potentials, Jefimenko's equations, Lienard-Wiechert potentials, fields of moving point charge.

UNIT - IV RADIATION

Electric dipole radiation, magnetic dipole radiation, radiation from an arbitrary source, power radiated by a point charge: Larmor formula and Lienard's relativistic generalization, radiation reaction: Abraham-Lorentz formula, physical basis of radiation reaction.
Plasma oscillations: Debye wave number and Landau damping.

UNIT – V RELATIVISTIC ELECTRODYNAMICS

Lorentz transformations, Lorentz transformation matrix, covariant and contravariant vectors, magnetism as a relativistic phenomenon, electromagnetic field transformation and field tensor, Maxwell's equations and Lorentz force law using tensor notation, current density four-vector, relativistic potentials.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. D.J. Griffiths, *Introduction to Electrodynamics,* 4th Ed., Prentice-Hall India, 2013.
2. J.D. Jackson, *Classical Electrodynamics*, 3rd Ed., Wiley 1998.

References

1. J.D. Jackson, *Classical Electrodynamics*, 1st Ed., Wiley, 1974.
2. E.C. Jordan, and K. G. Balmain, *Electromagnetic Waves and Radiating Systems*, Prentice Hall, 1995.
3. Schwinger *et. al.*, *Classical Electrodynamics*, Persesus Books, 1998.
4. G.S. Smith, *Classical Electromagnetic Radiation*, Cambridge, 1997.

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<tr><td colspan="8">Course Nature : Theory</td></tr>
<tr><td colspan="8">Assessment Method (Max. Marks: 100)</td></tr>
<tr><td rowspan="2">In Semester</td><td>Assessment Tool</td><td>Cycle Test I</td><td>Cycle Test II</td><td>Model Examination</td><td>Assignment</td><td>Attendance</td><td>Total</td></tr>
<tr><td>Marks</td><td>10</td><td>10</td><td>20</td><td>5</td><td>5</td><td>50</td></tr>
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	End Semester	50
	Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH104	**Electronic Devices and Applications**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To enhance comprehension capabilities of students through understanding of electronic devices.	a	b	c	e	l
2	To give clear understanding of operational amplifier and its importance.	a	b	l		
3	To understand the physical construction, working and operational characteristics of semiconductor devices.	a	b	c	g	h
4	To introduce the basic building blocks of linear integrated circuits & digital converters.	a	b	c	g	h
5	To introduce the basics of microprocessor and microcontrollers.	a	b	g	h	j

UNIT – I SEMICONDUCTOR DEVICES AND POWER DEVICES

Fundamentals: Classification based on band gap: insulator, conductors and semiconductors, n-type and p-type semiconductors, understanding the p-n junction, forming a p-n junction, diffusion-“built-in” electric field, forward bias, reverse bias, I-V characteristics, breakdown voltage.

Zener diode, Schottky barrier diode, varactor diode, light emitting diode (LED), surface emitting LED, edge emitting LED, seven segment display, solar cells, photodiodes, photo-conductive cells, photo transistors, tunnel diode and its working principle, unijunction transistor, p-n-p-n devices and characteristics, thyristor, silicon controlled switch (SCS).

UNIT - II OPERATIONAL AMPLIFIER

Op-amp parameters, ideal op-amp, open loop op-amp configuration-differential amplifier, inverting amplifier, non-inverting amplifier, equivalent circuit of an op-amp, ideal voltage transfer curve; op-amp linear application-dc amplifier, ac amplifier, summing amplifier, scaling amplifier, averaging amplifier, instrumentation amplifier, integrator, differentiator, solving problems using integrator and differentiator.

UNIT – III APPLICATIONS OF OPERATIONAL AMPLIFIER

Active filters low-pass, high-pass, band-pass, band-reject, all-pass filter, waveform generators: square wave, triangular, saw tooth, comparators: basic comparator types, characteristics, applications, zero crossing detector, Schmitt trigger, log-antilog amplifiers, a stable and monostable multivibrators using op-amp.

UNIT – IV ANALOG TO DIGITAL (A/D) AND DIGITAL TO ANALOG (D/A) CONVERTER

Basic introduction to logic gates and flip flops, digital clock, different types of registers, serial in serial out, serial in parallel out, parallel in serial out and parallel in parallel out and applications, asynchronous and synchronous counters, decade counters, sample and hold circuits, types of D/A converter, binary weighted resistors, A/D converter, flash converter, successive approximation, astable and monostable multivibrators using 555 timer.

UNIT - V MICROPROCESSOR

Registers, bus organized computers, microprocessor, 8085 architecture, qualitative overview of memory interfacing, interfacing i/o devices. **Assembly language programming**: instruction classification, addressing modes, timing diagram, data transfer, logic and branch operations-programming examples.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. R.L. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory*, 9th Ed., Pearson Education, 2009.
2. T.L. Floyd, *Electronic devices*, 9th Ed., Pearson Education. Ltd., 2013.
3. A.R. Gayakwad, *Op-amps and linear integrated circuits*, 3rd Ed., Prentice-Hall, Inc., 2000.
4. D.P. Leach, A.P Malvino and G. Saha, *Digital Principles and Applications*, 7th Ed., 2011.
5. R.S. Gaonkar, *Microprocessor Architecture, Programming & Applications with 8085*, Prentice Hall, 2002.

Unit-I : Boylestad, Floyd
Unit-II : Gayakwad
Unit-III : Gayakwad
Unit-IV : Leach
Unit-V : Gaonkar

References

1. W.D. Stanley, *Operational amplifiers with linear integrated circuits*, 4th Ed., Pearson Education India, 2002.
2. D.D. Givone, *Digital Principles and Design*, Tata McGraw-Hill, 2002.

3. K. Udaya Kumar, *The 8085 Microprocessor: Architecture, Programming and Interfacing*, Pearson Education India, 2008.
4. A. Sproul, *Understanding the pn Junction Solar Cells*, Resources for the Secondary Science Teacher (2003): 13-24.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH105	**General Physics Laboratory**	**-**	**-**	**6**	**-**	**6**	**3**

Instructional Objectives At the end of this course the learner is expected:		**Student Outcomes**				
1	To make the students familiarize with the basics of experimental physics.	a	b	c	g	j
2	To enable the students to explore the concepts involved in the thermodynamic processes.	a	b	c	e	g
3	To make the students understand the basics of modern optics.	a	b	c	g	k
4	To make the students verify experimentally the basic laws of physics.	a	c	e	g	h

List of experiments (any nine experiments and a virtual lab):

1. Determination of Stefan-Boltzmann's constant by studying the radiation received from a blackbody radiator as a function of time.
2. Measurement of a diameter of given thin wire using interference pattern formed due to an air wedge between two glass plates.
3. Paramagnetic susceptibility of a $FeCl_3$ solution at variable magnetic fields using Quincke's tube method and deducing the magnetic moment of the ion.
4. To study the rate of flow of heat through a material per unit-area per unit-temperature gradient and to determine the thermal conductivity of the bad conductor using Lee's disc method.
5. Cornu's method of determination of elastic constants-Young's modulus and Poisson's ratio of a transparent beam by formation of Newton's rings.
6. Temperature characteristics of a thermistor using Wheatstone network and to determine the band gap of the material of the thermistor.

7. Determination of compressibility of a liquid and study of parameters-wavelength and velocity of the ultrasonic wave in liquid using ultrasonic interferometer.
8. To plot the current-voltage characteristics of a photo-resistor at constant irradiance and to measure the photo-current as a function of irradiance at a constant voltage.
9. Measurement of numerical aperture and attenuation characteristics of the optical fiber for variable lengths.
10. Determination of Young's modulus of a material of a beam by uniform bending using single optic lever.
11. Study of Fresnel diffraction at straight edge and a slit.
12. Study of Fraunhofer diffraction at a single slit.
13. To determine the refractive indices of liquids using hollow prism.
14. To study the characteristics and dead time of a GM Counter.
15. To study Poisson and Gaussian distributions using a GM Counter.

Virtual lab: Choose one virtual experiment from physical sciences at http://vlab.co.in/.

Text Books

1. D.Chattopadhyay, P.C.Rakshit, and B.Saha, *An Advanced Course in Practical Physics*, 6th Ed., 2002.
2. Wersnop and Flint, *Advanced Practical Physics for Students*, 2nd Ed., Methuen Publishers, 2007.
3. J. Singh, *Semiconductor Devices: Basic Principles,* John Wiley, 2001.
4. D.R. Behekar, S.T. Seman, V.M. Gokhale., and P.G. Kale, *Practical Physics*, KitabMahal Publication, 2000.
5. A.C. Mellissinos, *Experiments in Modern Physics*, 2nd Ed., Academic Press, 2003.
6. D.P.Khandelwal, *A Laboratory Manual of Physics for Undergraduate Classes*, Vani Publishing House, 2002.
7. G.L. Squires, *Practical Physics*, 4th Ed., Cambridge University Press, 2001.

Course Nature : Practical				
Assessment Method (Max. Marks: 100)				
In Semester	Assessment Tool	Evaluation of Experiments	Model exam	Total
	Marks	40	10	50
			End Semester	50
			Total	100

SEMESTER II

Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH201	**Mathematical Physics-II**	**3**	**1**	**-**	**1**	**4**	**4**
Instructional Objectives At the end of this course the learner is expected:			**Student Outcomes**				
1	To introduce advanced mathematical methods in physics and their applications.		b	c	e	f	j

2	To enable students to use mathematical concepts required in physics.	c	d	e	l	
3	To develop expertise in solving the complex problems in physics.	c	d	e	f	h
4	To prepare the students to formulate, interpret and draw inferences from complex physical concepts.	b	c	f	h	l

UNIT – I ELEMENTARY NUMERICAL ANALYSIS

Numerical differentiation, numerical integration by Simpson and Trapezoid rules, numerical solution of differential equations by Euler and Runge-Kutta method, finite difference method, linear and non-linear least square fitting, generation of random numbers, Monte-Carlo technique, integration, simulations.

UNIT – II SPECIAL FUNCTIONS

Bessel function of first and second kind, generating function, integral representation and recurrence relations for Bessel's functions of first kind, orthogonality, Legendre function: generating function, recurrence relations and special properties, orthogonality; various Legendre polynomials, associated Legendre functions: recurrence relations, parity and orthogonality; Hermite functions and Laguerre function: generating function, recurrence relations and orthogonality.

UNIT – III FOURIER SERIES AND INTEGRAL TRANSFORMS

Fourier series, general properties, advantages and applications, Gibbs phenomenon; development of the Fourier integral, inversion theorem, Fourier transform, Fourier transforms of derivatives, applied optics momentum representation; Laplace transforms, Laplace transforms of derivatives, properties of Laplace transform, inverse Laplace transformation.

UNIT – IV INTEGRAL EQUATIONS

Definitions and classifications: Fredholm, Volterra equations of first and second kind, transformation of a differential equation into an integral equation, Neumann series, Separable kernels, Hilbert-Schmidt theory: symmetrization of Kernels, orthogonal eigenfunctions, non-homogeneous integral equation, Green's function in one dimension.

UNIT – V GROUP THEORY

Basic definitions, multiplication table, conjugate elements and classes, subgroups, direct product of groups, isomorphism and homomorphism, permutation groups, definition of representation and its properties, reducible and irreducible presentation, Schurs' Lemmas (statements only), orthogonal theorem, characters of a representation, Lie groups, three dimensional rotation group, unitary groups: SU(2), O(3), SO(2).

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. J.H. Mathews, *Numerical Methods: for Mathematics, Science and Engineering*, 2nd Ed., Prentice-Hall International, 1992.

2. G. Arfken and H.J. Weber, *Mathematical Methods for Physicists*, Academic Press, 6th Ed., San Diego, 2005.
3. P.K. Chattopadhyay, *Mathematical Physics*, Wiley Eastern, New Delhi, 2005
4. C. Harper, *Introduction to Mathematical Physics*, Prentice Hall of India, New Delhi, 2004.
5. P.L. Devries, *A First Course in Computational Physics*, Wiley, New York, 1994.
6. A.W. Joshi, *Matrices and Tensors in Physics*, Wiley Eastern, New Delhi, 2002.

Unit-I : Devries, Mathews
Unit-II : Arfken and Weber, Chattopadhyay, Harper Unit-
III : Arfken and Weber, Chattopadhyay, Harper Unit-IV :
Arfken and Weber, Chattopadhyay, Harper Unit-V :
Joshi, Chattopadhyay

References

1. L.A. Pipes, *Applied Mathematics for Engineers and Physicists*, McGraw-Hill, 1958.
2. B.S. Rajput, *Mathematical Physics*, Pragati Prakashan, 2015.
3. M.L. Boas, *Mathematical Methods in the Physical Sciences*, 3rd Ed., John Wiley, 2005.
4. B.D.Gupta, *Mathematical Physics*, 4th Ed., Vikas Publishing House, 2009.
5. S.Hassani, *Mathematical Physics: A Modern Introduction to Its Foundations*, 2nd Ed., Springer, 2013.

Course Nature : Theory							
Assessment Method (Max.Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH202	**Quantum Mechanics-I**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives		**Student Outcomes**				
At the end of this course the learner is expected:						
1	To understand the inadequacy of classical physics and the need for quantum theory of radiation and matter.	a	b	c		j
2	To learn the general formalism and the mathematical background of Schrodinger's quantum theory.	a	b	c	l	
3	To obtain analytical solutions of simple systems in one, two and three dimensions.	c	d	e		
4	To develop problem solving skills.	c	d	e	f	l

UNIT – I GENERAL FORMALISM

Inadequacy of classical physics, wave-particle duality, wave packets, postulates of quantum mechanics, wave function and its physical interpretation (eigenvalues and eigenvectors, orthonormality, completeness, closure), time-dependent Schrodinger equation, time-independent Schrodinger equation, continuity equation, Dirac notation, dynamical variables and operators, Hermitian operators, expectation values, generalized uncertainty relation, change of basis and unitary transformations, Ehrenfest theorem.

UNIT – II QUANTUM DYNAMICS

Time evolution operator, Schrodinger and Heisenberg pictures of time evolution, time variation of expectation values, one-dimensional barrier, quantum tunneling effect, infinite and finite square well, harmonic oscillator in one dimension, analytic method, abstract operator method.

UNIT – III SYMMETRIES AND QUANTUM MECHANICS IN THREE DIMENSIONS

Symmetries in quantum mechanics-overview, spatial translation-continuous and discrete, time translation, parity, time reversal; Schrodinger equation in spherical, polar coordinate system.

UNIT – IV HYDROGEN ATOM

Angular equation, Legendre polynomials and spherical harmonics, radial equation, spherical trap, Laguerre polynomials (in connection with H-atom), energy quantization, hydrogen atom spectrum.

UNIT – V THEORY OF ANGULAR MOMENTUM

Angular momentum operators, ladder operators, commutation relation among operators, eigenvalues and eigenfunctions, space quantization, spin angular momentum, Pauli spin matrices and their eigenvalues and eigenvectors, addition of angular momentum, introduction to Clebsch-Gordon coefficients, irreducible tensor operators and Wigner-Eckart theorem.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. D.J. Griffiths, *Introduction to Quantum Mechanics*, 2nd Ed., Pearson Publication, 2009.
2. P.M. Mathews, K. Venkatesan, *A Textbook of Quantum Mechanics*, 2nd Ed., McGraw Hill, 2010.
3. R.L. Liboff, *Introductory Quantum Mechanics*, 4th Ed., Pearson Education, 2003.
4. V.K.Thankappan, *Quantum Mechanics*, 4th Ed., New Academic Science, 2005.
5. R. Shankar, *Principles of Quantum Mechanics*, 2nd Ed., Plenum Press, 1994.

Unit-I : Griffiths, Mathews & Venkatesan, Liboff
Unit-II : Griffiths, Mathews & Venkatesan, Thankappan
Unit-III : Mathews & Venkatesan, Griffiths, Shankar
Unit-IV : Griffiths, Thankappan, Shankar
Unit-V : Griffiths, Mathews & Venkatesan, Thankappan

References

1. Y. Peleg, R. Pnini, E. Zaarur, E. Hecht, *Schaum's Outline of Quantum Mechanics*, 2nd Ed.,

McGraw Hill, 2010.
2. L.I. Schiff, *Quantum Mechanics*, 3rd Ed., McGraw Hill Book Company, 1968.
3. J.J. Sakurai, *Modern Quantum Mechanics*, 2nd Ed., Pearson, 2014.
4. E. Merzbacher, *Quantum Mechanics*, 3rd Ed., Wiley India Pvt. Ltd, 2011.
5. B.H. Bransden, C.J. Jochain, *Quantum Mechanics*, 2nd Ed., Pearson Education, 2007.
6. S. Prakash, *Advanced Quantum Mechanics*, Revised Ed., Pragathi Prakashan Publishing Limited, 2008.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH203	**Condensed Matter Physics-I**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To understand the basics of crystal structures and crystal systems.	a	b	c		
2	To realize the nature of bonding and binding in all crystals.	a	b	c	l	
3	To make students familiar with elastic waves and phonons.	a	b	c	e	
4	To enhance the ability of students to understand electron and band theories.	c	d	e	f	l

UNIT – I CRYSTALS

Crystal lattices, Bravais lattices, lattices with basis, Wigner Seitz unit cells, reciprocal lattice, Brillouin zone, X-ray and electron diffraction; Ewald's sphere, structure factors.

UNIT – II BONDING IN CRYSTALS AND ELASTIC CONSTANTS

Crystals of inert gases, ionic crystals, covalent crystals, metals, hydrogen bonds, atomic radii, analysis of elastic strains, elastic compliance and stiffness constants, elastic waves in cubic crystals.

UNIT – III CRYSTAL VIBRATIONS AND THERMAL PROPERTIES

Vibrations of crystals with monatomic basis, two atoms per primitive basis, quantization of elastic waves, phonon momentum, inelastic scattering by phonons, phonon heat capacity, anharmonic crystal interactions, thermal conductivity.

UNIT – IV FREE ELECTRON THEORY

Energy levels in one dimension, effect of temperature on the Fermi, Dirac distribution, free electron gas in three dimensions, heat capacity of the electron gas, electrical conductivity and Ohm's law, thermal conductivity of metals.

UNIT – V ENERGY BANDS

Nearly free electron model, Bloch functions, Kronig-Penney model, wave equation of electron in a periodic potential, number of orbitals in a band, tight binding approximation, Orthogonal Plane Wave (OPW) method, pseudo potential method.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. C. Kittel, *Introduction to Solid State Physics*, 8th Ed., J. Wiley and Sons, 2005.
2. M.A. Wahab, *Solid state Physics*, 2nd Ed., Narosa Publishing House, 2006.
3. G.D. Mahan, *Condensed Matter in a Nutshell*, 1st Ed., Princeton University Press, 2010.

Unit-I : Kittel
Unit-II : Kittel
Unit-III : Kittel
Unit-IV : Kittel, Mahan
Unit-V : Kittel, Wahab

References

1. N.W. Ashcroft and D.M. Mermin, *Solid State Physics*, Holt, Rinehart and Winston, 1976.
2. A.J. Dekker, *Solid State Physics*, Macmillan, 2009.
3. M.A. Omar, *Elementary Solid State Physics*, Addison-Wesley, 2009.
4. H.P. Myers, *Introduction to Solid State Physics*, Taylor and Francis, 1997.
5. S.O. Pillai, *Solid State Physics*, New Age International Publishers, 2002.
6. F. Han, *Problems in Solid State Physics with Solutions*, World Scientific, 2011.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH204	Statistical Mechanics and Thermodynamics	3	1	-	1	4	4
Instructional Objectives At the end of this course the learner is expected:			**Student Outcomes**				
1	To understand basic principles of thermodynamics.		a	b	c	e	
2	To develop an understanding of the statistical mechanics.		a	b	c	j	
3	To acquire the knowledge of various statistical distributions.		a	b	c	e	l
4	To understand the applications of statistical mechanics in broad areas of modern physics.		c	d	e	f	h

UNIT – I THERMODYNAMICS

Principles of thermodynamics, first law of thermodynamics, heat and work, isothermal and adiabatic process, second law of thermodynamics, concept of entropy, entropy change in reversible and irreversible process, Carnot's cycle, Carnot's engine and its efficiency, third law of thermodynamics, thermodynamic potentials: internal energy, enthalpy, Helmholtz free energy, Gibbs free energy, Maxwell relations.

UNIT - II ELEMENTS OF STATISTICAL MECHANICS

Review of elementary probability theory, random variables, binomial, Poisson and normal distributions, central limit theorem, postulates of statistical mechanics, thermodynamic limit, contact between statistics and thermodynamics, entropy of mixing and Gibb's paradox, Sackur - Tetrode equation.

UNIT – III ENSEMBLE DESCRIPTION

Phase space, trajectories and density of states, Liouville's theorem, ensemble descriptions: microcanonical, canonical ensemble, partition function, partition function of an ideal monatomic and diatomic gas, thermodynamic properties, energy fluctuations in canonical ensamble, grandcanonical ensemble, grand partition function, density fluctuation in grandcanonical ensemble, equivalence of canonical and grandcanonical ensemble, equipartition theorem and virial theorem.

UNIT – IV STATISTICAL DISTRIBUTIONS

Distinguishable particles: Maxwell-Boltzmann distribution, indistinguishable particles: Fermi-Dirac and Bose-Einstein statistics, examples: Bose-Einstein condensation, superconductivity, the electron gas, blackbody radiation and Planck's distribution law.

UNIT – V PHASE TRANSITIONS AND FLUCTUATIONS

First order phase transitions, Clausius-Clapeyron equation, phase diagrams; Landau theory of phase transition: Landau free energy, derivation in simple models, Ising model: definition, the Bragg-William approximation, one dimensional Ising model. **Fluctuations:** thermodynamic fluctuations, random walk and Brownian motion, diffusion equation.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. M. Zemansky, and R. Dittman, *Heat and Thermodynamics*, 8th Ed., McGraw-Hill Education, 2011.
2. R.K. Pathria, P.D. Beale, *Statistical Mechanics*, 3rd Ed., Elsevier, 2011.
3. F. Reif, *Fundamentals of Statistical and Thermal Physics*, Waveland Press, 2009.
4. K. Huang, *Statistical Mechanics*, 2nd Ed., Wiley, 2008.

References

1. L.D. Landau and E.M. Lifshitz, *Statistical Physics*, 3rd Ed., Pergamon Press, 1980.
2. R.E. Sonntag, G.J. Van Wylen, *Introduction to Thermodynamics, Classical and Statistical*, 3rd Ed., Wiley, 1991.
3. J.M. Seddon and D. Julian, *Thermodynamics and Statistical Mechanics*, 3rd Ed., RSC publication, 2001.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH205	Electronics & Computer Laboratory	-	-	6	-	6	3
Instructional Objectives **At the end of this course the learner is expected:**			**Student Outcomes**				
1	To familiarize the students with electronic instruments and computer applications		b	c	d	f	g
2	To impart hands-on experience on verification of circuit laws and theorems.		b	c	g	h	l
3	To study experimentally the characteristics of diodes, BJT's and FET's.		a	b	c	g	
4	To make the student understand the basic concepts in multivibrators, ICs and digital devices		a	c	d	e	g

UNIT – I ELECTRONICS LABORATORY

List of experiments (any ten experiments):

1. To verify the network theorem.
2. To study the characteristics of the following.
   a. Current vs. voltage.
   b. Rectifiers.
   c. Filtering and ripple.
   d. Diode clamps.
3. To obtain common emitter/base/collector characteristics of NPN/PNP transistor.
4. To understand working of transistor as a switch and to draw DC load line for the given circuit.
5. To observe input-output waveforms of common emitter (CE) amplifier and to measure gain of amplifier at different frequencies and plot frequency response.
6. To observe input-output waveforms of common collector (CC) amplifier and to measure gain of amplifier at different frequencies and plot frequency response.
7. To measure the gain of two stage RC coupled amplifier.
8. To measure the gain of FET common source (CS) amplifier.
9. UJT characteristics and design of sawtooth wave oscillator.
10. To observe the input and output characteristics of adder, subtractor, differential amplifier, inverting amplifier and non-inverting amplifier, summing amplifier by using IC741.
11. Design of square wave generator using IC 741 and Timer 555 ICs - 555 IC as VCO.
12. Design of monostable multivibrator using the ICs 741 and 555 timer- study of frequency divider.
13. Design of Schmitt's trigger using the ICs 741 and 555 timer.
14. Counters and shift registers using ICs 7476/7473.
15. Design of binary weighted and R/2R Ladder DAC using the IC 741.
16. Construction of ADC using DAC, comparator and counter.

Text Books

1. D.A. Bell, *Laboratory manual for Electronic Devices and Circuits*, 4th Ed., Oxford University Press, 2009.

2. N. Ahlhelm, *Lab Experiments in Digital Electronics*, Create Space Independent Publishing Platform, 2010.
3. A.Gaykwad, *Operational Amplifier and Linear Integrated Circuits,* 11th Ed., Prentice Hall, 2006.
4. D.A. Bell, *Fundamentals of Electrical Circuits: Lab Manual*, 4th Ed., Oxford University Press, 2009.
5. L.K Maheswari and M.M.S. Anand, *Laboratory Manual for Introductory Electronic Experiments*, New Age, 2010.
6. M. Wiesner, *Lab Experiments-Digital Electronics*: *A Practical Approach*, Prentice Hall, 2009.
7. S. Salivahanan and N. Suresh Kumar, *Electronic Devices and Circuits*, Tata McGraw-Hill, 2011.

UNIT – II COMPUTER LABORATORY

Introduction, computer hardware, software, C++/Fortran programming language, algorithms, structured programming, data and statements, I/O statements, control statements, unconditional and conditional looping, break and continue statements, nested loops, arrays and structures.

List of numerical problems (any ten problems):

1. Generation of waves on superposition like stationary waves and beats.
2. Fourier analysis of square waves.
3. To find the roots of quadratic equations.
4. Construction of wave packet and verification of uncertainty principle.
5. Find first order derivative at given x for a set of 10 values with the help of Lagrange interpolation.
6. To generate random numbers between (i) 1 and 0, (ii) 1 and 100.
7. Perform numerical integration on 1-D function using Simpson and Weddle rules.
8. To find determinant of a matrix - its eigenvalues and eigenvectors.
9. To demonstrate the frequency and amplitude modulation.
10. Motion of one-dimensional simple harmonic oscillator using Euler's method.
11. To study the motion of electron in cathode ray tube.
12. Choose a set of 15 data points and find the least squared fitted curve.
13. Solution of n simultaneous linear equations using Gauss elimination method.
14. Brownian motion using Monte Carlo method.
15. Nuclear radioactive decay using Monte Carlo method.
16. Monte Carlo determination of pi.

Text Books

1. W.H. Press*et al., Numerical Recipes in C++: The Art of Scientific Computing*, 2nd Ed., Cambridge University Press, 2002.
2. E. Balagurusamy, *Object Oriented Programming with C++*, 2nd Ed., Tata McGraw-Hill, 2002.
3. P.L. DeVries, *A first course in Computational Physics*, 2nd Ed., Wiley, 2011.
4. S. Chandra, *Computer Applications in Physics*, 2nd Ed., Narosa Publishing House, 2008.
5. R.C. Verma, P.K. Ahluwalia and K.C. Sharma, *Computational Physics*, 1st Ed., New Age, 2005.

Course Nature : Practical				
Assessment Method (Max. Marks: 100)				
In Semester	Assessment Tool	Evaluation of Experiments	Model exam	Total
	Marks	40	10	50
			End Semester	50
			Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH206	**Seminar**	-	-	2	-	2	1

Instructional objectives At the end of this course the learner is expected:		**Student Outcomes**				
1.	To develop student strength in organizing and presenting acquired knowledge coherently.	a		b		
2.	Communicate effectively with a wide range of audiences.	a	b	k		

Course Nature : Practical						
Assessment Method (Max. Marks: 100)						
In Semester	Seminar I		Seminar II			
Assessment Tools	Presentation	Interaction	Abstract	Presentation	Interaction	Total
Marks	30	20	10	30	10	100
Total						100

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SEMESTER III

Course Code	Course Title	L	T	P	O	L+T+P	C

18PPH301	Quantum Mechanics-II		3	1	-	1	4	4
Instructional Objectives **At the end of this course the learner is expected:**			**Student Outcomes**					
1	To learn the use of approximation methods of quantum mechanics.		a	b	c	d	e	
2	To understand basic concepts of scattering amplitude, symmetries in scattering and to solve scattering problems, to work with partial wave analysis.		b	c	d	e	f	
3	To introduce relativistic quantum mechanics: Klein-Gordan and Dirac equations.		b	c	d	e	l	
4	To learn to describe the many-body systems and solve problems using various approximation techniques.		c	d	e	f	l	

UNIT – I APPROXIMATION METHODS-I

Time-independent perturbation theory for discrete levels, non-degenerate cases and degenerate case, removal of degeneracy, Zeeman effect, Stark effect, spin-orbit coupling, fine structure of hydrogen.

UNIT – II APPROXIMATION METHODS-II

Time-dependent perturbation theory, constant and harmonic perturbations, Fermi's golden rule and its application to radiative transition in atoms, selection rules for emission and absorption of light, Einstein's coefficients, spontaneous and stimulated, variational method, ground state of helium atom, WKB approximation.

UNIT – III IDENTICAL PARTICLES

Systems of identical particles, symmetric and anti-symmetric wave functions, bosons and fermions, Pauli's exclusion principle, second quantization (postulates), occupation number representation.

UNIT – IV SCATTERING THEORY

Non-relativistic scattering theory, scattering amplitude and cross-section, the integral equation for scattering, Born approximation, partial wave analysis, optical theorem.

UNIT – V RELATIVISTIC QUANTUM MECHANICS

Elements of relativistic quantum mechanics, Klein-Gordon equation, Dirac equation, Dirac matrices, spinors, positive and negative energy solutions, physical interpretation, nonrelativistic limit of the Dirac equation, second quantization and real scalar field.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. D.J. Griffiths, *Introduction to Quantum Mechanics*, 2nd Ed., Pearson Publication, 2009.

2. P.M. Mathews, K. Venkatesan, *A Textbook of Quantum Mechanics*, 2nd Ed., McGraw Hill, 2010.
3. R. Shankar, *Principles of Quantum Mechanics*, 2nd Ed., Plenum Press, 1994.
4. F. Schwabl, *Advanced Quantum Mechanics*, Springer, 2005.
5. V.K. Thankappan, *Quantum Mechanics*, 4th Ed., New Academic Science, 2005.

Unit-I : Griffiths, Thankappan, Shankar
Unit-II : Griffiths, Thankappan, Shankar
Unit-III : Griffiths, Mathews & Venkatesan
Unit-IV : Griffiths, Thankappan, Liboff
Unit-V : Mathews & Venkatesan, Thankappan, Schwabl

References

1. L. Schiff, *Quantum Mechanics*, McGraw-Hill, 1968.
2. J. J. Sakurai, *Modern Quantum Mechanics*, Benjamin /Cummings, 1985.
3. L.D. Landau and E. M. Lifshitz, *Quantum Mechanics - Nonrelativistic Theory*, 3rd Ed., Pergamon, 1981.
4. R.L. Liboff, *Introductory Quantum Mechanics*, 4th Ed., Pearson Education Inc., 2003.
5. F. Schwabl, *Quantum Mechanics*, Narosa Publishing House, 1998.
6. J. Bjorken and S. Drell, *Relativistic Quantum Mechanics*, McGraw-Hill, 1965.
7. P.A.M. Dirac, *The Principles of Quantum Mechanics*, Oxford University Press, 1991.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH302	**Condensed Matter Physics-II**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To extend the knowledge of band theory in semiconductors.	a	b	c	d	l
2	To understand the various electric field and magnetism related concepts of condensed matter physics.	a	b	c	d	h
3	To enhance the knowledge in understanding advanced topics such as superconductivity.	a	b	c	d	l
4	To realize the importance of defects and liquid crystals.	c	d	e	g	h

UNIT – I SEMICONDUCTOR CRYSTALS

Band gap, equations of motion, intrinsic carrier concentration, Hall effect, impurity conductivity, thermoelectric effects, semimetals.

UNIT - II DIELECTRICS AND FERROELECTRICS

Macroscopic electric field, local electric field at an atom, dielectric constant and polarizability, structural phase transitions, ferroelectric crystals, displacive transitions.

UNIT – III MAGNETISM

Langevin diamagnetism equation, quantum theory of diamagnetism of mononuclear systems, paramagnetism, quantum theory of paramagnetism, paramagnetic susceptibility of conduction electrons, ferromagnetic order, magnons, ferrimagnetic order, antiferromagnetic order, ferromagnetic domains.

UNIT – IV SUPERCONDUCTIVITY

Occurrence of superconductivity, Meissner effect, type I and type II superconductors, thermodynamics of superconducting transitions, origin of energy gap, isotope effect, London equations, London penetration depth, coherence length, elements of Bardeen-Cooper-Schrieffer(BCS) theory, flux quantization, normal tunneling and Josephson effect, high-T_c superconductors, superfluids.

UNIT – V DEFECTS AND DISORDERS

Lattice vacancies, diffusion, color centers, dislocations, quasi crystals, types of liquid crystals, classification, calamitic thermotropic liquid crystals, lyotropic liquid crystals, mesogenic materials.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. C. Kittel, *Introduction to Solid State Physics*, 8th Ed., J. Wiley and Sons, 2005.
2. S. Singh, *Liquid Crystals Fundamentals*, World Scientific Publishing Co. Pvt. Ltd., 2002.

Unit-I : Kittel
Unit-II : Kittel
Unit-III : Kittel
Unit-IV : Kittel
Unit-V : Kittel and Singh

References

1. N.W. Ashcroft and D.M. Mermin, *Solid State Physics*, Holt, Rinehart and Winston, 1976.
2. M.A. Wahab, *Solid State Physics*, 2nd Ed., Narosa Publishing House, 2006.
3. A.J. Dekker, *Solid State Physics*, Macmillan, 2009.
4. M.A. Omar, *Elementary Solid State Physics*, Addison-Wesley, 2009.
5. H.P. Myers, *Introduction to Solid State Physics*, Taylor and Francis, 1997.
6. S.O. Pillai, *Solid State Physics*, New Age International Publishers, 2002.
7. F. Han, *Problems in Solid State Physics with Solutions*, World Scientific, 2011.
8. H. Ibach and H. Luth, *Solid State Physics*, 4th Ed., Springer, 2010.
9. G.D. Mahan, *Condensed Matter in a Nutshell*, 1st Ed., Princeton University Press, 2010.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH303	**Atomic and Molecular Physics**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To develop the skills to solve real physical problems using quantum mechanics.	b	c	d	e	f
2	To provide the accomplishments necessary for advanced courses such as optics, astrophysics, condensed matter physics and nuclear physics.	b	c	d	e	l
3	To emphasize the modern developments in experimental techniques especially spectroscopy.	d	e	f	g	h
4	To realize the role and practical application of physics of atoms and molecules in the modern world.	f	g	h	j	l

UNIT – I ATOMIC PHYSICS I

Fine structure of hydrogen like atoms, mass correction, spin-orbit term, Darwin term, intensity of fine structure lines, the ground state of two-electron atoms, perturbation theory and variation method, many-electron atoms, *LS*- and *jj*-coupling schemes, Lande interval rule.

UNIT – II ATOMIC PHYSICS II

The idea of Hartree-Fock equations, the spectra of alkalis using quantum defect theory, selection rules for electric and magnetic multipole radiation, oscillator strengths and the Thomas-Reiche-Kuhn sum rule.

UNIT – III MOLECULAR STRUCTURE

Born-Oppenheimer separation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules, molecular orbital and valence bond methods for H_2^+ and H_2, correlation diagrams for heteronuclear molecules.

UNIT – IV MOLECULAR SPECTRA

Rotation, vibration-rotation and electronic spectra of diatomic molecules, the Franck-Condon principle, electron spin and Hund's cases, idea of symmetry for diatomic and polyatomic molecules.

UNIT – V LASERS

Multilevel rate equations and saturation, Rabi frequency, laser pumping and population inversion, He-Ne laser, solid state laser, free-electron laser, non-linear phenomenon, harmonic generation, laser accelerator, liquid and gas lasers, semiconductor lasers and diode.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. B.H. Bransden and C.J. Jochain, *Physics of Atoms and Molecules*, 2nd Ed., Pearson

Education, 2003.
2. E.U. Condon and G. H. Shortley, *The Theory of Atomic Spectra*, Cambridge University Press, 1989.
3. C.J. Foot, *Atomic Physics*, Oxford Univ. Press, 2005.
4. C.N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill, 2008.
5. W. Demtroder, *Atoms, Molecules and Photons*, Springer, 2006.

Unit-I : Bransden, Condon, Foot
Unit-II : Bransden, Condon, Foot
Unit-III : Banwell, Demtroder
Unit-IV : Banwell, Demtroder
Unit-V : Banwell, Demtroder

References

1. S.M. Hollas, *Basic Atomic & Molecular Spectroscopy*, Royal Society of Chemistry, 2002.
2. G. Herzberg, *Molecular Spectra and Molecular Structure*, Van Nostrand, 1950.
3. W. Demtroder, *Laser Spectroscopy*, 3rd Ed., Springer, 2003.
4. W. Demtroder, *Molecular Physics*, Wiley-VCR, 2005.
5. P.S. Sindhu, *Molecular Spectroscopy*, Tata McGraw-Hill, 1985.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH304	Project Phase I	-	-	8	-	8	4

	Instructional objectives At the end of this course the learner is expected:	Student Outcomes				
1.	To be proficient in experimental/theoretical research	a	b			
2.	To be able to analyze and interpret scientific data and present it in a coherent fashion	a	k			

Course Nature : Practical						
Assessment Method (Max. Marks: 100)						
In Semester	Review I		Review II			
Assessment Tools	Literature survey and short write up	Seminar	Statement of proposed research	Oral Presentation	Interaction	Total
Marks	30	20	20	20	10	100
Total						100

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MAJOR ELECTIVE - I

Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH3EA	Structure and Properties of Materials	3	1	-	1	4	4

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To understand the basics of structure and properties of materials.	a	b	c	d	g
2	To realize the importance of defects, diffusion and phase transitions in materials.	b	c	d	e	l
3	To make students familiar with advanced materials.	b	d	e	g	i

UNIT – I INTRODUCTION AND STRUCTURE OF MATERIALS

Properties of materials: structure of atoms, quantum states, atomic bonding in solids, binding energy, interatomic spacing, chemical bonding, ionic/covalent/metallic/secondary bonding, variation in bonding character and properties.

UNIT – II CRYSTAL DEFECTS AND THEIR SIGNIFICANCE

Point defects: thermodynamics, Schottky and Frenkel defect, Kroger-Vink notation, defect interactions, dislocations, burgers vector, types of dislocations, dislocation movement, slip systems, energetics of dislocations and their interactions, planar defects: stacking faults, grain boundaries (low angle and high angle), antiphase domain boundaries, twinning surface defects with relevance to thin films, non-equilibrium structures such as metallic glasses.

UNIT – III DIFFUSION

Fick's law of diffusion, solution to Fick's second law, application of Fick's second law, Kirkendall effect, atomic mechanisms of diffusion, interstitial diffusion, steady state and non-steady state diffusion, substitutional diffusion, self-diffusion, vacancy diffusion, diffusion in alloys.

UNIT – IV PHASE DIAGRAMS

Gibbs phase rule, phase equilibria (single and multicomponent systems), solid solutions and alloys, phase diagrams, single component systems, eutectic phase diagram, lever rule, iron carbide phase diagram, study of properties of phase diagrams, nucleation kinetics and growth, kinetics of transformation, homogeneous and heterogeneous nucleation, differential scanning calorimetry.

UNIT – V COMPOSITES

Types of composite materials, the concept of load transfer, matrix materials, polymers, metals and ceramics, classification of polymers, copolymers, tacticity, geometric isomerism, crystallization of polymer, fibers: glass, boron, carbon, organic and metallic fibers, fiber packing arrangements, particle reinforced composites, structural composites.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. V. Raghavan, *Material Science & Engineering*, Prentice –Hall of India, New Delhi, 2001.
2. W.D. Callister Jr., *Materials Science and Engineering: An Introduction*, 7th Ed., John Wiley & Sons, 2007.
3. B.S. Mitchell, *An Introduction to Materials Engineering and Science for Chemical and Materials Engineers*, 1st Ed., Wiley, 2003.
4. W. Smith, J. Hashemi, *Foundations of Materials Science and Engineering*, 5thEd., McGraw-Hill Education, 2009.

References

1. J. I. Gersten, F. W. Smith, *The Physics and Chemistry of Materials*, Willey, 2001
2. C.R. Barrett, A. S. Tetelman, W. D. Nix, *The Principles of Engineering Materials*, Facsimile Ed.,Pearson, 1973.
3. D.A. Porter, K. E. Easterling, M. Y. Sherif, *Phase Transformations in Metals and Alloys*, CRC Press, New York, 2009.
4. L. Hollaway, *Handbook of Polymer Composites for Engineers*, Woodhead Publishing, 1994.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title		L	T	P	O	L+T+P	C
18PPH3EB	**Photonics**		**3**	**1**	**-**	**1**	**4**	**4**
Instructional Objectives **At the end of this course the learner is expected:**			**Student Outcomes**					
1	To develop theoretical and practical knowledge in photonics.		a	b	c	d		g
2	To understand basic concepts of photonics at nanoscale.		a	b	c	d		e
3	To familiarize with the latest developments in photonics and its applications.		b	d	e	g		i

UNIT – I NONLINEAR OPTICS

Linear optics: homogeneous isotropic media, wave propagation in linear isotropic media, anisotropic materials, tensor nature of anisotropy, harmonic oscillator: optical response, nonlinear optical susceptibility: susceptibility tensor, wave propagation in nonlinear media, second harmonic generation.

UNIT – II LIGHT SCATTERING

Extinction, scattering, and absorption cross sections, optical theorem, light scattering from small objects, Mie theory, Mie scattering, Rayleigh scattering, importance of scattering and extinction in optical experiments.

UNIT - III NEAR-FIELD OPTICS

Angular spectrum representation of optical fields, far-field and evanescent field, angular spectrum representation of dipole field, scanning near-field optical microscopy, overcoming diffraction limit, applications of optical near-field.

UNIT – IV PLASMONICS

Dielectric response of metals, frequency dependence of permittivity, dispersion relationship, plasmons, surface plasmons and localized surface plasmons, classical free electron theory of metals, Drude model permittivity, conductivity, excitation of surface plasmons: Otto and Kretschmann configurations, application of surface plasmons, plasmons in semiconductors and other novel plasmonic materials.

UNIT – V OPTICAL PROPERTIES OF MATERIALS

Complex dielectric function and refractive index, optical properties of metals, permittivity of metals, damping constant, optical properties of semiconductors, optical properties of semiconductor nanocrystals: quantum dots, excitons, optical properties of novel materials like graphene and topological insulators.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. R. Boyd, *Nonlinear Optics*, 3rd Ed., Academic Press, 2008.
2. C.F. Bohren, D. R. Huffman, *Absorption and Scattering of Light by Small Particles,* Wiley-VCH, 2008.
3. J.D. Jackson, *Classical Electrodynamics*, 3rd Ed., John Wiley & Sons, 2005.
4. S.A Maier, *Plasmonics: Fundamentals and Applications*, Springer, 2007.
5. S.V. Gaponenko, *Optical Properties of Semiconductor Nanocrystals*, Cambridge University Press, 1998.

References

1. H.C. van de Hulst, *Light Scattering by Small Particles,* 3rd Ed., Dover Publications, 2009.
2. L. Novotny and B. Hecht, *Nano-Optics*, Cambridge Press, 2012.
3. D.J. Griffiths, *Introduction to Electrodynamics*, 4th Ed., Prentice-Hall India, 2014.
4. F.J. Garcia de Abajo, "Graphene Plasmonics: Challenges and Opportunities." *ACS Photonics* 1.3 (2014): 135-152.
5. W.L. Barnes, *et al., "*Surface Plasmon Sub-wavelength Optics", Nature 424.6950 (2003): 824-830.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH3EC	**Computational Physics**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To understand the basics of computational physics.	b	c	d	e	j
2	To study numerical algorithms and their implementation to solve problems.	c	d	e	f	i
3	To learn different optimization methods, probability, random number generation.	b	c	d	e	f
4	To understand different methods like kinetic Monte Carlo, molecular dynamics, density functional theory.	c	d	e	f	l

UNIT – I BASICS OF COMPUTATIONAL PHYSICS

Introduction and objectives of computational physics, review of basic programing language (C++) *e.g.* algorithms, structured programming, numerical precisions, data and statements, i/o statements, control statements, unconditional and conditional looping, break and continue statements, concepts of arrays and pointers, basic idea of scientific and parallel computing.

UNIT – II INTEGRAL AND DIFFERENTIAL EQUATIONS

Integral equations: calculation of scattering cross section (quantum scattering with a spherically symmetric potential)
Ordinary differential equations: classical electrons in crossed electric and magnetic fields
Partial differential equations: Laplace's equation, wave equations, diffusion equation and Maxwell's equations.

UNIT – III SCHRODINGER EQUATION

Solution of the generalized eigenvalue problem, perturbation theory and solution of Schrödinger equation for electrons in atoms by Hartree-Fock, Slater approximation, Born-Oppenheimer approximation, self-consistent procedure, first principles method, introduction to density functional theory (DFT), Hohenberg-Kohn theorems, Kohn-Sham approach, exchange correlation functional: LDA and GGA, other XC functional.

UNIT – IV MOLECULAR DYNAMICS SIMULATIONS

Integration methods, molecular dynamics simulations, classical and tight binding molecular dynamics, Langevin dynamics simulations for Brownian motion, simulations of planetary motion, oscillatory motion, chaotic motion, quantum molecular dynamics for hydrogen molecule.

UNIT – V THE MONTE CARLO METHOD

Monte Carlo simulations with various ensembles (random number generations), estimation of energy and chemical potential, Ising model, quantum Monte Carlo, genetic algorithms, transfer matrix methods for spin chains, finite element method for partial differential equations.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. E. Balagurusamy, *Object Oriented Programming with C++*, 2nd Ed., Tata McGraw-Hill, 2002.
2. J.M. Thijssen, *Computational Physics*, Cambridge University Press, 2007.
3. N.J. Giordano, *Computational Physics*, Prentice-Hall, Upper Saddle River NJ, 1997.
4. D. Frenkel and B. Smith, *Understanding Molecular Simulations*, Academic Press, 2002.
5. J.G. Lee, *Computational Materials Science*, 2nd Ed., CRC Press, Taylor and Francis Group, LLC. 2016

References

1. S. E. Koonin and D. C. Meredith, *Computational Physics: Fortran Version*, Addison-Wesley, 1990
2. W.H. Press, B.P. Flannery, S.A. Teukolsky, W.T. Vetterling, *Numerical Recipes in C*, 2nd Ed., Cambridge Univ. Press, 1992.
3. I. Prigogine and S.A. Rice, *New Methods in Computational Quantum Mechanics*, Wiley,

1996
4. D. Potter, *Computational Physics*, Wiley, New York NY, 1973.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH3ED	**Sensors**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives At the end of this course the learner is expected:		**Student Outcomes**				
1	To understand the principles of sensors.	a	b	c	d	e
2	To study different types of sensors.	a	b	c	d	e
3	To realize the applications of sensors in and around us.	b	d	e	g	i

UNIT – I SENSOR CHARACTERISTICS AND PHYSICAL EFFECTS

Active and passive sensors, static characteristics, accuracy, offset and linearity, dynamic characteristics, first and second order sensors, physical effects involved in signal transduction, photoelectric effect, photoluminescence effect, electroluminescence effect, Hall effect, thermoelectric effect, piezoresistive effect, piezoelectric effect, magneto resistive effect.

UNIT – II PHYSICAL SENSORS

Introduction, temperature sensors, sensors for aerospace and defense, accelerometer, pressure sensor, strain sensors, flow rate sensors, speed sensors, optical sensors, mechanical sensors, Anisotropic Magneto-Resistive (AMR) sensors, giant and colossal magneto resistors, magnetic tunneling junctions.

UNIT – III CHEMICAL SENSORS

Introduction, thermal sensors, mass sensors, electrochemical sensors, potentiometric sensors, amperometric sensors, conductometric sensors, optical sensors, sensitivity and selectivity, sensor arrays.

UNIT – IV BIOSENSORS

Description of biosensors, biomolecules used in biosensors and immobilization methods, properties and characteristic of biosensors and performance factors, enzymatic biosensors, immuno biosensors, DNA biosensors, cell based biosensors, electrochemical biosensor, optical biosensors.

UNIT – V SENSORS AND THEIR APPLICATIONS

On-board automobile sensors, home appliance sensors, aerospace sensors, medical diagnostic sensors, sensors for food monitoring, sensors for environmental monitoring.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. J. Vetelino and A. Reghu, *Introduction to Sensors*, 1st Ed., CRC Press, 2011.
2. J. Fraden, *Handbook of Modern Sensors: Physics, Designs, and Applications*, 4th Ed., Springer, 2010.
3. J. Janata, *Principles of Chemical Sensors*, 2nd Ed., Springer US, 2009.
4. J. Cooper, and T. Cass, *Biosensors*, 2nd Ed., Oxford University Press, USA, 2004.

Unit-I : Vetelino and Reghu
Unit-II : Fraden
Unit-III : Janata
Unit-IV : Cooper, and Cass
Unit-V : Vetelino and Reghu

References

1. A. Mulchandani, K. R. Rogers, *Enzyme and Microbial Biosensors-Techniques and Protocols*, Humana Press, Totowa, New Jersey, 1998.
2. F.-G. Bănică, *Chemical Sensors and Biosensors: Fundamentals and Applications*, John Wiley & Sons Ltd., 2012.
3. P. Gründler, *Chemical Sensors*, Springer-Verlag Berlin Heidelberg, 2007.
4. G. Meijer, *Smart Sensor Systems*, Wiley, 2008.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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SEMESTER IV

Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH401	Nuclear and Particle Physics	3	1	-	1	4	4

Instructional Objectives At the end of this course the learner is expected:		Student Outcomes				
1	To introduce students to the fundamental principles and concepts governing nuclear and particle physics.	a	b	c	d	e
2	To know about nuclear physics' scientific and technological applications as well as their social, economic and environmental implications.	c	d	e	f	j
3	To understand the concept of elementary particles.	a	b	c	d	e

UNIT – I BASIC PROPERTIES OF NUCLEI

The nuclear radius, nuclear size determination from electron scattering, nuclear form-factors, mass and abundance of nuclides, nuclear binding energy, nuclear angular momentum and parity, nuclear electromagnetic moments, nuclear excited states angular momentum, spin and moments of nuclei.

UNIT – II NUCLEAR FORCES

Dipole and quadrupole moments of the deuteron, central and tensor forces, evidence for saturation property, neutron-proton scattering, exchange character, spin dependence (ortho- and para-hydrogen), charge independence and charge symmetry, isospin formalism; general form of the nucleon-nucleon force, *s*-wave effective range theory, proton-proton scattering, evidence for hardcore potential.

UNIT – III NUCLEAR MODELS AND REACTIONS

The shell model, Nilson model, physical concepts of the unified model, electromagnetic decays: selection rules, electron capture and beta decays, energy relations and q-values in beta decays, Fermi theory of beta decay, Curie plots, Fermi and Gamow-Teller transitions, classification of beta transitions, selection rules for allowed and forbidden transitions, parity violation in beta-decay; Wu-Ambler experiment, helicity of electron and of neutrino; introduction to nuclear reactions: compound nuclear reactions and direct reactions.

UNIT – IV NUCLEAR DETECTORS

Interaction of radiation with matter: charged and neutral (qualitative overview), Ge and Si solid state detectors, calorimeters and their use for measuring jet energies; scintillation and Cerenkov counters, qualitative ideas; hybrid detectors and their applications.

UNIT – V ELEMENTARY PARTICLES

Relativistic kinematics, classification: spin and parity determination of pions and strange particles, Gell-Mann Nishijima scheme, properties of quarks and their classification, elementary ideas of SU(2) and SU(3) symmetry groups and hadron classification, the baryon decuplet, baryon octet, meson octet, quark spin and color, quark-antiquark combination; introduction to the standard model; qualitative idea of electroweak interaction - W & Z bosons.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

TEXT BOOKS

1. K.S. Krane, *Introducing Nuclear Physics*, Wiley India, 2008.
2. R.R. Roy and B.P. Nigam, *Nuclear Physics: Theory & Experiments*, New Age International, 2005.
3. S.S.M. Wong, *Introductory Nuclear Physics*, 2nd Ed., Wiley VCH, 2004.
4. C.A. Bertulani, *Nuclear Physics in a Nutshell*, 1st Ed., Princeton University Press, 2007.
5. D. Griffiths, *Introduction to Elementary Particles*, 2nd Ed., Academic Press, 2008.

Unit-I : Krane, Roy and Nigam, Wong
Unit-II : Krane, Roy and Nigam, Wong
Unit-III : Krane, Roy and Nigam, Wong
Unit-IV : Krane, Ref: Cohen
Unit-V : Krane, Wong, Griffiths

References

1. B.L. Cohen, *Concept of Nuclear Physics*, McGraw-Hill, 2003.
2. B. Martin, *Nuclear & Particle Physics: An Introduction*, Willey, 2006.
3. H.S. Hans, *Nuclear Physics: Experimental and Theoretical*, 2nd Ed., New Academic Science Ltd., 2010.
4. K. Heyde, *Basic Ideas and Concepts in Nuclear Physics*, 2nd Ed., Overseas Press, India, 2005.
5. I. Kaplan, *Nuclear Physics*, Addison Wesley, (Indian Ed., from Narosa Publishing House, New Delhi), 2002.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH402	**Advanced Laboratory**	**-**	**-**	**6**	**-**	**6**	**3**
Instructional Objectives **At the end of this course the learner is expected:**						**Student Outcomes**	

1	To gain knowledge on the synthesis procedures of various nanomaterials.	b	c	e	g	i
2	To understand laboratory experiments to investigate the properties of materials.	d	e	f	g	h
3	To learn the operation of the advanced characterization instruments.	g	h	i	j	l
4	To apply the basics of computational modeling and simulation using DFT.	d	e	f	i	k

List of Experiments:

1. Preparation of metal oxide nanoparticles using wet chemical precipitation method and determination of its phase, strain, crystallite size and lattice parameters using X-ray diffraction technique.
2. Metal oxide nano thin film fabrication using dip coating / spin coating technique and determination of film thickness using scanning electron microscopy (SEM) and composition using EDS.
3. Determination of roughness, and depth profile of metal oxide nano thin film fabricated using dip coating / spin coating technique by AFM.
4. Determination of Hall coefficient, carrier density and carrier mobility for a given semiconductor wafer.
5. Identification of functional groups using FTIR spectroscopy for polymer coated metal oxide nanoparticles synthesized using wet chemical precipitation method.
6. Determination of mineral concentration using XRF spectrometer for metal oxide / sulfide nanoparticles synthesized by chemical precipitation method.
7. Determination of the wavelength absorbance, particle size, and band gap using UV-Vis spectroscopy of metal oxide nano thin film fabricated using dip coating / spin coating technique
8. Determination of resistivity of germanium crystal at different temperature and estimation of energy band gap using four probe method.
9. Modeling, geometrical optimization and determination of total energy, and HOMO-LUMO gap of simple organic and inorganic molecules using Gaussview and Gaussian09.
10. Solve Schrodinger wave equation in one dimension for harmonic oscillator using Numerov's method.
11. Calculation of scattering of light from metallic nano particles using MNPBEM toolbox in matlab.

References

1. V. Raghvan, *Experiments in Materials Science*, 5th Ed., PHI Learning Pvt. Ltd., 2004.
2. P.M. Martin, *Handbook of Deposition Technologies for Films and Coatings*, 3rd Ed., Elsevier Inc., 2010.
3. Gauglitz, Günter, and Tuan Vo-Dinh, *Handbook of spectroscopy*, John Wiley and Sons, 2006.
4. Yang Leng, *Materials Characterization: Introduction to Microscopic and Spectroscopic Methods*, John Wiley and Sons, 2009.
5. Brundle, C. Richard, and Charles A. Evans, *Encyclopedia of Materials Characterization: Surfaces, Interfaces, Thin Films*, Gulf Professional Publishing, 1992.
6. Pretsch, Ernö, et al. *Structure Determination of Organic Compounds*, Vol. 13. Berlin: Springer, 2009.
7. Mario Birkholz, *Thin Film Analysis by X-ray Scattering*, John Wiley and Sons, 2006.
8. E.Hairer, S.P.Norsett, and G. Wanner, *Solving Ordinary, Differential Equations I*, Vol.1, 2000.
9. F. J. Garcı´a de Abajo, and A. Howie, *Retarded field calculation of electron energy loss in inhomogeneous dielectrics*, Phys. Rev. B 65, 115418, 2002.

Course Nature : Practical				
Assessment Method (Max. Marks: 100)				
In Semester	Assessment Tool	Evaluation of Experiments	Model exam	Total
	Marks	40	10	50
			End Semester	50
			Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPPH403	Project Phase II	-	-	16	-	16	8

<table>
<tr><td colspan="2">Instructional objectives
At the end of this course the learner is expected:</td><td colspan="5">Student Outcomes</td></tr>
<tr><td>1.</td><td>To be proficient in experimental/theoretical research</td><td>a</td><td>b</td><td></td><td></td><td></td></tr>
<tr><td>2.</td><td>To be able to analyze and interpret scientific data and present it in a coherent fashion</td><td>a</td><td>k</td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="8">Course Nature : Practical</td></tr>
<tr><td colspan="8">Assessment Method (Max. Marks: 100)</td></tr>
<tr><td rowspan="3">In Semester</td><td rowspan="2">Assessment Tool</td><td rowspan="2" colspan="1">Seminar</td><td colspan="4">Review III</td><td rowspan="2">Total</td></tr>
<tr><td colspan="2">Overview of the Dissertation</td><td>Research Findings</td><td>Oral Presentation and Interaction</td></tr>
<tr><td>Marks</td><td>10</td><td colspan="2">10</td><td>20</td><td>10</td><td>50</td></tr>
<tr><td rowspan="3">External Examination</td><td rowspan="2">Assessment Tool</td><td colspan="4">Project evaluation</td><td rowspan="2">Viva Voce</td><td rowspan="3">50</td></tr>
<tr><td colspan="2">Dissertation</td><td>Presentation</td><td>Research Outcome</td></tr>
<tr><td>Marks</td><td colspan="2">20</td><td>10</td><td>10</td><td>10</td></tr>
<tr><td colspan="7">Total</td><td>100</td></tr>
</table>

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MAJOR ELECTIVE-II

Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH4EA	Nanoscience and Nanomaterials	3	1	-	1	4	4

Instructional Objectives At the end of this course the learner is expected:		Student Outcomes				
1	To comprehend the principles of nanotechnology.	a	b	c	d	e
2	To make the students understand the basic concepts in nanoscience.	a	b	c	d	e
3	To enable the students to explore the field of nanomaterials.	d	e	i	j	l
4	To allow the students to have a deep knowledge of the fundamentals of nanomolecular materials.	b	c	d	e	l

UNIT – I INTRODUCTION TO NANOSCALE PHYSICS

Difference between bulk and nanoscale materials and their significance, zero dimensional, one-dimensional and two dimensional nanostructures, quantum dots, calculation of the density of states (DOS) in 1, 2 and 3 dimensions, nano ribbons and nanowires, carbon nanotubes, chiral vector and chiral angle, different types of carbon nanotubes, fullerenes/buckyballs/C60.

UNIT - II PROPERTIES OF NANOMATERIALS

Properties at the nanoscale, effect of confinement, quantum confinement, size quantization effect on electronic state, the Brusequation, relation between metal nanoparticle size with colour, surface plasmon, surface-to-volume ratio, chemical properties of nanomaterials.

UNIT - III SYNTHESIS OF NANOMATERIALS

Top-down approach and bottom-up approach, nanolithography, photolithography, electron-beam lithography, bottom-up approach, chemical methods, sol-gel processing, hydrothermal process.

UNIT – IV CHARACTERIZATION OF MATERIALS

Optical characterization (UV-Vis, PL, Raman), phenomena of diffraction radiation, X-ray diffraction, phase identification, Scherrer formula, strain and grain size determination, scanning electron microscope (SEM), transmission electron microscope (TEM), atomic force microscope (AFM), scanning tunneling microscopy (STM-basic).

UNIT – V APPLICATIONS OF NANOMATERIALS

Applications: nanoparticle-based drug delivery, storage devices and nanomaterial based Li-ion battery, TiO_2 photocatalysis, spintronic devices and spin field effect transistors (SPINFET), magnetic tunnel junction based devices and tunnel magnetoresistance effect in tunnel junction.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. T. Pradeep, *A Textbook of Nanoscience and Nanotechnology*, Tata McGraw Hill Education, 2012.
2. G. Cao, Y. Wang, *Nanostructures and Nanomaterials: Synthesis, Properties, and Applications*, 2nd Ed., Imperial College Press, 2004.
3. D. Bucknall, *Nanolithography and Patterning Techniques in Microelectronics*, CRC Press, 2005.
4. T.K. Sau, A.L. Rogach, *Complex-shaped Metal Nanoparticles: Bottom-Up Syntheses and Applications*, 1st Ed., Wiley-VCH, 2012.
5. P. Bandyopadhyay, M.Cahay, *Introduction to Spintronics*, 2nd Ed., CRC Press, 2015.

References

1. D. Sangeeta, J.R. LaGraff, *Inorganic Materials Chemistry Desk Reference*, 2nd Ed., CRC Press, 2004.
2. B.S. Murty, P. Shankar, B. Raj, B.B. Rath, J.Murday, *Textbook of Nanoscience and Nanotechnology*, Springer-Verlag Berlin Heidelberg, 2013.
3. B. Bhushan, *Springer Handbook of Nanotechnology*, Springer-Verlag Berlin Heidelberg, 2004.
4. G. L. Hornyak, H.F. Tibbals, J. Dutta, J. J. Moore, *Introduction to Nanoscience and Nanotechnology*, CRC Press, 2008.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title		L	T	P	O	L+T+P	C
18PPH4EB	Thin Film Technology		3	1	-	1	4	4
Instructional Objectives **At the end of this course the learner is expected:**			**Student Outcomes**					
1	To impart a sound basis for an understanding of vacuum technology.		a	b	c	d		e
2	To provide a fundamental knowledge on various principles and methods used in the synthesis of materials in thin film form.		a	b	c	d		e
3	To introduce nucleation and growth mechanisms of thin films based on thermodynamics and molecular theory.		d	e	i	j		l
4	To familiarize with physics and techniques involved in the measurement and characterization of thin films.		b	c	d	e		l

UNIT – I VACUUM TECHNOLOGY

Fundamentals of vacuum, basic definition and pressure regions of vacuum, kinetic theory of gases mean free path, types of flow, conductance, vacuum pumps and systems, rotary mechanical pump, roots pump, diffusion pump, turbo molecular pump, sputter ion pump, measurement of vacuum, concept of different gauges, capacitance gauges, Pirani gauge, ionization gauge and penning gauge, vacuum system components and operation.

UNIT – II PHYSICAL METHODS OF THIN FILM DEPOSITION

Thermal evaporation, resistive heating, flash evaporation, laser evaporation, rf-heating, co-evaporation, electron bombardment heating, sputtering plasma, discharges and arc, sputtering variants, sputtering yield low pressure sputtering, rf-sputtering, reactive sputtering, magnetron sputtering, magnetron configurations, bias sputtering, evaporation versus sputtering.

UNIT – III CHEMICAL METHODS OF THIN FILM DEPOSITION

Electrodeposition, electrolytic deposition, electro less deposition, anodic oxidation, spray pyrolysis, spin and dip coating, chemical vapor deposition (CVD), homogenous and heterogeneous process, CVD reactions, pyrolysis, hydrogen reduction, halide disproportionation, transfer reactions, CVD processes and systems, low pressure CVD, laser enhanced CVD, metalorganic CVD (MOCVD).

UNIT – IV GROWTH OF THIN FILMS AND THICKNESS MEASUREMENTS

Introduction: nucleation and early stages of film growth, thermodynamic aspects of nucleation, capillary theory, thin film growth modes Volmert, Weber (VW) growth, Frank-van der Merwe (FM) growth, Stranski-Krastanov growth, thickness measurement, electrical methods, microbalance monitors, quartz crystal monitor, mechanical method (stylus), optical interference methods, ellipsometry, interference fringes.

UNIT – V CHARACTERIZATION METHODS OF THIN FILMS

X-ray diffraction (XRD), scanning electron microscopy, transmission electron microscopy, energy dispersive analysis, Auger electron spectroscopy, X-ray photoelectron spectroscopy, Rutherford backscattering spectroscopy, secondary ion mass spectrometry.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. M. Ohring, *Materials Science of Thin Films: Deposition and Structure*, 2nd Ed., Academic Press (An Imprint of Elsevier), 2002.
2. S. Campbell, *The Science and Engineering of Microelectronic Fabrication*, 2nd Ed., OUP, 1996.
3. Kaufmann, *Characterization of Materials*, 2nd Ed., Wiley, 2003.

References

1. N.Yoshimura, *Vacuum Technology: Practice for Scientific Instruments*, Springer Publications, 2007.
2. The Vacuum Technology Book Volume II, Pfeiffer Vacuum [Online Book]
3. R.F. Bunshah, *Handbook of Deposition Technologies for Films and Coatings, Science, Technology and Applications*, Noyes Publications, 1994
4. D.M. Hoffman, B. Singh and J.H. Thomas, *Handbook of Vacuum Science & Technology*, Academic Press, 1998.
5. K.L.Chopra, *Thin Film Phenomena*, Robert E.Krieger Publishing Company, 1979.
6. Z.L. Wang, *Characterization of Nanophase Materials,* Wiley, 2000.
7. St J.N. Braithwaite, "Introduction to gas discharges." *Plasma sources science and technology* 9.4 (2000): 517.
8. E. Ahmed, et al. "Significance of substrate temperature on the properties of flash evaporated CuIn 0.75 Ga 0.25 Se 2 thin films." *Thin Solid Films* 335.1 (1998): 54-58.
9. L.B. Jonsson, et al. "Frequency response in pulsed DC reactive sputtering processes." *Thin Solid Films* 365.1 (2000): 43-48.
10. J.B. Mooney, and S.B. Radding. "Spray pyrolysis processing." *Annual Review of Materials Science* 12.1 (1982): 81-101.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH4EC	**Atmospheric Physics**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To develop knowledge in atmospheric physics and its	a	b	c	d	e

	applications in meteorology.					
2	To create an awareness among students about our weather and climate systems.	a	b	c	j	l
3	To develop the ability to understand the atmospheric processes, interpret and draw inferences from the meteorological diagrams.	b	c	d	e	f

UNIT – I BASICS OF THE ATMOSPHERE AND RADIATION PRINCIPLE

Thermodynamic state of the atmosphere (pressure, density, temperature), equation of state, hydrostatic equilibrium, hypsometric equations, atmospheric structure, standard atmosphere, thermal structure of the atmosphere; components of meteorology, meteorological conventions ; **Radiation**- orbital factors, planetary orbits, orbits of the earth, seasonal effects, daily effects, sunrise, sunset, and twilight, flux, radiation principles, propagation, emission and distribution of solar energy, absorption reflection and transmission. Beer's law, surface radiation budget, solar radiation, longwave radiation.

UNIT - II ATMOSPHERIC THERMODYNAMICS

Heat-Sensible and latent heats, Lagrangian heat budget, first law of thermodynamics ; **Moisture-** measures of water vapour, saturation, humidity variables, lifting condensation level, isohumes, surface moisture flux, saturated adiabatic lapse rate ; **Stability-**stability of the atmosphere, parcel and slice methods-entrainment, dry and saturated adiabatic and processes, potential temperature, equivalent potential temperature, concept of lapse rate, dry adiabatic lapse rate, static energy, hydrostatic equation, convective instability, thermodynamic diagrams.

UNIT – III CLOUD PHYSICS AND AEROSOLS, OZONE AND TRACE GASES

Clouds- their formation and classification, cloud condensation nuclei, warm and cold clouds, cloud droplet growth, precipitation mechanisms, artificial precipitation, radar observation, measurement of rainfall, growth of cloud droplets Rain, hail and snow, structure of thunderstorms and mesoscale convective systems ; **Atmospheric aerosols**- ozone chemistry, atmospheric trace gases and their role in atmospheric chemistry and radiation budget.

UNIT – IV ATMOSPHERIC DYNAMICS AND ATMOSPHERIC BOUNDARY LAYER

Fundamental forces in meteorology - pressure, gravity, centripetal and Coriolis forces, momentum equations, inertial flow, geostrophic and gradient winds, thermal wind, divergence and verticalmotion, Rossby's, Reynold's, Richardson's and Froude's number, equation of motion, scale analysis, geostrophic and hydrostatic approximation, gradient wind, vertical variation of wind, thermal wind, continuity equation and convergence, circulation and vorticity, vorticity equation; **Atmospheric boundary layer(ABL)**-boundary layer formation, ABL structure and evolution, ABL equation, Ekman layer, turbulence kinetic energy, eddy transport of heat, water vapors and momentum, Richardson criterion.

UNIT – V WEATHER AND CLIMATE CHANGE

Weather-surface and upper air-pressure and wind systems, synoptic observations-surface and upper air-pressure and wind systems, tropical weather systems, ITCZ, tropical cyclones, western disturbances, jet streams, monsoons over India; **Climate-** components of climate system, atmospheric radiation budget and greenhouse effect and the science of climate change, role of aerosols in climate change.

Text Books

1. R.B. Stull, *Meteorology for Scientists and Engineers*, 2nd Ed., Brooks Cole, 2000
2. J.R. Holton, *An Introduction to Dynamic Meteorology*,5th Ed., Academic Press, 2012.
3. R.B. Stull, *An Introduction to Boundary Layer Meteorology*, Vol. 13. Springer Science & Business Media, 2012.
4. M. Salby, *Fundamentals of Atmospheric Physics*, 1st Ed., Academic Press, 1996.
5. P.A. Menon, *Our Weather*, National Book Trust, 1989.
6. J.T. Houghton and A. C. Bruce, *Climate Change*, Cambridge University Press, 1992.

Unit-I : Stull 2000, Salby
Unit-II : Salby, Holton, Stull 2000,Stull 2012
Unit-III : Salby, Stull 2000
Unit-IV : Stull 2012, Holton
Unit-V : Menon, Houghton

References

1. A.C. Donald, *Essentials of Meteorology*, Brooks Cole, 2008.
2. J.T. Houghton, *The Physics of the Atmospheres*, Cambridge University Press, 2009.
3. R.K. Pachauri *et al.*, *Intergovernmental Panel on Climate Change*, IPCC, Climate Change,2014.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course title	L	T	P	O	L+T+P	C
18PPH4ED	**High Energy Physics**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives At the end of this course the learner is expected:		**Student Outcomes**				
1	To have a thorough understanding of particle physics.	a	b	c	d	e
2	To learn particle physics at a level sufficient for graduate studies.	a	b	c	i	j
3	To understand the standard model of physics.	a	b	c	d	e
4	To be able to work in high energy physics phenomenology.	b	d	e	f	l

UNIT – I CONSERVATION LAWS AND SYMMETRIES

Review of concepts of spin, parity, isospin in particle physics, example of pion; charge conjugation invariance, G-parity, time reversal, CP-violation and CPT theorems, introduction to symmetries: discrete and continuous symmetries, examples, Young's tables and their relation to group theory, symmetry groups O(3), SU(2), SU(3) and SU(6),applications of symmetry groups to hadron spectroscopy: meson mixing, mass formulae.

UNIT - II QUARK MODEL

Introduction to constituent quark model, quantum number of quarks & valence quark contents of hardrons, introduction to quarkonia (charm and bottom systems), simple applications to hadron phenomenology, e.g., unitary spin & spin hadron wave function of mesons and baryons, baryon masses.

UNIT - III ELECTROMAGNETIC INTERACTIONS

Low energy electron nucleon scattering and form factors, electromagnetic form factors of nucleons, deep inelastic structure functions and introduction to parton model, gauge invariance; local, global transformations and charge conservation, Noether's Theorem.

UNIT - IV WEAK AND STRONG INTERACTIONS

Weak: Introduction to four fermion Fermi theory, Fermi transitions. Gamow-Teller transitions, development of V-A theory, weak neutral current and Glashow-Iliopoulos-Maiani (GIM), neutrino-nucleon scattering, electroweak unification.

Strong: Introduction to gauge field theories, including non-abelian gauge field Yang-Mills theory, elements of QCD, Feynman diagrams.

UNIT – V UNIFICATION SCHEMES

Global symmetry breaking and Goldstone bosons, mass term, local symmetry breaking and the Higgs boson, introduction to Glashow-Weinberg-Salam model, introduction to the Standard Model and Lagrangian.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. D. Griffiths, *Introduction to Elementary Particles*, 2nd Ed., Wiley VCH, 2008.
2. W.N. Cottingham, D. A. Greenwood, *An Introduction to the Standard Model of Particle Physics*, 2ndEd., Cambridge University Press, 2007.
3. D.H. Perkins, *An Introduction to High Energy Physics*, 4th Ed., Cambridge University Press, 2000.
4. I.S. Hughes, *Elementary Particles*, 3rd Ed., Cambridge University Press, 1996.
5. F.E. Close, *Introduction to Quarks and Partons*, Academic Press, London, 1981.
6. M.P. Khanna, *Introduction to Particle Physics*, 3rd Ed., Prentice-Hall of India, New Delhi, 2004.

Unit-I : Griffiths, Cottingham and Greenwood, Hughes Unit-II : Griffiths, Cottingham and Greenwood, Hughes Unit-III : Cottingham and Greenwood, Close, Khanna

Unit-IV : Cottingham and Greenwood, Close, Khanna
Unit-V : Cottingham and Greenwood, Close, Khanna

References

1. A. Bettini, *Introduction to Elementary Particle Physics*, Cambridge University Press, 2014.
2. C. Quigg, *Gauge Theories of Weak, Strong and Electromagnetic Interactions*, Gorden & Breach, New York, 1994.
3. T.P. Cheng and L.F. Li, *Gauge Theory of Elementary Particle Physics*, Oxford University Press, Oxford, 1982.
4. D.C. Joshi, *Introduction to Quantum Electrodynamics and Particle Physics*, I.K. International Publishing House Pvt. Ltd., New Delhi, 2006.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH4EE	Applied Optics	3	1	-	1	4	4

Instructional Objectives At the end of this course the learner is expected:		Student Outcomes				
1	To learn about the potential of optics applications in different areas of research and development.	a	b	c	d	i
2	To enable students to use their knowledge in designing optical techniques.	d	e	f	h	l
3	To enhance the employability of students in optics/photonics industry.	g	h	i	j	l

UNIT – I PHYSICAL OPTICS

Wave motion, superposition of waves, interference, diffraction, basics of coherence theory, temporal and spatial coherence, Michelson and Fabry-Perot interferometer, statistical properties of laser speckle patterns, information processing using speckle patterns, laser speckle contrast imaging.

UNIT – II PHOTONIC CRYSTALS AND METAMATERIALS

Photonics crystals- 2D & 3D, colloidal photonic crystals, light propagation through disordered media, localization of light, photonic glass, random lasing, optical metamaterials, optical properties of metal dielectric composites, electric & magnetic metamaterials, negative index metamaterials, nonlinear optics with metamaterials.

UNIT – III OPTICAL ENGINEERING

Image formation (first-order optics), aberrations, prisms and mirrors, stops and apertures, basic optical devices, the design of optical systems: general, aplanatic points, solid immersion lens, numerical aperture increasing lens.

UNIT – IV APPLICATIONS OF OPTICAL TECHNIQUES

Mie scattering technique, static & dynamic light scattering technique, optical tweezers, AFM colloidal probe technique, magnetic chaining technique, knife edge scanning to measure laser beam profile, knife edge scanning based liquid refractometer.

UNIT – V OPTICAL MICROSCOPY & IMAGING TECHNIQUES

Basics of optical microscopy, bright field and dark field microscopy, polarizing microscopy, phase contrast microscopy, fluorescence microscopy, fluorescence confocal microscopy, light sheet fluorescence microscopy, nonlinear optical microscopy, two photon fluorescence microscopy.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. M. Bornand, E. Wolf, *Principles of Optics*, 7th Ed., Cambridge University Press, 1999.
2. J.D. Joannopoulos, R. D. Meade, J. N. Winn, *Photonic Crystals: Molding the Flow of Light*, 2nd Ed., Princeton University Press, 2008.
3. V. Shalaevand W. Cai, *Optical Metamaterials: Fundamentals & Applications*, 2nd Ed., Springer, 2010.
4. W.J. Smith, *Modern Optical Engineering*, 3rd Ed., McGraw-Hill, 2000.
5. C.F. Bohren and D. R. Huffman, *Absorption and scattering of light by small particles*, Professional paperback Ed., Wiley-VCH, 1998.
6. J. Mertz, *Introduction to Optical Microscopy,* 1st Ed., Roberts& Company publishers, 2010.

References

1. J.C. Dainty, *Laser Speckles and Related Phenomena*, 1st Ed., Springer, 1975.
2. L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics*, Cambridge University Press, 1995.
3. R. Boyd, *Nonlinear Optics*, 3rd Ed., Elsevier 2008.
4. L. Novotny and B. Hecht, *Nano-optics*, Cambridge University Press, 2006.
5. McPhedran, Ross C., et al. "Metamaterials and metaoptics." *NPG Asia Materials* 3.11 (2011): 100-108.

6. T. Lee, B. Senyuk, R.P. Trivedi, and I.I. Smalyukh, *Colloids and Soft Materials: An introduction to soft matter physics, Chapter 10: Optical Microscopy of Soft Matter Systems*, Wiley, 2016.
7. P.Torokand, F.J. Kao, *Optical Imaging & Microscopy*, Springer, 2003.
8. E. Hecht, *Optics*, 5th Ed., Addison Wesley Publishing Company Incorporated, 2016.
9. J.N. Israelachvili, *Intermolecular and Surface Forces*, 3rd Ed., Elsevier, 2011.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH4EF	**Soft Matter and Biological Physics**	**3**	**1**	**-**	**1**	**4**	**4**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To acquire the basic knowledge on soft matter and biological systems.	a	b	c	d	e
2	To understand the physics of colloids and polymers.	a	b	c	d	e
3	To develop an understanding of the structure and function of proteins and nucleic acids.	a	b	c	d	e
4	To acquire knowledge about various biophysical experimental techniques	c	d	e	i	l

UNIT – I INTRODUCTION TO SOFT MATTER AND BIOLOGICAL SYSTEMS

Soft matter, examples: liquid crystals, colloids, polymers, membranes, biological systems: cells and organisms (single and multicellular), macromolecular constituents of life, lipids, proteins, sugars and nucleic acids, ions and their importance, general idea of transport inside cells, diffusion and active transport, length, time and energy scales in condensed matter system.

UNIT – II COLLOIDAL SYSTEMS AND POLYMERS

Colloids: examples, types of colloids, forces between colloidal particles, Derjaguin, Landau, Verwey, and Overbeek (DLVO) theory, stability of colloids, polymers: model systems, freely jointed chain model, worm like chain model, rubber elasticity, basic idea of viscoelasticity.

UNIT – III MEMBRANES

Lipid bilayers, hydrophobicity: entropy driven interactions, self-assembly, physics of membranes: elasticity, Helfrich energy, plasma membranes: architecture, composition, fluid-mosaic model for membranes, membrane channels, active pumps, function, osmotic and electrostatic activity**,** diffusion and permeability, different types of transport systems across membranes.

UNIT – IV STRUCTURE OF NUCLEIC ACIDS AND PROTEINS

DNA and RNA structures, double helix, structure of nucleotides, sugar-phosphate backbone, nuclear bases, tautomerisation and ionization, genetic code, twenty amino acids: structure and function, the peptide bond-primary structure of a protein, methods of sequence determination, forces determining protein structure- secondary structure of a protein, helix, sheet, turns, super secondary structures and domains, tertiary and quaternary structure of a protein, enzymes: M-M kinetics.

UNIT – V EXPERIMENTAL METHODS

Light microscopy basics, resolution of a microscope, phase contrast and differential interference contrast microscopy, principles of fluorescence microscopy, introduction to spectroscopy- UV-VIS and infrared spectroscopy, principles and applications of Raman spectroscopy, Nuclear Magnetic Resonance(NMR) basics, NMR spectroscopy and structure determination, examples, principles and applications of FTIR techniques.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. R.A.L. Jones, *Soft Condensed Matter*, OUP Oxford, 2002.
2. R. Phillips, J. Kondev, J. Theriot, H. Garcia, *Physical Biology of the Cell,*2nd Ed., Garland Science; 2012.
3. A.L. Lehninger, D.L. Nelson, M. M. Cox, *Principles of Biochemistry*, CBS Publishers, 1993.
4. C.N. Banwell, and E.M. McCash, *Fundamentals for Molecular Spectroscopy,* 4th Ed., McGraw-Hill Education, 1995.

References

1. I.W. Hamley, *Introduction to Soft Matter*, Wiley, 2000.
2. P. Nelson, *Biological Physics: Energy, Information, Life*, W. H. Freeman, 2003.
3. L. Stryer, *Biochemistry*, W.H. Freeman and Co., 1997.
4. P. Narayanan, *Essentials of Biophysics*, New Age International Publishers, 2008.
5. D.B. Murphy and M. W. Davidson, *Fundamentals of Light Microscopy and Electronic Imaging,* 2nd Ed., Wiley-Blackwell, 2013.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH4EG	Quantum Field Theory	3	1	-	1	4	4
Instructional Objectives				**Student Outcomes**			

At the end of this course the learner is expected:							
1	To apply the fundamental concepts of classical field theory.	a	b	c	d	e
2	To emphasize the mathematical formulation of second quantization problems and to physically interpret the solutions.	a	b	c	d	e
3	To lay the solid background of mathematical methods to use in field theories.	b	c	d	e	i
4	To develop problem solving and critical thinking skills.	d	e	f	i	l

UNIT – I CLASSICAL FIELD THEORY

Review of classical field theory, Lagrangian field theory, Lorentz invariance, Noether's theorem and conserved currents, Hamiltonian field theory.

UNIT – II CANONICAL QUANTIZATION

The Klein-Gordon equation, the simple harmonic oscillator, free quantum fields,vacuumenergy,particles,relativisticnormalization,complexscalar fields, the Heisenberg picture, causality and propagators, applications, non-relativistic field theory.

UNIT - III INTERACTING FIELDS

Types of interaction, the interaction picture, Dyson's formula, scattering, Wick's theorem, Feynman diagrams, Feynman rules, amplitudes, decays and cross sections, Green's functions, connected diagrams and vacuum bubbles, reduction formula.

UNIT – IV THE DIRAC EQUATION

The Lorentz group, Clifford algebras, the spinor representation, the Dirac Lagrangian,chiralspinors,theWeylequation,parity,Majoranaspinors,symmetries and currents, planewave solutions.

UNIT – V QUANTIZING THE DIRAC FIELD

A glimpse at the spin-statistics theorem, Fermionic quantization, Fermi-Dirac statistics, propagators, particles and antiparticles, Dirac's hole interpretation, Feynman rules, **Quantum electrodynamics:** gauge invariance, quantization, inclusion of matter – QED, Lorentz invariant propagators, Feynman rules, QED processes.

Tutorials: Tutorial sheet with relevant problems will be provided by the Instructor.

Text Books

1. M. Peskin and D. Schroeder, *An Introduction to Quantum Field Theory*, Addison-Wesley, 1995.
2. L. Ryder, *Quantum Field Theory*, 2nd Ed., Cambridge University Press, 1996.
3. M. Srednicki, *Quantum Field Theory*, 1st Ed., Cambridge University Press, 2007.

References

1. S. Weinberg, *The Quantum Theory of Fields*, Vol. 1, 1st Ed., Cambridge University Press, 2005.
2. A. Zee, *Quantum Field Theory in a Nutshell*, 2nd Ed., Princeton University Press, 2010.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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NON-MAJOR ELECTIVES
(OPEN ELECTIVES OFFERED TO OTHER DEPARTMENTS)

Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH2NA	**Introduction to Nanotechnology**	**2**	**-**	**-**	**-**	**2**	**2**

Instructional Objectives **At the end of this course the learner is expected:**		**Student Outcomes**				
1	To impart the basic knowledge on nanoscience and nanotechnology.	a	b	c	d	e
2	To develop understanding on the exotic properties of nanostructured materials.	a	b	c	d	e
3	To introduce various techniques available for the processing of nanostructured materials.	d	e	i	j	l
4	To emphasize the importance and development of nanotechnology in various fields	b	e	j	l	

UNIT – I INTRODUCTION TO NANOSCIENCE

History and importance of nanotechnology, opportunity at the nanoscale, length and time scale in structures, difference between bulk and nanoscale materials and their significance, properties at nanoscale, optical, electronic, magnetic and chemical.

UNIT – II NANOSTRUCTURES AND DIMENSIONS

Classification of nanostructures: zero, one, two and three dimensional nanostructures, size dependency in nanostructures, quantum size effects in nanostructures, chemistry of tailored nano shapes, quantum dots, nanowells, nanoribbons and nanowires.

UNIT – III SYNTHESIS OF NANOMATERIALS

Synthesis of nanomaterials, top down and bottom up approach, method of nanomaterials preparation, wet chemical routes of synthesis: reduction, sol-gel, hydrothermal, sonochemical synthesis, physical routes, physical vapor deposition (PVD), chemical vapor deposition (CVD), laser ablation, sputtering.

UNIT – IV CHARACTERIZATION OF NANOMATERIALS

Scanning electron microscope (SEM), transmission electron microscope (TEM), scanning probe microscope (SPM), comparing SEM, TEM and SPM for different classes of nanomaterials.

UNIT – V APPLICATIONS OF NANOMATERIALS

Nanotechnology in energy systems, textiles, food and health care, agriculture, automotive industry, solar technology, pharmaceutical and drugs, nanoelectronics, nanosensors and devices.

Text Books

1. T. Pradeep, *Nano: The Essentials*, 1st Ed., McGraw Hill, 2007.
2. Chattopadhyay, Banerjee, *Introduction to Nanoscience and Nanotechnology*, PHI, 2009.

References

1. C.Binns, *Introduction to Nanoscience and Nanotechnology*, Vol. 14, John Wiley & Sons, 2010.
2. P.C. Poole Jr, and F.J. Owens, *Introduction to Nanotechnology*, John Wiley & Sons, 2003.
3. R. Kelsall, I.W. Hamley, and M.Geoghegan, *Nanoscale Science and Technology*, John Wiley & Sons, 2005.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH2NB	**Laser Physics**	**2**	**-**	**-**	**-**	**2**	**2**

Instructional Objectives At the end of this course the learner is expected:		**Student Outcomes**				
1	To develop knowledge in the basics of lasers.	a	b	c	d	e
2	To enhance comprehension in the principles of lasers.	a	b	c	d	e
3	To explore the control of laser properties.	b	c	d	e	l
4	To familiarize with the diverse applications of lasers.	b	c	d	e	i

UNIT – I INTERACTION OF RADIATION WITH MATTER

Introduction to electromagnetic radiation, wavelength, wave number, frequency, interaction of light with atoms and molecules, absorption, emission, kinetics of optical absorption, stimulated and spontaneous emission, intensity of spectral lines, line broadening mechanism.

UNIT – II BASIC PRINCIPLES OF LASER

Principle of lasers, population inversion, conditions of lasing action, characteristics of a laser-coherence, monochromaticity, divergence, intensity, Einstein's co-efficients, laser pumping, two and three level laser systems.

UNIT – III TYPES OF LASERS

Solid state lasers, the ruby laser, Nd:YAG Laser, semiconductor lasers, features of semiconductor lasers, diode lasers, gas laser: He-Ne laser, CO_2laser, liquid lasers: dye lasers and chemical lasers.

UNIT – IV CONTROL OF LASER PROPERTIES AND PRODUCTION

Laser pumping, resonators, vibrational modes of resonators, number of modes/unit-volume, open resonators, control resonators, Q factor, losses in the cavity, threshold condition, quantum yield, mode locking (active and passive).

UNIT – V APPLICATIONS OF LASERS

Ether drift and absolute rotation of the earth-laser isotope separation, laser range finder- laser in pollution detection, holography- optical communication, optical fiber.

Text Books

1. B.B. Laud, *Lasers and Nonlinear Optics*, 3rd Ed, New Age Int.Pub.2011.
2. K. Thyagarajan, and A.K. Ghatak, *Lasers Theory and Applications*, 2nd Ed, Plenum Press, 1986.

References

1. A.K. Ghatak and K. Thyagarajan. *Optical electronics*, Cambridge University Press, 1989.
2. Seigman, *Lasers*, 3rdEd.,Oxford Univ. Press, 1986.
3. Maitland and Dunn, *Laser Physics*, N.H. Amsterdam, 1969.
4. J. Hecht, *The laser guidebook*, 1986.
5. O. Seelto, *Principles of Laser*, 5th Ed., Springer Publication,2010.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH3NA	Medical Physics	2	-	-	-	2	2

Instructional Objectives At the end of this course the learner is expected:		Student Outcomes				
1	To understand the general concepts in radiation and its interaction and dose measurement.	a	b	c	d	e
2	To apply the physics concepts in clinical trials.	a	b	c	d	e
3	To educate scientifically the principles of radiation and its effect in the medical field.	b	c	d	e	l
4	To emphasize the significance of various medical techniques and therapy.	b	c	d	e	i

UNIT – I IONISING RADIATION AND DOSIMETRY

Generation of radiation, Interaction of charged particles with matter, interaction of high energy photons with matter, radiation depth of interaction, range, attenuation curves, dose and exposure measurement, maximum permissible levels, overview of measurement methods: film dosimeters, thermos luminescent dosimetry (TLD), dose measurement during radiography.

UNIT – II RADIOISOTOPES AND NUCLEAR MEDICINE

Diagnosis with radioisotopes, isotopes, half-life, nuclear radiations, energy of nuclear radiations, units of activity, isotope generators, principles of measurement: counting statistics, sample counting, liquid scintillation counting, non-imaging investigations examples: haematological measurements, Glomerular filtration rate, radionuclide imaging, bone imaging, dynamic renal function.

UNIT – III IMAGE PRODUCTION-I

Radionuclide imaging: the gamma camera, energy discrimination, collimation, image display, single-photon emission tomography (SPET), positron emission tomography (PET), ultrasonic imaging: pulse–echo techniques, tissue interaction with ultrasound, transducer arrays, applications: Doppler imaging, CT imaging: absorption of X-rays, data collection, image reconstruction, beam hardening, spiral CT.

UNIT – III IMAGE PRODUCTION-II

Electrical impedance tomography (EIT): image reconstruction, data collection, multi-frequency and 3D imaging, magnetic resonance imaging (MRI): the nuclear magnetic moment, precession in the presence of a magnetic field, T1 and T2 relaxations, the saturation recovery pulse sequence, the spin–echo pulse sequence, localization: gradients and slice selection, frequency and phase encoding, the FID and resolution, imaging and multiple slicing.

UNIT – V ELECTROPHYSIOLOGY

Sources of biological potentials, the nervous system, neural communication, the interface between ionic conductors: Nernst equation, membranes and nerve conduction, muscle action potentials, volume conductor effects, the ECG/EKG and its detection and analysis, characteristics of the ECG/EKG, the electrocardiographic planes, recording the ECG/EKG, ambulatory ECG/EKG monitoring.

Text Books

1. B.H. Brown, R.H. Smallwood, D.C. Barber, P.V. Lawford, and D.R. Hose, *Medical Physics and Biomedical Engineering*, Institute of Physics Publishing, 1999.
2. S.A. Kane, *Introduction to Physics in Modern Medicine*, CRC Press, 2009.

Unit-I : Chapter 5 (Brown, Smallwood, Barber, Lawford, Hose)
Unit-II : Chapter 6 (Brown, Smallwood, Barber, Lawford, Hose), Kane
Unit-III : Chapter 12 (Brown, Smallwood, Barber, Lawford, Hose)
Unit-IV : Chapter 12 (Brown, Smallwood, Barber, Lawford, Hose)
Unit-V : Chapter 16 (Brown, Smallwood, Barber, Lawford, Hose)

References

1. F.M. Khan, and J.P. Gibbons, *Khan's the physics of radiation therapy*. Lippincott Williams and Wilkins, 2014.
2. P. Suetens, *Fundamentals of Medical Imaging*. Cambridge university press, 2017.
3. W.J. Meredith, and J.B. Massey, *Fundamental Physics of Radiology*. Butterworth-Heinemann, 2013.
4. F.A. Smith, *A Primer in Applied Radiation Physics*, World Scientific Publishing Co. Inc, 2000.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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Course Code	Course Title	L	T	P	O	L+T+P	C
18PPH3NB	Energy Storage and Devices	2	-	-	-	2	2

Instructional Objectives At the end of this course the learner is expected:		Student Outcomes				
1	To understand the basic concepts of energy storage.	a	b	c	d	e
2	To study different types of energy storage devices.	a	b	c	d	e
3	To realize the applications of energy storage devices	d	e	i	j	l

UNIT – I BASIC CONCEPTS AND ENERGY STORAGE

Definition and units of energy, power, conservation of energy, second law of thermodynamics, renewable energy resources**,** energy storage - need of energy storage; different modes of energy storage. capacitors, electrochemical storage, electrical and magnetic storage, chemical energy storage, hydrogen for energy storage.

UNIT – II ELECTROCHEMICAL ENERGY STORAGE SYSTEMS

Electrochemical energy storage systems batteries: primary, secondary, lithium, solid-state and molten solvent batteries; lead acid batteries; nickel cadmium batteries; advanced batteries. role of carbon nano-tubes in electrodes.

UNIT – III MAGNETIC AND ELECTRIC ENERGY STORAGE SYSTEMS

Magnetic and electric energy storage systems superconducting magnet energy storage (SMES) systems; capacitor and batteries: comparison and application; super capacitor: electrochemical double layer capacitor (EDLC), principle of working, structure, performance and application, role of activated carbon and carbon nano-tube.

UNIT – IV FUEL CELL BASICS AND STORAGE

Basics Fuel cell definition, difference between batteries and fuel cells, fuel cell history, components of fuel cells, principle of working of fuel cell advantages and disadvantages of fuel cell power plant, fuel cell types: alkaline fuel cell, polymer electrolyte fuel cell, phosphoric acid fuel cell, molten carbonate fuel cell, solid oxide fuel cell, problems with fuel cells, applications of fuel cells.

UNIT – V HYDROGEN PRODUCTION AND STORAGE METHODS

Production: from fossil fuels, electrolysis, thermal decomposition, photochemical, photocatalytic, hybrid; Storage: Metal hydrides, metallic alloy hydrides, carbon nano-tubes; sea as the source of deuterium.

Text Books

1. R.A. Huggins, *Energy Storage*, 1st Ed., Springer, 2010.
2. J.-M.Tarascon, and Patrice Simon, *Electrochemical Energy Storage*, 1stEd., Wiley, 2015.

3. F.Díaz-González, A. Sumper and O.Gomis-Bellmunt, *Energy storage in power systems*, 1st Ed., Wiley, 2016.
4. Srinivasan, *Fuel Cells from Fundamentals to Applications*, 1st Ed., Springer, 2006.
5. A.Basile, A.Iulianelli, *Advances in Hydrogen Production*, 1st Ed., *Storage and Distribution*, Woodhead Publishing, 2014.

References

1. N. Kularatna, *Energy Storage Devices for Electronic Systems: Rechargeable Batteries and Supercapacitors*, Academic Press, 2014.
2. X. Feng, *Nanocarbons for advanced energy storage*, Vol. 1, John Wiley and Sons, 2015.
3. M.Sylvin, *Fundamentals of electrochemistry*, 1st Ed., Sarup Book Publishers Pvt. Ltd., 2009.
4. A.G. Ter-Gazarian, *Energy Storage for Power Systems*, IET, 1994.

Course Nature : Theory							
Assessment Method (Max. Marks: 100)							
In Semester	Assessment Tool	Cycle Test I	Cycle Test II	Model Examination	Assignment	Attendance	Total
	Marks	10	10	20	5	5	50
						End Semester	50
						Total	100

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