Department of Physics
School of Basic and Applied Sciences

Syllabus

Integrated M. Sc. Physics
2023 onwards

Table of Contents:

1. PROGRAM OUTLINE

A. Preamble:

1. **Started**: 2010.
2. **Programmes offered**: Integrated M.Sc. M.Sc., and Ph.D in Physics
3. **Vision and Thrust areas of the Department in brief**:
   The department of Physics of CUTN envisages itself to be a centre of excellence in basic and applied aspects of Physics, both in teaching and research, in 20 years
4. **Unique feature of the department**:

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

B. Title: The title of the program is Integrated Master's of Science in Physics. The Rules and Regulations of the Central University of Tamil Nadu apply to this program.

C. Objectives of the Program:
On completion of the program, the students will be able to:
- Understand the fundamental laws of Physics and its advancement so far.
- Develop the insight into the nature, scope, and objective of Physics.
- Develop logical and rational thinking.
- Develop the art of innovation, making strategies, and solving scientific problems.
- Develop the scientific spirit.

D. Duration
The duration of the I MSc program shall be five academic years. Each academic year consists of two semesters. Each semester will consist of 19 weeks of instruction, excluding admission and examination.

E. Eligibility for admission
As per notification by the Examination Branch, Central University of Tamil Nadu.

F. Medium of instruction
Medium of instruction shall be English.

G. Methods of transaction
A list of suggestive methods of curriculum transaction are as follows:
- Lectures - cum- discussion.
- Lecture - cum - demonstration.
- Individual projects.
- Project reviews.
- Using library & ICT resources.

H. Attendance:

75% attendance is compulsory.

I. Course outline

Integrated MSc Physics incorporates the curricula of B.Sc (Physics) and M.Sc (Physics). The total credits of the program at the end of five academic years are 235 plus credits earned through MOOC. The program offers an exit option with a B.Sc degree at the end of third year.

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

(a) Core papers:

Total 20 number of core papers (theory + practical) at the end of three years and grand total 36 core papers (theory + practical) at the end of five years will be offered by the department of physics. These are mandatory papers covers essential components of physics.

(b) Allied Subjects:

Allied subjects are mandatory papers offered by Chemistry/Mathematics department. Allied courses will offered for first two years only

(c) Discipline Specific Elective (DSE):

DSEs will be offered by the department as listed in Table 2.

(d) Open Elective (OE):

Open elective offered by other departments.

(e) Skill Enhancement Courses (SEC):

SEC will be offered both at University and department level.

(f) Value Added Courses (VAC):

Students have to choose a VAC provided by the department or University.

(g) Ability Enhancement Compulsory Course (AECC):

Students have to choose a VAC provided by the department or University.

J. PANORAMA OF COURSE STRUCTURE:

Table - 1

<table>
<tr><td colspan="8"><h2>First Year</h2></td></tr>
<tr><td colspan="8">SEMESTER I</td></tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Course Type</td>
<td>Credits</td>
<td>Hours / week</td>
<td colspan="2">Marks</td>
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<tr>
<td></td><td></td><td></td><td></td><td></td>
<td>Int</td><td>Ext</td>
</tr>
<tr><td>PHY1011</td><td>General Physics</td><td>CC</td><td>4</td><td>4</td><td>40</td><td>60</td></tr>
<tr><td>PHY1012</td><td>Physics Laboratory- I</td><td>CCP</td><td>2</td><td>4</td><td colspan="2">100</td></tr>
<tr><td></td><td>Mathematics-I</td><td>Minor</td><td>4</td><td>4</td><td>40</td><td>60</td></tr>
<tr><td></td><td>Mathematics Laboratory I</td><td>Minor</td><td>2</td><td>4</td><td colspan="2">100</td></tr>
<tr><td></td><td>Open Elective</td><td>OE</td><td>3</td><td>3</td><td colspan="2">100</td></tr>
<tr><td></td><td>English</td><td>AECC</td><td>3</td><td>3</td><td>40</td><td>60</td></tr>
<tr><td></td><td>Disaster risk reduction</td><td>SEC</td><td>3</td><td>3</td><td>40</td><td>60</td></tr>
<tr><td></td><td>Yoga and fitness</td><td>VAC</td><td>2</td><td>2</td><td>40</td><td>60</td></tr>
<tr><td colspan="3">Total</td><td>23</td><td>27</td><td></td><td></td></tr>
<tr><td colspan="8">SEMESTER II</td></tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Course Type</td>
<td>Credits</td>
<td>Hours / week</td>
<td colspan="2">Marks</td>
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<tr>
<td></td><td></td><td></td><td></td><td></td>
<td>Int</td><td>Ext</td>
</tr>
<tr><td></td><td>Biology-I</td><td>Minor</td><td>4</td><td>4</td><td>40</td><td>60</td></tr>
<tr><td></td><td>Biology Laboratory I</td><td>Minor</td><td>2</td><td>4</td><td colspan="2">100</td></tr>
<tr><td></td><td>Chemistry-I</td><td>Minor</td><td>4</td><td>4</td><td>40</td><td>60</td></tr>
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	Chemistry Laboratory I	Minor	2	4	100	
	Open Elective	OE	3	3	40	60
	Tamil / Hindi	AECC	3	3	40	60
	Health Education and nutrition	SEC	3	3	40	60
	Environmental Science	VAC	4	4	40	60
Total			**25**	**29**		
Cumulative Total			**48**	**56**		
For students exiting after one year (Certificate)						
	Vocational Course	VOC	**4**	**4**		
Cumulative Total			**52**	**60**		

Second Year

SEMESTER III

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY1031	Sound and Optics	CC	4	4	40	60
PHY1032	Physics Laboratory II	CCP	2	4	100	
	Mathematics II	Minor	4	4	40	60
	Mathematics Laboratory II	Minor	2	4	100	
	Chemistry- II	Minor	4	4	40	60
	Chemistry Laboratory II	Minor	2	4	100	
	Open Elective	OE	3	3	40	60
	Tamil / Hindi	AECC	3	3	40	60

	Total		24	30		
	Cumulative Total		**72**	**86**		

SEMESTER IV

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	**Ext**
PHY1041	Heat and Thermodynamics	CC	4	4	40	60
PHY1042	Heat and Thermodynamics Laboratory	CCP	2	4	100	
PHY1043	Electricity and Magnetism	CC	4	4	40	60
PHY1044	Electricity and Magnetism Laboratory	CCP	2	4	100	
	Open Elective	OE	3	3	40	60
	English	AECC	3	3	40	60
	Cyber Security	SEC	4	4	40	60
	Basic Analytical Experiments	VAC	2	2	40	60
	NSS / NCC / etc	EXT	1	--		
	Total		**25**	**28**		
	Cumulative Total		**97**	**114**		

For students exiting after two years (Diploma)

		Vocational Course	**4**	**4**		
		Total	**101**	**108**		

Third Year

SEMESTER V

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY1051	Mathematical Methods In Physics	CC	4	4	40	60
PHY1052	Mechanics And Relativity	CC	4	4	40	60
PHY1053	Introductory Statistical Physics	CC	4	4	40	60
PHY1054	Quantum Physics & Its Applications	CC	4	4	40	60
PHY1055	Solid State Physics	CC	4	4	40	60
PHY1056	Solid State Physics Laboratory	CCP	2		100	
	Internship		2			
Total			**24**	**24**		
Cumulative Total			**121**	**138**		

SEMESTER VI

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY1061	Atomic Physics & Lasers	CC	04	04	40	60
PHY1062	Analog Electronics	CC	04	04	40	60
PHY1063	Nuclear Physics	CC	04	04	40	60
PHY1064	Atomic Physics & Laser Lab	CCP	02	04	100	
PHY1065	Analog Electronics Lab	CCP	02	04	100	
PHY1066	Computer Programming & Numerical Techniques Lab	CCP	02	04	100	
PHYEC13	Numerical Methods and Computer Programming	DSE	04	04	40	60
PHYSE01	Machine Shop	SEC	02	02	100	

	Total		24	30	
	Cumulative Total		145	168	
For students exiting after three years (Bachelor's Degree, B.Sc.)					
PHY1067	Mini Project	CC	6		
	Total credits (after 3 years)		151	168	

FOURTH YEAR

SEMESTER VII

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY1071	Classical Mechanics	CC	04	04	40	60
PHY1072	Mathematical Physics -I	CC	04	04	40	60
PHY1073	Quantum Mechanics -I	CC	04	04	40	60
PHY1074	Computational Condensed Matter Physics	CC	04	04	40	60
PHY1075	Computational Condensed Matter Physics Lab	CCP	02	04	100	
PHY1076	Digital Electronics & Microprocessor Lab	CCP	02	04	100	
PHYEC07	Digital Electronics & Microprocessor	DSE/MOOCS	04	04	40	60
	Research Methodology and Publication Ethics	VAC	02	02	40	60
	Total		**26**	**30**		
	Cumulative Total		**171**	**198**		

SEMESTER VIII

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext

PHY1081	Mathematical Physics -II	CC	04	04	40	60
PHY1082	Quantum Mechanics -II	CC	04	04	40	60
PHY1083	Statistical Mechanics	CC	04	04	40	60
PHY1084	Experimental Methods in Physics	CC	04	04	40	60
PHY1085	Experimental Technique Lab	CCP	02	04	100	
	MOOCs/SWAYAM/NPTEL	DSE	02	02	100	
	Courses can be chosen from the Times Group (Online)	VAC	2 (not included)	*		
	Total		**20**	**22**		
	Cumulative Total		**191**	**220**		
	For students exiting after four years (Bachelor's Degree – Honours/Research)					
	* Internship will be conducted in continuous mode for 160 hrs (1 credit = 40hrs)					

FIFTH YEAR

SEMESTER IX

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY1091	Condensed Matter Physics	CC	04	04	40	60
PHY1092	Nuclear And Particle Physics	CC	04	04	40	60
PHY1093	Electromagnetic Theory	CC	04	04	40	60
PHY1094	Condensed Matter Physics Lab	CCP	02	04	100	
PHY1095	Advanced Physics Lab	CCP	02	04	100	
PHYEC05	Atomics And Molecular Spectroscopy	DSE	04	04	40	60
	SEC	SEC	03	03	40	60

	Open Elective	OE	03	03	40	60
Total			**26**	**30**		
Cumulative Total			**217**	**250**		

SEMESTER X

Course Code	Course Title	Course Type	Credits	Hours / week	Marks	
					Int	Ext
PHY1101	Research Project/Dissertation	CC	12	**24**		
PHY1102	DSE-IV	Internship	02	..		
	Self Study Course	DSE	04	04		
	Total		**18**	28		
Total credits (after 5 years)			**235**	**278**		

List of Discipline Specific Elective (DSE) Courses

Table - 2

COURSE CODE	COURSE TITLE
PHYEC01	ADVANCED MATHEMATICAL PHYSICS
PHYEC02	ADVANCED PARTICLE PHYSICS
PHYEC03	ADVANCED QUANTUM MECHANICS
PHYEC04	ASTROPHYSICS
PHYEC05	ATOMIC & MOLECULAR SPECTROSCOPY
PHYEC06	CRYSTAL GROWTH & THIN FILM PHYSICS
PHYEC07	DIGITAL ELECTRONICS & MICROPROCESSOR
PHYEC08	GENERAL THEORY OF RELATIVITY & COSMOLOGY
PHYEC09	INTRODUCTION TO NONLINEAR DYNAMICS
PHYEC10	LASER PHYSICS AND ITS APPLICATIONS
PHYEC11	MICROWAVE PHYSICS

PHYEC12	NANOMATERIALS AND NANOTECHNOLOGY
PHYEC13	NUMERICAL METHODS AND COMPUTER PROGRAMMING
PHYEC14	PHYSICS OF MAGNETISM & SPINTRONICS
PHYEC15	PLASMA PHYSICS
PHYEC16	PROPERTIES OF MATERIALS
PHYEC17	QUANTUM OPTICS
PHYEC18	QUANTUM COMPUTATION AND QUANTUM INFORMATION
PHYEC19	QUANTUM FIELD THEORY
PHYEC20	SEMICONDUCTOR PHYSICS
PHYEC21	SOLAR ENERGY AND ITS APPLICATION
PHYEC22	VACUUM SCIENCE & NANO TECHNOLOGY

List of Open Elective course:

COURSE CODE	COURSE TITLE
PHYOE01	APPLIED OPTICS
PHYOE02	GENDER CONCERNS IN STEM STUDIES
PHYOE03	INTRODUCTION TO ASTRONOMY & ASTROPHYSICS
PHYOE04	MEDICAL PHYSICS
PHYOE05	PHYSICS OF ARTS

List of Skill Enhancement Courses (SEC):

COURSE CODE	COURSE TITLE
PHYSE01	MACHINE SHOP
PHYSE02	NANOSCIENCE AND NANOTECHNOLOGY

COURSE CODE	COURSE TITLE
PHYSE03	RENEWABLE ENERGY TECHNOLOGIES

List of Value-Added Courses (VAC):

COURSE CODE	COURSE TITLE
PHYVA01	DATA ANALYSIS TECHNIQUES
PHYVA02	COMPUTATIONAL MODELING OF MATERIALS

K. EVALUATION:

The performance of each student enrolled will be assessed at the end of each semester. Evaluation of the student will be done as per the Grading System adopted by the Central University of Tamil Nadu. The final result in each course will be determined based on (a) continuous assessment, and (b) performance in the Term End Examination which will be in the ratio of 40:60 (40 Continuous Assessment and 60 Term End Exam) in case of a theory paper. In the case of Practical, the result will be determined on the basis of continuous evaluation only. The passing minimum in the course shall be 50% in theory and 50% in Practical components separately, and an overall 50%. The student who fails in either theory or practical examination, he/she has to clear the same in the subsequent supplementary examination notified by the examination section, CUTN. Please note that the evaluation process has to be followed as per the University.

2. VISION, MISSION, AND OBE PATTERN

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

B. Mission statement of the department:

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

C. Program Outcomes

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

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

D. Specific Outcomes (PSO)

PSO-1	Apply the knowledge gained in fundamental and applied Physics in solving scientific problems at varied complexity, analyze the same to formulate/ develop substantiated solutions.
PSO-2	Apply the research-based knowledge and advanced method to design new experiments, analyze resulting data and interpret the same to provide valid conclusions.
PSO-3	Gain broad understanding of ethical and professional skill in scientific applications in the context of local, global, economic, environmental and societal realities and to develop sustainable practical solutions for academic and research problems within professional and ethical boundaries.

PSO-4	Educate scientifically the new development in Science and Technology and make them critical thinkers and innovators.	
PSO-5	Engage in independent and lifelong learning in the broadest context of technological change and pursue his/her career either in higher studies or in various sectors.	

E. Graduate Attributes

    (a) Disciplinary/ interdisciplinary knowledge

    (b) Computational and ICT skills/ digital literacy.

    (c) Communication skills.

    (d) Ethics/ moral awareness.

    (e) Problems solving/ Analytical/ reflective thinking.

    (f) Critical thinking

    (g) Cooperation/ teamwork.

    (h) Self-directed learning.

    (i) Research related skills

F. PSO to Mission Statement Mapping:

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

G. PO to PSO Mapping:

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

SEMESTER - I

Course Code: PHY1011
Course Title: General Physics
Course Type: Theory (Core)
Credits : 04

Unit 1:
Overview of Newtonian Mechanics: Ordinary and partial differentiation, vectors and scalars, scalar product, vector product, triple product, gradient, divergence and curl, coordinate systems: polar, spherical polar and cylindrical, unit vectors.Unit and dimension, Newton's laws of motion, centripetal and centrifugal force, Projectile motion, Conservation of energy and momentum, elastic and inelastic collision.

(12 Hours)

Unit 2:
Gravitation & Rigid Body dynamics: Kepler's law of planetary motion, satellite motion: escape velocity, weightlessness, gravitational field; Moment of inertia and its general theorems, calculation of moment of inertia for various geometrical shapes, angular momentum and its conservation law, torque, Kinetic energy of rotation.

(12 Hours)

Unit 3:
Elasticity: Hooke's law, concept of stress and strain, elastic constants, Youngs; modulus, Poisson's ratio, relation between elastic constants and Poisson's ratio – work done in stretching and twisting a wire, twisting couple on a cylinder – rigidity modulus by static torsion, torsional pendulum (with and without masses) cantilever, expression for Bending moment, expression for depression at the loaded end of the cantilever, oscillations of a cantilever, expression for time period, experiment to find Young's modulus, non-uniform bending, experiment to determine Young's modulus by Koenig's method, uniform bending, expression for elevation, experiment to determine Young's modulus using microscope.

(**12 Hours)**

Unit 4:
Fluid mechanics: Pressure in a fluid, pressure gauges, Archimedes' principle, Surface tension: definition, molecular forces, excess pressure over curved surface, application to spherical and cylindrical drops and bubbles, determination of surface tension by Jaegar's method, variation of surface tension with temperature Viscosity, streamline and turbulent flow, fluid motion in capillary tube, Poiseuille's formula, corrections, terminal velocity and Stoke's formula, variation of viscosity with temperature.

(12 Hours)

Unit 5:
Waves: Travelling waves, longitudinal and transverse waves, harmonic waves, wave equation, superposition principle, Phasors, wavefront, plane, spherical and cylindrical waves, phase and group velocities, energy transport, intensity of waves, waves in stretched strings, speed of waves in stretched string, standing waves and normal modes, superposition of waves, resonance, beats, wave-packet.

(12 Hours)

Reference Books::
1. Mechanics by D.S Mathur.
2. Fundamentals of Physics, Halliday and Resnick (Wiley).
3. Mechanics by J.C. Upadhaya.
4. D.S.Mathur, 2010, Elements of Properties of Matter, S.Chand & Co.
5. BrijLal & N. Subrahmanyam, 2003, Properties of Matter, S.Chand & Co.
6. University Physics by Sears and Zeymansky.

	Course Outcomes	Level
CO-1	Newtons's laws of motion, laws of Gravitation, Waves, Hooke's law, Archimedes' principle	Remember
CO-2	Motion of rigid body, satellite motion, rotational motion, elasticity, concept of surface tension and viscosity, different types of waves.	Understand
CO-3	Newtonian mechanics, conservation of energy and momentum, properties of matter w.r.t elasticity, fluid dynamics, propagation of waves.	Analyze
CO-4	To solve linear and rotational motion of a rigid body, bending of beam problem, fluid motion, solving wave equation.	Apply

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHY1012
Course Title: Physics Laboratory-I
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Measurements of length (or diameter) (a) Vernier Calipers, (b) Screw gauge, (c) Travelling microscope
2. To study the random errors in observations
3. To determine Young's modulus - cantilever bending
4. To determine Young's modulus - Koeing's method

5. Torsional pendulum
6. Study the Motion of Spring and calculate (a) Spring constant, (b) g and (c) Modulus of rigidity.
7. Projectile motion
8. Conservation of energy & momentum
9. Archimedes principle
10. Centripetal force
11. Measurement of surface tension using capillary rise method.

Reference Books::

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
2. A Text Book of Practical Physics, I. Prakash & Ramakrishna, Kitab Mahal
3. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, reprinted 1985, Heinemann Educational Publishers
4. A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Publication

Course Outcomes		Level
CO-1	Students can understand the basics of measurement,	Understand
CO-2	Concept of Bending of beam, projectile motion, surface tension and motion of spring.	**Understand**
CO-3	Conservation of energy and momentum	**Understand**
CO-4	To calculate Young's modulus, surface tension.	**Apply**
CO-5	To measure the time period and spring constant of spring.	**Apply**

Mapping of Program Outcomes with Course Outcomes

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

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

SEMESTER - III

Course Code : PHY1031
Course Title : Sound and Optics
Course Type : Theory (Core)
Credits   : 04

Unit 1:
SOUND: Introduction to transverse and longitudinal waves, waves in stretched strings, sound waves as pressure fluctuations, vlocity of longitudinal waves in gaseous medium, Calculation of velocity of sound in air, Effect of pressure, temperature and humidity on the speed of sound, Doppler effect and its applications, musical sound and noises, characteristics of musical sounds, intensity of sound, measurement of intensity, Ultrasonic waves, Production of ultrasonic waves, Detection of ultrasonic waves, Properties of ultrasonic waves, outline of the applications of ultrasonic waves.

(12 Hours)

Unit 2:
GEOMETRICAL OPTICS: Fermat's principle, Mirrors: plane mirrors, spherical mirrors, lenses, imaging, aberration in lenses, methods of minimizing aberrations, color dispersion, total internal reflection, prisms, refraction by prism, combination of prisms to produce (i) dispersion without deviation, (ii) deviation without dispersion, stops, telescope, microscope, eyepieces, compound microscope, adaptive optics, optical fibers

(12 Hours)

Unit 3:
INTERFERENCE: Superposition of coherent and incoherent waves, conditions for interference, Young's double-slit experiment, Double beam interference from thin film: fringes of equal inclination, fringes of equal thickness, Newton's rings, Michelson's Interferometer, determination of wavelength of a doublet source, Multiple beam interference, Stoke's parameter, Fabry-Perot interferometer, Fabry-Perot spectroscopy, resolution, finesse

(12 Hours)

Unit 4:
DIFFRACTION: Huygens-Fresnel principle, Fraunhofer diffraction from (i) single slit, (ii) circular apertures, (iii) double slits, (iv) many slits, diffraction grating, transmission grating, resolution of imaging systems, Rayleigh's criterion, resolving power of microscopes, prisms and gratings, Fresnel's diffraction, zone-plate, Fresnel diffraction from a circular aperture, opaque disc; near-field diffraction of straight edge and single slit using Cornu's spiral.

(12 Hours)

Unit 5:
POLARIZATION: Polarization of light, Plane, elliptically and circularly polarized light, production and detection of polarized light, Brewster's angle, polarizer, Malus' law, Nicol prism, Rochon and Wollaston prism, wave-plates (quarter, half, full), Optical activity, Fresnel's explanation of rotation, Huygens's explanation of double refraction, specific rotatory power, Laurent's half shade polarimeter.

(12 Hours)

Reference Books:
1. Fundamentals of Physics, Halliday and Resnick (Wiley)
2. University Physics with Modern Physics, Sears & Zemansky's (Addison- Wesley-Pearson)
3. Optics, Eugene Hecht (Addison Wesley)
4. Optics, Ajoy Ghatak (McGraw Hil)
5. Fundamentals of Optics, F. A. Jenkins & H. E. White (McGraw-Hill Primls Custom Publishing)

	Course Outcomes	Level
CO-1	Understanding various properties and application of sound waves	Understand
CO-2	Enabling to understand the principle to build optical instruments	Apply
CO-3	Introduction to the wave nature of light	Understand
CO-4	Learning about diffraction of light	Understand
CO-5	Analyzing polarization of light	Analyze

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHY1032

Course Title: Physics Laboratory - II
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Simple pendulum and Compound pendulum
2. Resonance air column and water column
3. Newton's rings
4. Sonometer
5. Focal length 'f' of lenses
6. Angle of prism and minimum deviation of solid prism

7. Diffraction using grating.
8. Air wedge
9. Angle of prism and minimum deviation of liquid prism
10. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.

Reference Books::

1. Virtual labs, https://www.vlab.co.in/
2. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
3. A Text Book of Practical Physics, I. Prakash & Ramakrishna, Kitab Mahal
4. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, reprinted 1985, Heineman

	Course Outcomes	Level
CO-1	Students can understand the fundamentals of various waves	Understand
CO-2	Students can analyze those experiments	Analyze
CO-3	Students can utilize the instrumental facility to do the experiments	Utilize
CO-4	Students can do this practical experiments with various options to get new ideas for self-developments	Apply
CO-5	Students can develop their self-knowledge to think for the innovative ideas	Innovate

Mapping of Program Outcomes with Course Outcomes

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

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SEMESTER - IV

Course Code : PHY1041
Course Title : Heat & Thermodynamics
Course Type : Theory (Core)
Credits   : 04

Unit 1:
ZEROTH & FIRST LAW OF THERMODYNAMICS: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient

(12 Hours)

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

(12 Hours)

Unit 3:
ENTROPY: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero

(12 Hours)

Unit 4:
THERMODYNAMIC POTENTIALS & MAXWELL'S RELATIONS: Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. First and second order Phase Transitions with examples, Clausius Clapeyron equations. Joule-Kelvin effect – porous plug experiment – Joule-Thomson effect, liquefaction of gas by Linde's Process – adiabatic demagnetization. Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process.

(12 Hours)

Unit 5:
KINETIC THEORY OF GASES: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance. Concepts of conduction, convection and radiation.

(12 Hours)

Reference Books:
1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman,
2. A Treatise on Heat, Meghnad Saha, and B.N.Srivastava
3. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich,
5. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger

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

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHY1042
Course Title: Heat & Thermodynamics Laboratory
Course Type: Practical (Core)
Credits: 02

 List of Experiments:
1. *Preliminary experiments:* An introduction to the subject Temperature of mixing - mix hot and cold water - note their initial and final temperature - try and predict the final temperature.
   a. Galton's board
   b. Thermometry - Measuring temperature using different thermometers such as (a) alcohol (b) mercury (c) IR (contact less) (d) digital (e) min-max (f) dry-wet (for humidity)
   c. Place a cube of ice on three different black colored boards - one made of metal, one of wood and one of plastic - qualitative concepts of specific heats and thermal conductivity.

2. Newton's law of cooling
3. Pressure coefficient of air - Joly's bulb
4. Thermal conductivity of a good conductor - Searle's method
5. Thermal conductivity of a bad conductor - Lee's method
6. Specific heat by method of mixtures
7. Verification of Stefan-Boltzmann law
8. Mechanical equivalent of heat
9. Seeback effect and thermocouple
10. Latent heat of steam/ice
11. Verification of Boyle's law

Reference Books:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
2. A Text Book of Practical Physics, I. Prakash & Ramakrishna, Kitab Mahal
3. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, reprinted 1985, Heinemann Educational Publishers
4. A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Publication.

	Course Outcomes	Level
CO-1	Understand notion of heat, randomness and temperature using different systems	Understand/Re member
CO-2	Illustrate different thermodynamics concepts by employing various experiments.	Apply
CO-3	Compare and examine the experimental result with theoretical predictions.	Analyze/Evaula te
CO-4	Arrange for the experiment, Demonstrate and Verify the Hypothesis.	Skills
CO-5	Design a new experimental set up.	Create

Mapping of Program Outcomes with Course Outcomes

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

Course Code : PHY1043
Course Title : Electricity & Magnetism
Course Type : Theory (Core)
Credits   : 04

Unit 1:
ELECTROSTATICS: Inverse square law, Electric field and intensity, Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. Conservative nature of Electrostatic Field. Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole.

(12 Hours)

Unit 2:
ELECTROSTATIC ENERGY OF SYSTEM OF CHARGES: Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere. Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss' Law in dielectrics**.**

(12 Hours)

Uni 3:
MAGNETOSTATICS: Magnetic force between current elements and definition of Magnetic Field B. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability. Relation between B, H, M. Ferromagnetism. B-H curve and hysteresis.

(12 Hours)

Unit 4
ELECTROMAGNETIC INDUCTION & AC CIRCUTS: Faraday's Law. Lenz's Law. Self-Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge Conservation and Displacement current. AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit. Peak, average and RMS values of ac current and voltage. – power factor and current values in an AC circuit.

(12 Hours)

Unit 5:
NETWORK THEOREMS: Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits. Thermoelectricity- Seebeck effect- laws of thermo e.m.f-– measurement of thermo e.m.f using potentiometer. Ballistic galvanometer and damping correction

(12 Hours)

Reference Books::
1. Introduction to Electrodynamics, D J Griffiths.
2. Brijlal and Subramaniam, "Electricity and Magnetism",
3. Electronic principles, A.Malivino D. Bates
1. Electricity and Magnetism, Satya Prakash

	Course Outcomes	Level
CO-1	Revision of basic laws of Electrostatic and magnetism	Remember
CO-2	Identify and explain chemical, thermal and magnetic effect of electric current	Understand
CO-3	Learning Electromagnetic induction (L&M) in circular coil and solenoid	Apply
CO-4	Analyses and solves electrical circuits with dc and ac source	Analyze
CO-5	Studying the maxwell's equation in vacuum and medium and electromagnetic waves in free space and matter	Apply

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1044
Course Title: Electricity & Magnetism Laboratory
Course Type: Practical (Core)
 Credits: 02

List of Experiments:
1. Resonance in LCR.Circuits and Transient response of resonant circuit
2. Method of Average resistance of a wire by Carey-Foster Method and hence to determine the value of unknown resistance
3. Charging and discharging of Capacitor
4. Comparison of EMF of cells using Potentiometer
5. Potentiometer: calibration of an Ammeter
6. Comparison of Capacitance- Ballistic Galvanometer
7. Comparison of EMF using Ballistic Galvanometer
8. Measurement of Inductance using Ballistic Galvanometer

9. De Sauty's bridge- Capacitance in Series and Parallel
10. Owen's Bridge- Inductance in Series and Parallel

Reference Books::

1. Virtual labs, https://www.vlab.co.in/
2. Brijlal and Subramaniam, "Electricity and Magnetism", Ratan Prahasan Mardis Educational and University Publishers, Delhi, 1990
3. Jacob Millman and Christos C Halkias, "Electronic Devices and Circuits", Tata McGraw Hill Edition, 1991.

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

Mapping of Program Outcomes with Course Outcomes

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

SEMESTER - V

Course Code: PHY1051
Course Title: Mathematical Methods in Physics
Course Type: Theory (Core)
Credits: 04

Unit 1:
VECTOR CALCULUS & VECTOR ALGEBRA: Ordinary and partial Differentiation, Taylor series, Maclaurin series, approximation errors, vectors and scalars, scalar product, vector product, triple product, gradient, divergence and curl. Invariances, vector differentiation, del and Laplacian operators, Gauss' divergence theorem, Green's and Stokes theorems and their applications. Sketching of graphs qualitatively, plotting of curves, Cartesian coordinates, Curvilinear coordinates: polar, spherical polar and cylindrical, and basis line element, area element, volume element, Jacobian. Idea of four-vectors.

(12 Hours)

Unit 2:
DIFFERENTIAL EQUATIONS: Ordinary and partial differential equations: separable variables, exact equations, integrating factors, Bernoulli's equation; Second-order equations with constant coefficients, general solutions, complementary function, particular integral, Green's function, Wronskian, rules for D-operators, Euler equation, power series solutions, Frobenius Method, Linear second-order partial differential equations, Laplace's equation, the wave equation, Poisson's equation

(12 Hours)

Unit 3:
MATRIX ALGEBRA: Definition of a matrix, addition and multiplication of matrices, the commutator, powers of a matrix, functions of matrices, transpose of a matrix, symmetric and skew-symmetric matrices, Hermitian and anti-Hermitian matrix, orthogonal matrix, unitary matrix, trace of a matrix, rotation matrices, matrix representation of a vector product, the inverse of a matrix, systems of linear equations, eigen-values and eigenvectors, Cayley-Hamilton theorem, diagonalization.

(12 Hours)

Unit 4:
CALCULUS OF VARIATION: The Euler-Lagrange equation and its applications: Brachistochrone problem, minimum area of soap film, geodesics, Constrained minima/maxima, Lagrange multiplier, Lagrangian formulation with constraints

(12 Hours)

Unit 5:
PROBABILITY: Independent and dependent events, sample space, probability theorems, conditional probability and Bayes theorem, random variables discrete and continuous distributions, Binomial, Poisson and Normal distribution, central limit theorem.

(12 Hours)

Reference Books::
1. Mathematical methods in physical sciences, Mary L Boas
2. Mathematical methods for physicists: G.B.Arfken, Hans Webber
3. Mathematical methods for physics and engineering: K.F.Riley, M.P.Hobson et. al.
4. Mathematical Physics, V. Balakrishnan

Course Outcomes		Level
CO-1	To get an idea of ordinary and partial differentiation, their application, and sketching of functions.	**Understand, Analyze**
CO-2	To get the idea of differential equation, its solution and its application in various physical problems.	**Apply, skill**
CO-3	To get the idea of function of matrices, various operations, use of matrices.	**Understand, Analyze, Apply**
CO-4	Learn about calculus of variation and its application.	**Understand, Analyze, Apply**
CO-5	Get the idea of probability, distribution functions, and application in real life.	**Skill**

Mapping of Program Outcomes with Course Outcomes

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

Course Code: **PHY1052**
Course Title: **Mechanics and Relativity**
Course Type: **Theory (Core)**
Credits   **:**   **04**

Unit 1:
SIMPLE HARMONIC MOTION: Simple Harmonic Oscillations. Differential equation of SHM and its solution, Linearity and Superposition Principle. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor. Superposition of two collinear oscillations having equal

frequencies and different frequencies (Beats). Superposition of two perpendicular Harmonic oscillations, Lissajous figures.

(12 Hours)

Unit 2:
MOTION IN CENTRAL FORCE: Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution; Conservation of Angular Momentum, energy, effective potential; Planetary orbits and Kepler's Laws, potential energy diagram, idea of orbits, Rocket motion-Satellite. Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere.

(12 Hours)

Unit 3:
RIGID BODY DYNAMICS: Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation, non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems

(12 Hours)

Unit 4:
LAGRANGIAN MECHANICS: Generalized coordinates, conjugate momentum, constraints, Lagrangian, Principle of least action, Lagrange Equations, Symmetries and conservation theorems, Hamiltonian, phase space, Louville's theorem

(12 Hours)

Unit 5:
SPECIAL THEORY OF RELATIVITY: Michelson-Morley Experiment and its outcome, Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Transformation of velocity, mass, energy and momentum, four-vector, invariance under Lorentz transformation and velocity addition equations in terms of hyperbolic functions.

(12 Hours)

Reference Books::
1. Theoretical Mechanics - M. R. Spiegel, (Schaum's Outline Series) (McGraw-Hill).
2. Mechanics - K. R. Symon (Addison-Wesley).
3. Introduction to Classical Mechanics - R. G. Takwale and P. S. Puranik (Tata McGrawHill).
4. R. P. Feynman, Lectures on Physics (vol-1), Narosa Publishing, 2008.
5. An Introduction to Mechanics – D. Kleppner and R.J. Kolenkow (Tata McGraw-Hill)
6. Sears and Zemansky, University Physics.(1987)

	Course Outcomes	Level
CO-1	Revision of basic concepts of calculus and vector algebra	**Remember**
CO-2	Learning solving differential equations	**Understand**
CO-3	Learning matrix algebra	**Understand**
CO-4	Learning about elasticity as well as surface tension and their application	**Apply**

Course Outcomes	Program Outcomes				
	PO-1	PO-2	PO-3	PO-4	PO-5
CO-5	Knowing the applications of viscosity and hydrodynamics				Apply

Mapping of Program Outcomes with Course Outcomes

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

Course Code : PHY1053
Course Title : Introductory Statistical Physics
Course Type : Theory (Core)
Credits   : 04

Unit 1: Probability Theory & Statistics: Sample space, Probability theorems, method of countings (maxwell-boltzman, Bose Einstein, Fermi-Dirac cases) random variables, discrete and continuous distribution, moments, fluctuations

(12 Hours)

Unit 2: Classical Statistics:
Macrostate & Microstate, Elementary Concept of Ensemble and Ergodic Hypothesis (statement only). Phase Space. Microcanonical ensemble, Postulate of Equal a-priori probabilities. Boltzmann hypothesis: Entropy and Thermodynamic Probability Canonical ensemble, Partition Function, Thermodynamic Functions of an Ideal Gas

(12 Hours)

Unit 3:Bose-Einstein Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's laws.

(12 Hours)

Unit 4:Fermi-Dirac Statistics: Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

12 Hours)

Unit 5:
Spectral distribution of Black body radiation: Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula.

Rayleigh-Jean's Law. Ultraviolet Catastrophe.Spectral Distribution of Black Body Radiation.Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.

(12 Hours)

Reference Books::

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
2. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
3. Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall
4. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W.Sears and Gerhard L. Salinger, 1986, Narosa.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
6. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press

	Course Outcomes	Level
CO-1	Understand concept of mechanical systems	Understand
CO-2	Applying the ensemble concepts to isolated and closed thermodynamics system.	Apply
CO-3	Understand the concept of statistical distribution.	Understand
CO-4	Analyze the different statistical distribution	Analyze
CO-5	Find out the application of statistical concepts in spectral distributions	Evaluate

Mapping of Program Outcomes with Course Outcomes

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

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Course Code : PHY1054
Course Title : Quantum Physics & its Applications
Course Type : Theory (Core)
Credits   : 04

Unit 1:
CLASSICAL TO QUANTUM MECHANICS: Difficulties of classical physics and origin of quantum theory, black body radiation, Compton effect, Double slit experiment with light, De Broglie waves, phase velocity and group velocity, Davisson and Germer's experiment, uncertainty principle – consequences.

(12 Hours)

Unit 2:
TIME DEPENDENT SCHRODINGER EQUATION: Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum, Ehrenfest theorem. Wave Function of a Free Particle.

(12 Hours)

Unit 3:
TIME INDEPENDENT SCHRODINGER EQUATION: Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle.

(12 Hours)

Unit 4:
SOLVING SCHRODINGER EQUATION FOR SIMPLE PROBLEMS: Continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problems: (i) free particle: continuous state, (ii) step potential (Energy less than step height and energy more than step height), (iii) Finite Square well potential (scattering & bound state solutions)(iv) Infinite square well potential (asymmetric & symmetric), (v) barrier penetration problem – quantum mechanical tunneling, (vi) linear harmonic oscillator

(12 Hours)

Unit 5:
MANY ELECTRON SYSTEMS: Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms- L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms.

(12 Hours)

Reference Books:
1. Introduction to Quantum Mechanics, Griffiths and Schroeter, 3rd Edn, (Cambridge)
2. Quantum Mechanics, Zettili, 2nd Edn. (Wiley)
3. Quantum Mechanics, Ghatak and Lokanathan, 6th Edn. (Laxmi Publications)
4. A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, McGraw Hill

Course Outcomes		Level
CO-1	Understand the limitations of classical physics and the need for quantum theory	Understand
CO-2	Understand the basic concepts of wave functions, normalization, eigen functions and eigenvalues in quantum mechanics	Understand
CO-3	Apply the basic concepts of quantum mechanics to one dimensional motion of particles	Apply
CO-4	Analyze one dimensional problems to solve for scattering and bound state solutions	Analyze
CO-5	Understand the periodic table of atomic elements, spectral notations, and spin-orbit couplings in quantum physics	Understand

Mapping of Program Outcomes with Course Outcomes

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

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Course Code : PHY1055
Course Title : Solid State Physics
Course Type : Theory (Core)
Credits   : 04

Unit 1:
ELEMENTS OF CRYSTALLOGRAPHY: bonding in solids; Types of bonds in crystals - Ionic, covalent, Metallic, Vander waal's and Hydrogen Bonding - Bond energy of sodium chloride molecule - variation of interatomic force with interatomic spacing - cohesive energy of ionic solids - application to sodium chloride crystal - evaluation of Madelung constant for sodium chloride.

(12 Hours)

Unit 2:
CRYSTAL STRUCTURE & CRYSTAL DIFFRACTION: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis – Primitive and unit cell-seven classes of crystal-Bravais Lattice-Miller Indices-Structure of crystals-- Simple cubic, Face centered cubic, Body centered cubic and Hexagonal close packed structure -Sodium Chrloride, Zinc Blende and Diamond Structures. Miller Indices, Wigner -

Seitz cell - Reciprocal lattice - application to diffraction - Brillouin Zones. diffraction methods for structure determination. Bragg's Law. Atomic and Geometrical Factor. Laue method, powder method and rotating crystal method- Diffraction and the structure factor.

(12 Hours)

Unit 3:

MAGNETIC PROPERTIES OF SOLIDS: Spontaneous Magnetization – Dia-, Para-, antiferro, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of diamagnetism. Quantum Mechanical Treatment of Paramagnetism - Exchange interaction: Heisenberg model, Temperature dependence of Magnetization - Curie's law, Weiss's Theory of Ferromagnetism - Curie-Weiss law for susceptibility- Ferromagnetic Domains - Bloch wall - domains and magnetic anisotropy; Discussion of B-H Curve. Hysteresis and Energy Loss - Spin wave and magnons.

(12 Hours)

Unit 4:

DIELECTRIC PROPERTIES OF MATERIALS: dielectric function Polarization - Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability - frequency and temperature effects on polarization-dielectric loss. Clausius Mosotti Equation - -determination of dielectric constants. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes.

(12 Hours)

Unit 5:

SUPERCONDUCTIVITY: General Properties of Superconductors -Experimental Results - Critical Temperature - effect of magnetic field -Meissner effect - effect of current - thermal properties - entropy - specific heat -energy gap - isotope effect - London equations – Coherence length- Penetration Depth - Normal tunnelling AC & DC Josephson effects - - SQUID - Type–I and Type–II Superconductors - Explanation for the Occurrence of Super Conductivity - BCS theory - flux quantization-,. Josephson junctions. Superfluidity Application of Superconductors - High TC superconductors.

(12 Hours)

Reference Books:

1. Introduction to Solid State Physics, Charles Kittle, Wiley Publication (2019).
2. .Solid State Physics by S.O.Pillai, New Age International (P) Ltd.,(2002).
3. Solid State Physics by A. J.Dekker, Macmillan India(1985).
4.. Solid State Physics by HC Gupta, Vikas Publishing House Pvt. Ltd., New Delhi (2001).

	Course Outcomes	**Level**
CO-1	To get knowledge about various aspects of chemical bonding and understand the formation of solids with various crystal structures and symmetries.	**Understand** Analyse,
CO-2	Apply the knowledge to resolve the crystal structure of solids through XRD and structural characterization tools.	Remember, Evaluate, Analyse, Skill
CO-3	Gain knowledge about the origin of magnetism, ordering of magnetism, and various theory involved in understanding magnetism in solids.	**Understand/An alyze/** Apply

CO-4	Understand the concept of electronic polarization and its role on piezoelectricity and ferroelectricity.	Acquire, Understand, Apply
CO-5	Analyse the role of electron phonon coupling on superconductivity and understand various aspects of superconductivity including high Tc superconductors.	Understand,An alyse Apply,

Mapping of Program Outcomes with Course Outcomes

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

Course Code : PHY1056
Course Title: Solid State Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Determination of magnetic susceptibility of paramagnetic solution
2. Determination of the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. Study of the frequency dependent of Dielectric Constant of a dielectric Materials
5. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
6. Estimation of the refractive index of a dielectric layer using SPR
7. Study of PE Hysteresis loop of a Ferroelectric Crystal
8. To study the BH curve of iron using a Solenoid and determine the energy loss
9. Determine band gap from temperature dependent e resistivity of a semiconductor (Ge) crystal using two-probe method
10. To determine the Hall coefficient of a semiconductor sample

Reference Books::
1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House

2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn., 2011, Kitab Mahal
4. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India

	Course Outcome	**Level**
CO 1	Identification of crystal structure of solids	Remember
CO2	Prediction of the thermal and electrical properties of solids and explanation of their origin	Understand
CO3	Estimation of band gap, charge carriers type and carrier concentration in solids	Apply
CO4	Demonstration of Dielectric and DC/AC conductivities of insulators	Analyse
CO5	Able to convert solar energy into electrical and thermal energy	Apply
CO6	Able to understand ferroelectric phase transitions and magneto-resistance behaviour of materials	Apply

Mapping of Program Outcomes with Course Outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1	2	2	2	1	1
CO2	2	2	2	1	1
CO3	3	2	3	2	1
CO4	2	2	3	3	2
CO5	2	2	2	1	2
CO6	2	2	3	2	2

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SEMESTER - VI

Course Code : PHY1061
Course Title : Atomic Physics and LASERS
Course Type : Theory (Core)
Credits   : 04

Unit 1:
THE ELECTRON AND POSITIVE RAYS: e/m of an electron by Dunnington's method – charge of an electron by Millikan's oil drop method – properties of positive rays – e/m of positive rays by Thomson's parabola method (problems calculation of e/m ratio of positive rays) – mass spectrographs and uses– Bainbridge and Dempster's mass spectrographs.

(12 Hours)

Unit 2:
PHOTOELECTRIC EFFECT: Photoelectric emission – Leonard's experiment – Richardson and Compton experiment – laws of photoelectric emission – Einstein's photoelectric equation (problems using Einstein's photoelectric equation) – experimental verification by Millikan's method –photoelectric cell – photo emissive cell – photovoltaic cell – photo conducting cell – applications of photoelectric cells – Photomultiplier.

(12 Hours)

Unit 3:
ATOMIC STRUCTURE: Sommerfield's relativistic atom model – vector atom model – various quantum numbers – L-S and J-J coupling – Pauli's exclusion principle – magnetic dipole moment of an electron due to orbital and spin motion – Bohr magneton - Stern and Gerlach experiment – Lande 'g' factor.

(12 Hours)

Unit 4:
SPLITTING OF SPECTRAL LINES: excitation, ionisation and critical potentials – Davis and Goucher's method – optical spectra – spectral notation and selection rules – fine structure of sodium D-line – Zeeman effect – experimental arrangement and classical theory of normal Zeeman effect – Larmor's theorem – quantum theory of normal Zeeman effect –anomalous Zeeman effect –explanation of splitting of D1 and D2 lines of sodium – Paschen Back effect - Stark effect

(12 Hours)

Unit 5:
LASERS: General principles of lasers – properties of lasers action – spontaneous and stimulated emission – population inversion – optical pumping.
Main features of a laser : Directionality, high intensity, high degree of coherence, spatial and temporal coherence, Einstein's coefficients and possibility of amplification, momentum transfer, life time of a level, kinetics of optical obsorption. Threshold condition for laser emission, Laser pumping, He-Ne laser and RUBY laser (Principle, Construction and Working). Applications of laser in the field of medicine and industry, holography.   **(12 Hours)**

Reference Books:
1. Perspective of Modern Physics, Arthur Beiser, McGraw Hill.
2. Modern Physics, S. Ramamoorthy, National Publishing & Co.
3. Laser and Non-Linear Optics by B.B.Laud, Wiley Easter Ltd.,New York,1985.
4. R. Murugesan, Modern Physics, S. Chand & Co**. (**All units**)** (Units I&II-Problems)
5. Brijlal & N. Subrahmanyam, Atomic & Nuclear Physics, S. Chand & Co. (All units)

Course Outcomes		Level
CO1	List the properties of electrons and positive rays, define the specific charge of positive rays, and know different mass spectrographs.	Remember
CO2	Outline the photoelectric effect and the terms related to it, State laws of photoelectric emission, Explain experiments and applications of the photoelectric effect, and Solve problems based on photoelectric equation.	Understand
CO3	Explain different atom models, Describe different quantum numbers and different coupling schemes.	Analyze
CO4	Differentiate between excitation and ionization potentials, Explain Davis and Goucher's experiment, Apply the selection rule, analyse the Paschen-Back effect, Compare Zeeman and Stark effect.	Apply
CO5	Understand the condition for the production of laser, and Appreciate various properties and applications of lasers.	Apply

Mapping of Program Outcomes with Course Outcomes

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

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Course Code : PHY1062
Course Title : Analog Electronics
Course Type : Theory (Core)
Credits   : 04

Unit 1:
SEMICONDUCTOR DIODES: P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, (2) Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode, (3) Solar Cell.

(12 Hours)

Unit 2:
BIPOLAR JUNCTION TRANSISTORS: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Current gains α and β, Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff and Saturation Regions.

(12 Hours)

Unit 3:
AMPLIFIERS: Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers. RC-coupled amplifier and its frequency response

(12 Hours)

Unit 4:
OPERATIONAL AMPLIFIER (BLACK-BOX APPROACH): Characteristics of an Ideal and Practical Op-Amp. (IC 741) Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground.

(12 Hours)

Unit 5:
APPLICATION OF OP-AMPS AND CONVERSIONS: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator. Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion

(12 Hours)

Reference Books::
1. Integrated Electronics, J. Millman and C.C. Halkias, Tata Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, J.D. Ryder, Prentice Hall.
3. Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, PHI Learning
4. Electronic Devices & circuits, S.Salivahanan & N.S.Kumar, Tata Mc-Graw Hill
5. Op-Amps and Linear Integrated Circuit, R. A. Gayakwad, Prentice Hall
6. Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk,2008, Springer
7. Semiconductor Devices: Physics and Technology, S.M. Sze, Wiley India
8. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

	Course Outcomes	**Level**
CO-1	Different types of semiconductors, concept of diode and its application.	**Understand/Apply**
CO-2	Working principle of rectifiers, transistor, amplifier, characteristics of OPAMP	**Understand**
CO-3	Use of diodes	**Understand/Analyze**
CO-4	Transistors in DC circuits.	**Apply**
CO-5	Use of OP-AMPS in electronic circuit.	**Apply**

Mapping of Program Outcomes with Course Outcomes

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

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Course Code : PHY1063
Course Title : Nuclear Physics
Course Type : Theory (Core)
Credits   : 04

Unit 1:
GENERAL PROPERTIES OF NUCLEI: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, isobar, isotope and isotones, mass spectrometer (Bainbridge), angular momentum, parity, magnetic moment, electric moments, nuclear excites states.

(12 Hours)

Unit 2:
NUCLEAR MODELS: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

(12 Hours)

Unit 3:
RADIOACTIVITY :(a) Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy, kinematics for β-decay, positron emission, electron capture, neutrino hypothesis, basic idea about non-conservation of parity in β-decay. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion.
Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

(12 Hours)

Unit 4:
PARTICLE DETECTORS AND ACCELERATORS
Detectors: gas detectors –ionization chamber – G-M counter – scintillation counter – photo multiplier tube (PMT) – semiconductor detectors – neutron detector.
Accelerators: linear accelerators – cyclotron – synchrotron – betatron– electron synchrotron – proton synchrotron (bevatron)

Unit 5:
PARTICLE PHYSICS: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons.

(12 Hours)

Reference Books:

1. Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
2. Concepts of nuclear physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
3. Introduction to the physics of nuclei & particles, R.A. Dunlap. (Thomson Asia, 2004).
4. Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press
5. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
6. Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
7. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
8. Techniques for Nuclear and Particle Physics Experiments, W. R. Leo,(Springer-Verlag Berlin Heidelberg, 1994)

	Course Outcomes	Level
CO-1	Properties of nuclei, nuclear models, laws of radio-activity, detectrion methods of radiation, classification of fundamental forces and particles.	Remember
CO-2	Liquid-drop model, Shell model, alpha decay, beta decay, interaction of radiation with matter, fission and fusion reaction, interaction of radiation with matter, working principles of accelators	Understand
CO-3	Shell model to find nuclear spin, magnetic moment and electrical quadrupole moments of various nuclei. Apply quantum mechanics to solve alpha-decay and beta-decay process, also to understand nuclear reactions. Theory of interaction of radiation with matter to understand the working principle of radiation detectors. Conservation of various quantum numbers to understand three fundamental forces.	Apply
CO-4	Liquid drop models give a very simple idea to model a system and explain its properties. Finding out scattering cross sections, mechanism of nuclear and particle physics experiments and detection of sub-atomic particles.	Apply

Mapping of Program Outcomes with Course Outcomes

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

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

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Course Code: PHY1064
Course Title: Atomic Physics & LASER Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Determination of e/m of an electron
2. Determination charge of an electron by Millikan's oil drop method
3. Study of Photoelectric Effect
4. Study the characteristics of photovoltaic cell
5. Study the characteristics of photo-conducting cell
6. Study the characteristics of the Photomultiplier tube
7. Study the spin of electrons by Stern and Gerlach experiment
8. Study the splitting of spectral lines by the Zeeman effect
9. Determination of Lande 'g' factor by ESR
10. Determination of particle size by LASER
11. Study the Haidinger fringes.
12. Study the Laser beam characteristics
13. Determination of laser parameter divergences and wavelength for a given laser source using grating.

	Course Outcomes	**Level**
CO-1	Verification of e/m and charge of an electron	Remember
CO-2	Understanding the concepts of Photoelectric Effect and characteristics of photovoltaic cells, photo-conducting cells and Photomultiplier tube.	Understand
CO-3	Reveal the space quantization and spin of electrons.	Apply
CO-4	Analyze the splitting of spectral lines under a magnetic field	Analyze
CO-5	Acquire knowledge on characteristics and unique features of LASER over conventional Light source.	Skill

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1065
Course Title: Analog Electronics Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Verification of network theorems
2. Study of IV characteristics of a zener diode and voltage regulation by zener diode.
3. Half wave, full wave and bridge rectifier using diodes.
4. Clipping and clamping circuits using junction diode
5. A study of Transistor Characteristics (a) CB, (b) CE and (c) CC
6. Studies on BJT CE amplifier
7. RC phase shift oscillator
8. Operational amplifier: Summing, Inverting, , Differentiator , Integrator
9. Construction of inverting operational amplifier using transistors
10. Construction of non-inverting operational amplifier using transistors

Reference Books:

Course Outcomes		Level
CO-1	Verification of network theorems	Remember
CO-2	Understanding the output characteristics of Zenor diodes	Understand

		Apply
CO-3	Demonstration of voltage regulator using Zenor diodes, Construction of amplifiers and Oscillators	Apply
CO-4	Construction of clipper and clamper circuit	Analyze
CO-5	Construction of inverting and non-inverting operational amplifiers and design of ckt for adder, subs tractor, differentiator and integrator	Skill

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1066
Course Title: Computer Programming & Numerical Techniques Lab
Course Type: Practical (Core)
Credits: 02

List of experiments:
1. Different operating systems, programming languages
2. Determination of root of a polynomial by Bisection method
3. Determination of root of a polynomial by Secant method
4. Determination of root of a polynomial by Newton-Raphson method
5. Solution of linear simultaneous equations by Gauss-Elimination method
6. Solution of ordinary differential equations: Euler's I & II method
7. Solution of ordinary differential equations: Runge-Kutta (RK2 & RK4) Method
8. Numerical Integration-1: Midpoint method & Trapezoidal method
9. Numerical Integration-1: Simpson's method, Gauss Quadrature method
10. Interpolation: Newton's divided difference method
11. Interpolation: Lagrange method

Reference Books:
1. Venkatraman, M. K., "Numerical Methods in Science and Engineering", National Publishing Company, Madras, 1996.
2. Schaum's Outline of Programming with C++, McGraw-Hill; 2nd Edition
3. Numerical Recipes in C++: The Art of Scientific Computing , Cambridge
4. Numerical methods by Balaguruswamy - TMH.

Course Outcomes		Level
CO-1	Numerical techniques for solving differential equation, integration, finding root of polynomials and predicting data using interpolation method	**Remember**
CO-2	Root finding methods, numerical methods to solve linear and differential equation, integration.	**Understand**
CO-3	The theoretical procedure of various root finding methods and finding solutions for linear differential equations in computer programs and solve numerical problems.	**Apply**
CO-4	Skill to solve numerical problems using computer programs and use of different programming techniques for efficient programs.	**Skill**

Mapping of Program Outcomes with Course Outcomes

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

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SEMESTER - VII

Course Code: PHY1071
Course Title: Classical Mechanics
Course Type: Theory (Core)
Credits: 04

Unit 1:
LAGRANGIAN DYNAMICS: Lagrangian Formulation-System of particles-Constraints and degrees of freedom, Generalized Coordinates, Concept of virtual work, Conservation Laws -Conservation of Linear and Angular momenta- Symmetric properties-D'Alembert Principle, Lagrange equation from D'Alembert principle, Application of Lagrange equations of motion -free particle in Space -Atwood's machine – bead sliding in rotating wire, velocity dependent potential, cyclic coordinates, symmetry properties and conservation theorems.

(12 Hours)

Unit 2:
HAMILTONIAN DYNAMICS: Calculus of Variation-Hamiltonian's Variation principle-Lagrange's equation from Hamilton's principle-Hamilton's principle for nonholonomic system-Hamilton's equations from Variational principle, phase space diagrams, Legendre transformation and Hamilton's equations of motion-Cyclic co-ordinates and conservation theorem, Noether's theorem, Liouville's theorem.

(12 Hours)

Unit 3:
CENTRAL FORCE PROBLEM: Central force and motion in a plane, Reduction of a two-body central force to equivalent one body problem, Equation of motion and first integral, Differential equation for an orbit, Equivalent one-dimensional problem and classification of orbits for some specific potential. Integral power law potential, Virial theorem, Relation between kinetic and potential energy. Keplers Problems: Equation of orbit and the kind of the orbit, Scattering in a central force field-transformation of Scattering to Laboratory co-ordinates, Relativistic Lagrangian and Hamiltonian for a particle.

(12 Hours)

Unit 4:
KINEMATICS OF RIGID BODY: Independent co-ordinate of a rigid body, Orthogonal transformation, Formal properties of transformation matrix, Euler angles, Euler's theorem, Finite rotation, Infinitesimal rotations (contact transformation). Angular momentum, Moment of inertia tensor, Product of inertia, Inertia tensor, Principal moment of inertia: Principal axis, Kinetic energy of motion of a rigid body about a point. Moment of inertia tensor-Euler's equation of motion-Torque free motion of a rigid body-heavy Symmetrical top.

(12 Hours)

Unit 5:
CANONICAL TRANSFORMATION & HAMILTON-JACOBI THEORY: Canonical transformation, Legendre transformation, Generating functions, Conditions for canonical transformation, Poisson's brackets, Langrange brackets, Invariance of Poission bracket under canonical transformation, Angular momentum Poission bracket relation. Hamilton Jacobi equation for Hamilton's principal function, Harmonic oscillator problem by Hamilton Jacobi method, Hamilton's characteristic function. Harmonic oscillations-Small oscillations-Normal co-ordinates-Normal frequencies of vibrations -Vibrations of linear triatomic molecule

(12 Hours)

Reference Books::
1. H. Goldstein: Classical Mechanics, Narosa Publishing House, 2001.
2. N. C. Rana and P. S. Joag: Classical Mechanics, Tata Mc-Graw Hill, New Delhi, 1991.
3. J. C. Upadhyaya: Classical Mechanics, Himalaya Publishing, 2006.
4. P. V. Panat: Classical Mechanics, Narosa Publishing House, 2000.
5. S. L. Gupta, V. Kumar, H. V. Sharma: Classical Mechanics, Pragati Prakashan, Meerut, 2009.

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

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1072
Course Title: Mathematical Physics -I
Course Type: Theory (Core)
Credits: 04

Unit 1:
FUNCTION OF REAL VARIABLES: Features of a function, sketching functions, interpreting graph of functions using the concepts of calculus. Functions represented by integrals -, Gaussian integral in 1, 2 and 3 dimensions, step function □, Dirac delta function – Defining relation, sequences of function tending to □-function, relation between □ and □ function, properties of Dirac delta function, derivative of □-function.

(12 Hours)

Unit 2:
SPECIAL FUNCTIONS: Error function, complementary error function, Gamma function, Legendre, Hermite, Laguerre function Generating function, Recurrence relations and their differential equations Orthogonality of eigenfunctions Bessel's function of first kind, Spherical Bessel function, Associated Legendre function, Spherical harmonics.

(12 Hours)

Unit 3:
LINEAR VECTOR SPACES: Linear Vector Spaces and its dual, Linear Dependence and Independence of vectors, Basis and Dimensions, Infinite dimensional vector space- Hilbert space, subspace, Rank and Nullity of a Matrix, Examples from Real Function Space and Polynomial Space, Orthogonal Vectors, Orthogonal Basis, Gram- Schmidt process of generating an Orthonormal Basis, Change of basis, singular value decomposition. Linear Transformations. Representation of Linear Transformations by Matrices. Hermitian and Skew- Hermitian Matrices. Orthogonal and Unitary Matrices. Similar Matrices. Inner Product. Properties of Eigenvalues and Eigen Vectors of Orthogonal, Hermitian and Unitary Matrices similarity transformation. Exponential of a Matrix.

(12 Hours)

Unit 4:
CURVILINEAR COORDINATES & TENSORS: Orthogonal coordinate systems, Gradient, Curl, Divergence and Laplacian in orthogonal coordinate systems, Spherical, Polar and Cylindrical co-ordinates, Poisson's and Laplace Equations. Coordinates Transformation in N- dimensional Space, Einstein's summation convention, Tensors, . Contravariant, covariant and mixed tensor, tensors of rank greater than 2, Algebra of Tensors: Sum, Difference and Product of Two Tensors. Contraction, Quotient Law of Tensors, Symmetric and Anti-symmetric Tensors, Kronecker and Alternating Tensors Jacobian, Pseudo tensors, Fundamental operations with tensors, line element and metric tensor, tensor form of gradient, divergence, and curl, Covariant derivative, Christoffel's symbol, relative and absolute tensors.

(12 Hours)

Unit 5:
GROUP THEORY: Definition of group symmetry elements, homomorphisms; isomorphism; Subgroups and cyclic groups; Cosets; Abelian groups, Reducible and irreducible representation –Character table. O(3), SU(2) groups.

(12 Hours)

Reference Books::
1. Mathematical methods in physical sciences, Mary L Boas
2. Mathematical methods for physicists: G.B.Arfken, Hans Webber
3. Mathematical methods for physics and engineering: K.F.Riley, M.P.Hobson et. al.
4. Mathematical Physics, V. Balakrishnan

Course Outcomes		Level
CO-1	To get an idea of functions used in most of the physical systems, their basic properties and behaviour. Acquire the skill to get qualitative features of functions which can be used while analysing solutions of a physical problem.	Understand, Analyze, Skill
CO-2	Students will get to know about special functions which appear in many particle problems	Analyze, Apply
CO-3	To learn the abstract way of defining quantities like space, dimensionality of spaces etc which can be applied in various branches of physics.	Understand, Apply
CO-4	Learn the technique of tensor notation. Application of tensor notation in analysing various physical systems.	Skill, Apply, Analyse
CO-5	Get the idea of Group theory and its application in many branches of physics	Skill

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHY1073
Course Title: Quantum Mechanics -I
Course Type: Theory (Core)
Credits: 04

Unit 1:
GENERAL FORMALISM: Historical background, Stern-Gerlach experiment leading to concept of vector space, Ket and bra notation for vector space, Inner product, Norm of a vector, Orthonormality and linear independence, Basis and dimension, Outer product, Projection operator, Completeness (closure property), Hilbert space, Operator, Hermitian operator, Eigen value and eigen function, Representation theory, Change of basis, Unitary operator, Matrix elements, Unitary transformation, Diagonalization, Coordinate and momentum representation.   **(12 Hours)**

Unit 2:
MEASUREMENTS IN QUANTUM MECHANICS: Expectation values, Compatible and incompatible observable, Base kets as simultaneous eigen kets of maximal set of commuting observables, Examples, Heisenberg uncertainty principle, Gaussian wave packet, Schrödinger picture, Heisenberg picture and interaction picture, density matrix, pure and mixed states, evolution. Invariance Principle and Conservation Laws: Symmetry and conservation laws, Displacement in space- conservation of linear momentum, Displacement in time –conservation of energy, Rotations in space- conservation of angular momentum, Space- inversion parity.

(12 Hours)

Unit 3:
SOLUTION OF SCHRODINGER EQUATION: One dimensional simple harmonic oscillator: Eigen function and Eigen value by solving Schrödinger equation and also by operator method, Creation and annihilation operators. Two beads on a wire and a particle in a two-dimensional box. Two dimensional harmonic oscillators. Linear combination of atomic orbitals (LCAO) approximation. Periodic lattice, Bragg reflection.

(12 Hours)

Unit 4:
ANGULAR MOMENTUM: Angular Momentum: Orbital Angular Momentum, Spherical harmonics, Operators Orbital angular momentum operators L , Lx, Ly and Lz, Spin angular momentum and total angular momentum, Commutation relations, Ladder operators, Matrix representation of Operators Jx, Jy, Jz, and J , Pauli spin matrices, Addition of two angular momentums, Clebsch- Gorden coefficients. Selection Rules and simple applications.

(12 Hours)

Unit 5:
THREE DIMENSIONAL PROBLEMS: Free particle in Cartesian coordinates, free particle in spherical polar coordinates, radial wave functions, radial momentum, particle in a three-dimensional box, degeneracy, density of states, charged particle in magnetic field, Fermi energy and Landau levels, Two-particle problem, effective potential, angular momentum barrier, Solution of Schrödinger equation for Hydrogen atom-energy levels and stationary state wave functions

(12 Hours)

Reference Books::
1. D. J. Griffiths and D. F. Schroeter, Introduction to Quantum Mechanics, Cambridge University Press, 2018, 3rd Ed.
2. R.L. Liboff, Introdunctory Quntum Mechanics, Pearson Education, 2003, 4th Edition.
3. J. J. Sakurai, Modern Quantum Mechanics, Pearson Education, 2005.
4. N. Zettili, Quantum Mechanics Concepts and Applications, John Wiley, 2009, 2nd edition.
5. P. M. Mathews and Venkatesan, A Text Book of Quantum Mechanics, Tata McGraw Hill, 2010.
6. Quantum Mechanics – A. K. Ghatak and S. Lokanathan (Macmillan, Delhi).
7. Quantum Mechanics – J. L. Powell and B. Crasemonn, (Oxford, Delhi).
8. C. Cohen-Tannoudji, Quantum Mechanics (vol.2), John Willey & sons, 2005.
9. Aruldhas G, "Quantum Mechanics", Printice-Hall of India Pvt. Ltd. 2002
10. R. Eisberg and R. Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Wiley India Pvt. Ltd., 2006.
11. Basic Quantum Mechanics , J. M. Cassels.
12. Quantum Mechanics, S. P. Singh.

	Course Outcomes	Level
CO-1	Understand basic concepts of Quantum mechanics,	Remember, Understand
CO-2	Study the different pictures of quantum dynamics and conservation laws	Apply, Understand
CO-3	Applying the Quantum mechanics concepts to solve one and two dimensional problems.	Apply
CO-4	Concept of spin and angular momentum operator algebra	Understand, Apply, Analyze
CO-5	Applying the Quantum mechanics concepts to solve three dimensional problems.	Apply

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1074
Course Title: Computational Condensed Matter Physics
Course Type: Theory (Core)
Credits: 04

Unit 1:
INTRODUCTION & BASIC CONCEPTS: Theoretical Background, Basic equations for interacting electrons and nuclei, Coulomb interaction in condensed matter, independent electron approximations, Exchange and correlation, Periodic solids and electron bands, Structures of crystals: lattice + basis, The reciprocal lattice and Brillouin zone, Excitations and the Bloch theorem.

(12 Hours)

Unit 2:
Time reversal and inversion symmetries, Integration over the Brillouin zone and special points, Density of states Uniform electron gas and simple metals. Non-interacting and Hartree-Fock approximation, The correlation hole and energy. Density functional theory: foundations, Thomas-Fermi-Dirac approximations: example of a functional. The Hohenberg-Kohn theorems, Constrained search formulation of density functional theory, Extensions of Hohenberg-Kohn theorems, The Kohn-Sham ansatz. Replacing one problem with another: The Kohn-Sham variational equations Exc, Vxc and the exchange correlation hole Meaning of the eigenvalue. Intricacies of exact Kohn-Sham theory.

(12 Hours)

Unit 3:
Functionals for exchange and correlation, The local spin density approximation (LSDA), Generalized-gradient approximation (GGAs) , LDA and GGA expressions for the potential Vxc(r), Non-collinear spin density, Non-local density formulations: ADA and WDA, Orbital dependent functionals I: SIC and LDA+U. Orbital dependent functional II: OEP and EXX, Hybrid functionals , Tests of functionals Solving Kohn-Sham equations – Self-consistent coupled Kohn.Sham equations - Total energy functionals, Achieving self-consistency – Numerical mixing schemes, Force and stress.

(12 Hours)

Unit 4:
Determination of electronic structure – Atomic sphere approximation in solids, Plane waves and grids: basics - The independent particle Schrodinger equation in a plane wave basis. The Bloch theorem and electron bands - Nearly free-electron-approximation - Form factors and structure factors. Plane-wave method - 'Ab initio' pseudopotential method - Projector augmented waves (PAWs) - Simple crystals: structures, bands, - Supercells: surfaces, interfaces, phonons, defects - Clusters and molecules. Localized orbitals: tight-binding – Tight-binding bands: illustrative examples - square lattice and CuO2 planes - Examples of bands: semiconductors and transition metals - Electronic states of nanotubes. Localized orbitals: full calculations – Solution of Kohn-Sham equations in localized bases. Analytic basis functions: gassians - Gassian methods: ground state and excitation energies - Numerical orbitals - Localized orbitals: total energy, force, and stress - Applications of numerical local orbitals - Green's function and recursion methods - Mixed basis.

(12 Hours)

Unit 5:
Augmented plane waves (APW's) and 'muffin-tins' – Solving APW equations: examples Muffin-tin orbitals (MTOs). Linearized augmented plane waves (LAPWs) - Applications of the LAPW method - Linear muffin-tin orbital (LMTO) method - Applications of the LMTO method - Full potential in augmented methods - Molecular dynamics (MD): forces from the electrons - Lattice dynamics from electronic structure theory - Phonons and density response functions - Periodic perturbations and phonon dispersion curves - Dielectric response functions, effective charges - Electron-phonon interactions and superconductivity.

(12 Hours)

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

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

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1075
Course Title: Computational Condensed Matter Physics Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Introduction to Quantum Espresso simulation software package (GUI-BURAI) and plotting software
2. Optimizing crystal structure of Si and GaAs.
3. Analyzing band structure of Si, GaAs and graphene.
4. Plotting the total and partial density of states   (DOS) and analyzing the bonding interaction present in Si, GaAs and graphene.
5. Plotting and analyzing the band structure, total DOS and partial density of states of TiO2. Explain why it is a transparent conductor.
6. Absorption spectra for Si, GaAs and TiO2.
7. Band structures of n-type and p-type semiconductors.
8. Finding optimized magnetic ordering of Fe.
9. Charge density and Electron localized function of NaCl, Si and Fe.
10. Calculating phonon spectra of graphene.

Reference Books:
8. H.Skriver, The LMTO Methods, Springer (1984).
9. Electronic Structure Basic Theory and Practical Methods Richard M. Martin, Cambridge University Press (2004).
10. Modeling Materials Continuum, Atomistic and Multiscale Techniques ELLAD B. TADMOR, Cambridge University Press (2012).
11. Atomic and Electronic Structure of Solids, Efthimios Kaxiras, Cambridge University Press (2003).
12. Computational Chemistry of Solid State Materials, *Richard Dronskowski,* WILEY-VCH (2005).
13. Mizutani U. Introduction to the Electron Theory of Metals (CUP,2001).
14. Roessler U. Solid State Theory.. An Introduction (2ed., Springer, 2009)

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Course Code: PHY1076
Course Title: Digital Electronics & Microprocessor Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Design of various types of active filters
2. Construction of seven segment display.
3. Voltage regulator using IC723
4. Study of gate ICs – NOT,OR,AND, NOR,NAND, XOR, XNOR
5. Half adder / Half subtractor using basic logic gate ICs
6. NAND as universal building block
7. NOR as universal building block
8. Construction of Op-Amp- 4 bit Digital to Analog converter (Binary Weighted and R/2R ladder type)
9. Study of R-S, clocked R-S and D-Flip flop using NAND gates
10. Study of J-K, D and T flip flops using IC 7476/7473
11. Construction of Encoder and Decoder circuits using ICs
12. Microprocessor 8085 – addition, subtraction, multiplication, division (8bit only)

13. Microprocessor 8085 – square, square root, largest/smallest of numbers, ascending/descending order, Fibonacci series (8 bit only)

Reference Books:

1.Analog Electronics: Analog and Digital Circuit Systems- Jacob Milman & Halkias, TMH
2. A practical introduction to Analog and Digital circuits by Daniel M Kaplan, and Christopher G. White, Cambridge University Press 2010.
3. Integrated Electronics by Jacob Milman & Halkias, TMH.

Course Outcomes		Level
CO-1	Conduct the experiments on application of OP-Amps	Remember
CO-2	Construction of voltage stabilizer and logic gates using ICs	Understand
CO-3	Analyze the applications of counters and registers	Apply
CO-4	Able to implement logic gates in flip-flops	Analyse
CO-5	Able to write the program/code in microprocessor	Skill

Mapping of Program Outcomes with Course Outcomes

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

SEMESTER - VIII

Course Code: PHY1081
Course Title: Mathematical Physics -II
Course Type: Theory (Core)
Credits: 04

Unit 1:
COMPLEX ANALYSIS: Complex Numbers and their Graphical Representation. Euler's formula, De-Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Equations. Examples of analytic functions. Sequence and series of functions, convergence tests, absolute and uniform convergence, Taylor and Laurent series, analytic continuation.
(12 Hours)

Unit 2:
SINGULARITIES: poles, removable singularity, essential singularity, branch points, branch cut. Integration of a function of a complex, variable. Cauchy's Integral formula. Simply and multiply connected region. Residues and Residue Theorem. Application of Contour Integration in solving Integrals.
(12 Hours)

Unit 3:
FOURIER SERIES, TRANSFORM, & APPLICATION: Fourier series, orthogonality of functions, Dirichlet conditions. Application: Summing of Infinite Series. Fourier integral theorem, Fourier transform, Parseval's identity, convolution theorem, transform of derivates, Fourier transforms of simple function occurring in physical application.
(12 Hours)

Unit 4:
LAPLACE TRANSFORM & ITS APPLICATION: Laplace Transform (LT) of Elementary functions. Properties of LTs, Change of Scale, Shifting. LTs of Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Periodic Functions. Convolution Theorem. Inverse LT. Evaluation of inverse Laplace transform using counter integration. Application of Laplace Transforms to 2nd order Differential Equations, Coupled differential equations of 1st order.
(12 Hours)

Unit 5:
PROBABILITY & STATISTICS: Independent and dependent events, Conditional Probability. Bayes' Theorem, Independent random variables, Probability distribution functions, special distributions: Binomial, Poisson and Normal, moment generating functions,
Experiment, sample and population, sample statistics – moments and moment generating functions, covariance and correlation, maximum likelihood estimator, method of least squares, Hypothesis testing.
(12 Hours)

Reference Books::
1.Mathematical methods in physical sciences, Mary L Boas
2. Mathematical methods for physicists: G.B.Arfken, Hans Webber
3. Mathematical methods for physics and engineering: K.F.Riley, M.P.Hobson et. al.
4. Mathematical Physics, V. Balakrishnan

	Course Outcomes	Level
CO-1	To get an idea of complex variables and its uses in physical problems.	**Understand, Analyze**
CO-2	To use the idea of complex analysis in solving physical problems.	**Apply, skill**

		Understand, Analyze, Apply
CO-3	Learn the techniques of Fourier Series and Fourier transform.To apply the idea of Fourier Series and transform in various branches of Physics, Chemistry, Finance etc.	Understand, Analyze, Apply
CO-4	Learn Laplace transformation technique and its application.	Understand, Analyze, Apply
CO-5	Learn statistical methods and techniques.	Skill

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1082
Course Title: Quantum Mechanics -II
Course Type: Theory (Core)
Credits: 04

Unit 1:
TIME INDEPENDENT PERTURBATION THEORY: Time independent perturbation **theory** for non-degenerate energy levels – Degenerate energy levels – Stark effect in Hydrogen atom – Ground and excited state – Variation method – Helium atom – WKB approximation – Connection formulae (no derivation) – WKB quantization – Application to simple harmonic oscillator.

(12 Hours)

Unit 2
TIME DEPENDENT PERTURBATION THEORY: Constant perturbation, Transition to continuum, Fermi's golden rule, Harmonic perturbation, Radiative transitions; Adiabatic approximation, Sudden approximation. Semi-Classical Theory of Radiation: Einstein coefficients, Atom field interaction, Interaction energy, Dipole matrix elements, Stimulated emission rate, Spontaneous emission rate, Selection rules

(12 Hours)

Unit 3:
IDENTICAL PARTICLES: Principle of indistinguishability, Symmetry of wave functions, Spin and statistics, Pauli's exclusion principle, Construction of wave function of two electrons in L-S and j-j coupling, Allowed states, Ortho and para helium; Exchange force; Scattering of identical particles, Cases of spin half and spin zero particles.

Unit 4:
SCATTERING: The scattering experiments, Relationship of cross-section and wave function, Scattering amplitude; Partial wave analysis: Expansion of a plane wave in terms of partial waves, Scattering by central potential, Zero energy scattering; Scattering by a square well potential, Effective range, Resonant scattering, Optical theorem, Born approximation, Integral equation for scattering, Born's first approximation, Spherically symmetric potential, Criterion for validity of Born approximation, Scattering of electrons by atoms, Rutherford scattering.

(12 Hours)

Unit 5:
RELATIVISTIC WAVE EQUATION: Klein Gordan equation, Dirac equation, Properties of Dirac matrices, Free Dirac particle, Equation of continuity, Interpretation Of Negative Energy States – Antiparticle, Covariant form of Dirac Equation – Properties of the gamma matrices – Traces – Relativistic invariance of Dirac equation – Probability Density – Current four vector – Bilinear covariant CLASSICAL FIELDS: Euler Lagrange equation – Hamiltonian formulation – Noether's theorem – Quantization of real and complex scalar fields– Second Quantization of K-G field.

(12 Hours)

Reference Books::
1. D. J. Griffiths and D. F. Schroeter, Introduction to Quantum Mechanics, Cambridge University Press, 2018, 3rd Ed.
2. R.L. Liboff, Introductory Quntum Mechanics, Pearson Education, 2003, 4th Edition.
3. J. J. Sakurai, Modern Quantum Mechanics, Pearson Education, 2005.
4. N. Zettili, Quantum Mechanics Concepts and Applications, John Wiley, 2009, 2nd edition.
5. P. M. Mathews and Venkatesan, A Text Book of Quantum Mechanics, Tata McGraw Hill, 2010.
6. Quantum Mechanics – A. K. Ghatak and S. Lokanathan (Macmillan, Delhi).
7. Quantum Mechanics – J. L. Powell and B. Crasemonn, (Oxford, Delhi).
8. C. Cohen-Tannoudji, Quantum Mechanics (vol.2), John Willey & sons, 2005.
9. Aruldhas G, "Quantum Mechanics", Printice-Hall of India Pvt. Ltd. 2002
10. R. Eisberg and R. Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Wiley India Pvt. Ltd., 2006.
11. Basic Quantum Mechanics , J. M. Cassels.
12. Quantum Mechanics, S. P. Singh.

	Course Outcomes	**Level**
CO-1	Finding the energy levels of quantum systems subject to time independent perturbations.	Understand
CO-2	Applying the concept of time dependent perturbation theory to study atom-light interactions.	Apply
CO-3	Apply the concepts of quantum mechanics to the case of identical particles	Apply
CO-4	Analyze the quantum scattering of identical particles and find the cross section for scattering.	Analyze
CO-5	Understand the relativistic effects in quantum mechanics	Understand

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHY1083
Course Title: Statistical Mechanics
Course Type: Theory (Core)
Credits: 04

Unit 1:
REVIEW OF THERMODYNAMICS & PROBABILITY: Quasistatic and nonquasistatic processes, laws of thermodynamics, entropy of a probability distribution, random walks. Macrostates, microstates, phase space and ensembles. Ergodic hypothesis, postulate of equal a-priori probability and equality of ensemble average and time average. Boltzmann's postulate of entropy. Counting the number of microstates in phase space. Entropy of ideal gas: Sackur-Tetrode equation and Gibbs' paradox. Liouville's Theorem.

(12 Hours)

Unit 2:
ENSEMBLE THEORIES: Canonical Ensemble System in contact with a heat reservoir, expression of entropy, canonical partition function, Helmholtz free energy, fluctuation of internal energy. Grand Canonical Ensemble System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number. Chemical potential of ideal gas. Chemical equilibrium and Saha Ionization Equation. Mean field theory and Van der Wall's equation of state.

(12 Hours)

Unit 3:
QUANTUM STATISTICAL MECHANICS: Density Matrix; Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices – one electron in a magnetic field, particle in a box; Identical particles – B-E and F-D distributions. Ideal Bose and Fermi gas Equation of state; Bose condensation; Equation of state of ideal Fermi gas; Fermi gas at finite temperature.

(12 Hours)

Unit 4:
PHASE TRANSITION: Phase Transition and Critical Phenomena Ising model – partition function for one dimensional case, Phase transitions – first order and continuous, critical exponents and scaling relations. Calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension, Rudiments of Real Space Renormalization Group Transformations.

(12 Hours)

Unit 5:
INTRODUCTORY NON-EQUILIBRIUM STATISTICS: Irreversible processes, Classical Linear Response Theory, Brownian Motion, Master Equation, Fokker-Planck Equation, Fluctuation-Dissipation Theorem

(12 Hours)

Reference Books::
1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
2. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
3. Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall
4. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W.Sears and Gerhard L. Salinger, 1986, Narosa.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
6.An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press

	Course Outcomes	Level
CO-1	Understand concept of ensemble	Understand
CO-2	Applying the ensemble concepts to open, closed thermodynamics system.	Apply/Analyze
CO-3	Understand the concept of quantum statistics.	Understand
CO-4	Solve different thermodynamics systems by using classical and quantum statistics	Skill
CO-5	Find out the application of ensemble concept in diffusive systems.	Evaluate

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHY1084
Course Title: Experimental Methods in Physics
Course Type: Theory (Core)
Credits: 04

Unit I:
Measurement of fundamental constants: e, h, c – Measurement of high and low resistances, inductance and capacitance – Detection of X-rays, Gamma rays, charged particles, neutrons – Ionization chamber – Proportional counter – GM counter – Scintillation detectors – Solid State detectors.

(12 Hours)

Unit II:
Emission and Absorption Spectroscopy – Measurement of Magnetic field – Hall effect – Magnetoresistance – X-ray and neutron Diffraction. **(12 Hours)**

Unit III:
Vacuum Techniques – Basic idea of conductance, pumping speed – Pumps: Mechanical Pump – Diffusion pump – Gauges – Thermocouple gauge – Penning gauge – Pirani gauge – Hot Cathode gauge – Low temperature systems – Cooling a sample over a range up to 4 K – Measurement of low temperatures. **(12 Hours)**

Unit IV:
Measurement of energy and time using electronic signals from the detectors and associated instrumentation – Signal processing – A/D conversion – multichannel analyzers – Time-of-flight technique – Coincidence Measurements – true to chance ratio – Correlation studies. Error Analysis and Hypothesis testing – Propagation of errors – Plotting of Graph – Distributions – Least squares fitting – Criteria for goodness of fits – Chi square test. **(12 Hours)**

Unit V:
Design of experiment – need for experiments (validation of theory/ verification of theory/ addition to database); computer interfacing; Data collection and analysis – errors and accuracy of data collected, types of errors, propagation of errors, reporting data – mean, variance, method of least Bsquares fit, central limit theorem, error bars. Data reproducibility and ethics of data collection.phase sensitive detection; shielding of cables. **(12 Hours)**

Reference **Books:**
1. J.P. Holman, Experimental Methods for Engineers. 7th Edition. McGraw Hill (2000).
2. J. M. Lafferty (Editor) (1998), Foundations of Vacuum Science and Technology, Wiley Interscience.
3. Douglas C. Montgomery, Design and Analysis of Experiments, John Wiley(2004).
Suggested Reading:
4. Anthony Kent, Experimental Low-Temperature Physics ,Macmillan Physical Science (1993).
5. T. G. Beckwith, R. D. Marangoni and J. H. Lienhard ,Mechanical Measurements,6th Edition(2006),Prentice Hall.

6. Ernest O Doebelin, Measurement Systems: Application and Design. 5th edition, Tata McGraw Hill.
7. Albert D Helfrick and William D Cooper (1992), Modern Electronic Instrumentation and Measurement Techniques. Prentice Hall.
8. Hermann K P Neubert, Instrument Transducers: An introduction to their performance and design. Oxford University Press(2003).
9. J. A. Blackburn Modern Instrumentation for Scientists and Engineers, Springer (2001).

Course Outcomes

	Course Outcome	**Level**
CO 1	Different experimental techniques, need for vacuum technology, methods used in the design of experiments.	Remember
CO 2	Understand the strength and limitation of each technique and choose the right technique for characterization of properties. Understand the methods used in the design of experiments and how these methods are connected to statistical models.	Understand
CO 3	Approach complex industrial and business research problems and address them through a rigorous, statistically sound experimental strategy. Apply the analytical techniques and graphical analysis to the experimental data.	Apply
CO4	Analyze the pros and cons of applying the experimental methods to correlate with the Physics theory.	Analyse
CO5	Design simple experiments him/her self and have a general insight into how data analysis is done in connection to designed experiments.	Skill

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHY1085
Course Title: Experimental Techniques Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Solar cell Characteristics
2. Fuel Cell Characteristics
3. Thin films - Electrodeposition by a simple method
4. Thin films-Electro deposition by three-electrode system
5. Thin films-Solution growth method (SILAR)
6. Measurement of Lattice parameters of powder XRD data
7. Find the miller indices - Using Powder XRD
8. Tauc plot-Determination of Bandgap
9. FTIR-Functional group identification
10. Thin film thickness measurement - optical method
11. Particle Size Analysis - SEM / TEM
12. DSC/TG/DTA Analysis
13. RAMAN - Vibrational Characteristics
14. Dielectric and Curie Temperature Measurement of
15. Ferroelectric Ceramics
16. Determination of the band gap of a Semiconductor by Four Probe Method
17. Ultrasonic Diffractometer
18. Hall Effect
19. Ultrasonic Interferometer
20. Specific Heat Capacity of Solid
21. Magnetoresistance in Semiconductor
22. Magnetic Susceptibility of a paramagnetic substance

Reference Books::
1. J.P. Holman, Experimental Methods for Engineers. 7th Edition. McGraw Hill (2000).
2. J. M. Lafferty (Editor) (1998), Foundations of Vacuum Science and Technology, Wiley Interscience.
3. Douglas C. Montgomery, Design and Analysis of Experiments, John Wiley(2004).

	Course Outcomes	**Level**
CO-1	Verification of characteristics of Solar cell, Fuel Cell	**Fundamental**
CO-2	Understanding the basics of thin film preparation, having an idea about lattice parameters, find the miller indices using XRD.	**Understanding**
CO-3	Knowing the specific heat capacity of a solid, liquid, and gas.	**Utilizing**
CO-4	Analyze and compare the characteristics of a conductor, semiconductor, and insulator.	**Developements**
CO-5	Acquire knowledge of magnetic susceptibility.	**Higher study**

Mapping of Program Outcomes with Course Outcomes

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

SEMESTER - IX

Course Code: PHY1091
Course Title: Condensed Matter Physics
Course Type: Theory (Core)
Credits: 04

Unit 1:
LATTICE DYNAMICS: Elastic properties - Quantization of elastic waves,; - Theory of elastic vibrations in mono and diatomic lattices - phonons – vibrations and thermal properties of solids - Dispersion relations - Phonon momentum and inelastic scattering by phonons. - lattice specific heat – Dulong and Petit's law - Vibrational modes - Einstein model - Density of modes in one and three dimensions - Debye Model of heat capacity - Anharmonic Effects - Explanation for Thermal expansion, Conductivity and resistivity – Umklapp process.

(12 Hours)

Unit 2:
THEORY OF ELECTRONS: Free electron theory and electronic specific heat; Response and relaxation phenomena. Drude model of electrical and thermal conductivity - Wiedemann – Franz law.. Hall effect magnetoresistance –and thermoelectric power. Fermi-Dirac distribution – Bloch theorem -Electrons in periodic lattice –Heat capacity of the electron gas – Ohm's law, Matthiessen's rule – nearly free electron - the origin and magnitude of energy gap – Bloch functions - Bloch theorem - Motion of an electron in a periodic potential – Kronig – Penney model - Approximate solution near a zone boundary – Limitations of K-P model – tight binding models band theory of solids: metals, semiconductors and insulators; conductivity, mobility and effective mass - Fermi surfaces: Reduced and periodic zone schemes of construction- de Haas – van Alphen effect - Cyclotron resonance.

(12 Hours)

Unit 3:
CRYSTAL IMPERFECTIONS AND ORDERED PHASES OF MATTER: Defects in Crystal: Point defects, Colour centers, F-centers, Line defects and planer defects – dislocations- Role of dislocations in crystal growth. Concentrations of Vacancy, Frenkel and Schottky imperfections - Burgers Vector – Presence of dislocation – surface imperfections- Ordered phases of matter: Translational and orientation order - Kinds of liquid crystalline order - Quasi crystals .

(12 Hours)

Unit 4:
THEORY OF FERROELECTRICS AND PIEZO ELECTRICS : Ferroelectricity – Classifications of Ferroelectric crystals - Dipole theory of ferroelectricity – Landau Theory of the phase transition – First and second order transition, Long range order, Short range order and Bragg William model.– Theory of the ferroelectric displacive transitions: Polarization catastrophe, Soft optical phonon, Thermodynamics of ferroelectric transition, –Ferroelectric domains – Ferroelectric domain wall motion -Antiferroelectricity – Piezoelectric and pyroelectric material - Phenomenological Approach to Piezoelectric Effects - Piezoelectric Parameters and Their Measurements.

(12 Hours)

Unit 5:
OPTICAL PROPERTIES OF SOLIDS: Optical constants, dispersion relation of optical constants from Maxwell's equations, Direct and indirect transitions Absorption in insulators, impurity and interband transitions Resume of macroscopic theory -- generalized susceptibility, Kramer's-Kronig relation, optical properties of metals - intra- and inter-band transitions; Conductivity and dielectric function of collision electron gas, Basic Theories and models of luminescence, phosphorescence, thermo-luminescence, electroluminescence and photo-conductivity, photoelectric effect- Moss-Burstein effect-Polorans – Excitons. Brillouin scattering - Raman effect.

(12 Hours)

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

Course Outcomes		Level
CO-1	Understand the concept of phonons and their role on specific heat of solids. Apply the knowledge to analyze the phonon dispersion relation for simple solids. Gain insight into the origin of thermal conductivity, thermal expansion though phonon scattering processes.	**Understand/Apply**
CO-2	Understand the electron dynamics in metals through simple concepts and apply it to understand electronic and thermal conductivity in solids. Gain knowledge about wave functions and apply the electronic heat capacity, Hall effect etc.	**Understand/analyse Apply**
CO-3	Study the role of various defect in solids and understand their stability and their influence on physical properties. Also analyse various ordering phenomena in condensed matter.	**Understand/Analyze**
CO-4	Understand the concept of electronic polarization and its role on piezoelectricity and ferroelectricity	**Understand/analyse Apply**

Course Outcomes	Understand the original optical properties in solids and their difference in the insulators and metals. Apply the concept to study various optoelectronic properties.	Understand/analyse Apply
CO-5	Understand the original optical properties in solids and their difference in the insulators and metals. Apply the concept to study various optoelectronic properties.	Understand/analyse Apply

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1092
Course Title: Nuclear & Particle Physics
Course Type: Theory (Core)
Credits: 04

Unit 1:
GENERAL PROPERTIES OF NUCLEUS: Review of basic concepts, Nuclear radius, shape, spin, parity, Magnetic and electric moments, Nuclear binding energy.
Nuclear Models: Binding energy & mass defect – Weizacker's formula – mass parabola - Liquid drop model - Bohr -Wheeler theory of fission- Activation energy for fission- Shell model, Spin–Orbit coupling and magic number, ground state Spin and Parity of nucleus, Magnetic dipole moments – Schmidt lines, Electric quadrupole moments, Collective model: vibrational and rotational states.
Properties of Nuclear force: Spin dependence-charge independence-tensor nature of nuclear force: deuteron ground state problem, nucleon-nucleon scattering cross section-, Yukaka theory of meson exchange.

(12 Hours)
Unit 2:
RADIOACTIVITY: Half-life and decay rate of radioactive elements, radioactive series, Energy Spectrum of α and β rays: Discrete energy spectrum of α particles, Geiger-Nuttal's law, Gammow theory of α decay, Continuous spectrum of β particles, Pauli's neutrino hypothesis, Fermi theory of β decay, Coulomb correction, Screening effect, Kurie's plot, Selection rules in β decay, Orbital electron capture, Parity violation in β decay. Gamma decay - Multipole radiation – Angular momentum and parity selection rules – Internal conversion – Nuclear isomerism

(12 Hours)
Unit 3:
NUCLEAR REACTIONS: Conservation principles in nuclear reactions, Threshold energy, nuclear reaction cross-sections, Energetic of nuclear reactions, Reaction dynamics, Q-value equation, Scattering and

reaction cross sections, Compound nucleus, Reciprocity theorem, Breit-Wigner one level formula, Resonance Scattering, Continuum theory, Optical model.

(12 Hours)

Unit 4:Fission & Fusion

Types of fission reaction-distribution of fission products – fissile and fertile materials – neutron emission in fission – spontaneous fission - Explanation of nuclear fission using liquid drop model, fission products and energy release. Spontaneous and induced fission transuranic elements, reactors. Nuclear Fusion: Introduction, Thermonuclear reactions and energy production, stellar burning, brief idea about Big-Bang nucleosynthesis.

(12 Hours)

Unit 5:

PARTICLE PHYSICS: Standard model of Particle Physics: Classifications of elementary particles, Isospin, Isospin quantum numbers, Strangeness and hyper charge, Hadrons, Baryons, Leptons, Invariance principles and symmetries, Invariance under charge-parity(CP), time(T) and CPT, CP violation in neutral K-meson decay, Tau- Theta puzzle, Feynman diagrams, Quark model, SU(3) symmetry, Gell-Mann-Nishijma formula, Gell-Mann Okuba Mass formula, Neutrinos of different flavour, Charm, Bottom and Top quarks, Higss Boson, brief idea of Beyond Standard Model Physics, Relativistic kinematics.

(12 Hours)

Reference Books::
1. K.S. Krane: Introductory Nuclear Physics, Wiley, New York. 1987.
2. D. Griffiths: Introduction to Elementary Particle Physics, Harper and Row, New York.1987.
3. R.R. Roy and B.P. Nigam: Nuclear Physics, New Age International, New Delhi, 1983.
4. S. Wong, Introductory Nuclear Physics, Prentice Hall of India
5. Francis Halzen and Alan D. Martin, An Introductory Course in Modern Particle Physics, Wiley, 1984
6. Radiation Detection and Measurement: G. F. Knoll (John Wiley, 1989).

	Course Outcomes	Level
CO-1	Properties of Strong force, Shell model, properties of radiation, various nuclear reactions, four fundamental forces and their properties, classification of elementary particles, symmetry and different quantum numbers.	**Remember**
CO-2	Shell model, Quantum mechanical treatment of nucleon system, scattering, Alpha decay, beta decay, interaction of radiation with matter, fission and fusion reaction, Gell-Mann's eight fold way, conservation of different quantum numbers and their relation to symmetry-Noether's theorem	**Understand**
CO-3	Shell model to find nuclear spin, magnetic moment and electrical quadrupole moments of various nuclei. Apply quantum mechanics to solve alpha-decay and beta-decay process, also to understand nuclear reactions. Theory of interaction of radiation with matter to understand the working principle of radiation detectors. Conservation of various quantum numbers to understand three fundamental forces.	**Apply**

CO-4	Liquid drop models give a very simple idea to model a system and explain its properties. Deuteron problem is helpful to solve quantum mechanical systems, and finding out scattering cross sections, solving kinematic problems related to particle decay using invariant mass methods.	**Apply**

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1093
Course Title: Electromagnetic Theory
Course Type: Theory (Core)
Credits: 04

Unit 1:
Boundary value problems and Laplace equation –uniqueness theorem – Solution of Laplace equation in Cartesian and spherical polar coordinates – Examples of solutions for boundary value problems. Dielectric sphere in a uniform field – Molecular polarizability and electrical susceptibility – Electrostatic energy in the presence of dielectric – Multipole expansion. Method of images, Point charge in the presence of grounded conducting sphere and charge insulated conducting sphere, Point charge near a conducting sphere at fixed potential, conducting sphere in uniform electric field by method of images.

(12 Hours)

Unit 2:
Electric fields in matter – induced electric dipoles, Polarization of a medium, field due to polarized object – concept of bound and surface charges, field of an uniformly polarized sphere, Gauss's law in the presence of dielectrics, linear dielectrics, dielectric constant, energy stored in dielectric.
Magnetic field in matter- magnetic dipoles, origin of diamagnetism, field due to magnetized object – concept of bound and surface currents, field of an uniformly magnetized sphere, Ampere's law in magnetized materials, linear magnetic media.

(12 Hours)

Unit 3:
Faraday's laws of Induction - Maxwell's displacement current, Maxwell Equations, Vector and scalar potentials, Gauge transformations, Lorentz gauge, Coulomb gauge, Green's functions for wave Equation, Energy and momentum of the field, Poynting theorem and conservation of energy and momentum for a system of charged particles and electromagnetic fields, Poynting theorem in linear dispersive media with losses, Poynting theorem for harmonic field.

(12 Hours)

Unit 4:
Radiating Systems, Radiation by Moving Charges: Retarded time and retarded potential, radiation of a localized oscillating source, Electric dipole fields and radiation, Magnetic dipole radiation, Multipole expansion of the electromagnetic fields, Retarded potential and fields of an current carrying wire, Lienard–Wiechert potentials and fields for a moving point charge, power radiated by an accelerated point charge – Larmor formula, Radiation reaction and its physical explanation, Abraham Lorentz formula, Radiation damping

(12 Hours)

Unit 5:
Plane waves in non-conducting media - Linear and circular polarization, reflection and refraction at a plane interface-normal and oblique incidence – Absorption and dispersion - Waves in a conducting medium, Reflection at a conducting surface, the frequency dependence of permittivity- Waveguides, Propagation of waves in a rectangular wave guide. Coaxial Transmission Line.

(12 Hours)

Reference Books::
1. J.D. Jackson: Classical Electrodynamics, 2nd edition, John Wiley, 1985.
2. D.J. Griffith: Introduction to Electrodynamics, 3rd edition, Pearson Pub., New Delhi, 2003
3. Panofsky and Phillips: Classical Electricity and Magnetism, 2nd edition, Addison Wesley, 1962.
4. L.D. Landau and E.M. Lifshitz: Classical Theory of Field, 4th edition, Pergamon Press, 2003.
5. L.D. Landau and E.M. Lifshitz: Electrodynamics of Continuous Media, Pergamon Press, 1995.
6. Hans C. Ohanian: Classical Electrodynamics, 2nd edition, Infinity Science Press, 2007.

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

Mapping of Program Outcomes with Course Outcomes

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

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Course Code: PHY1094

Course Title: Condensed matter Physics Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Calculation of Unit cell parameters using X-ray diffraction method
2. Measurement of thermal diffusivity
3. Measurement of DC/AC conductivity of solid samples
4. Determination of resistivity and band gap of a solid/semiconductor using four probe method
5. Study of solar cell characteristics
6. Thermal and Electrical conductivity of metals
7. Experimental analysis of flat plate collector of solar water heater
8. Measurement of magneto-resistance of semiconductor.
9. The variation of Hall Coefficient of a given extrinsic semiconductor as a function of temperature
10. Determination of Curie Temperature of Ferroelectric crystals using dielectric spectroscopy
11. Electron spin resonance and determination of g-factor

Reference Books::

	Course Outcome	Level
CO 1	Identification of crystal structure of solids	Remember
CO2	Prediction of the thermal and electrical properties of solids and explanation of their origin	Understand
CO3	Estimation of band gap, charge carriers type and carrier concentration in solids	Apply
CO4	Demonstration of Dielectric and DC/AC conductivities of insulators	Analyse
CO5	Able to convert solar energy into electrical and thermal energy	Apply

CO6	Able to understand ferroelectric phase transitions and magneto-resistance behavior of materials	Apply

Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5
CO1	3	3	**2**	**2**	**2**
CO2	3	3	**1**	3	3
CO3	3	3	3	**3**	2
CO4	3	3	3	2	2
CO5	3	**2**	3	3	**3**
CO5	3	1	2	3	1
CO6	2	1	3	1	**1**

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Course Code: PHY1095

Course Title: Advanced Physics Laboratory
Course Type: Practical (Core)
Credits: 02

List of Experiments:
1. Preparation of KDP single crystals.
2. Preparation of BaTiO3 ceramics.
3. Preparation of polymer thin film by spray-pyrolysis.
4. Preparation of metallic film by thermal evaporation.
5. Transmittance spectroscopy of single crystals
6. Experimental analysis of flat plate collector of solar water heater
7. Dielectric spectroscopy of BaTiO3 ceramics
8. P-E loops of KDP crystals.

	Course Outcome	**Level**
CO 1	Synthesis of ceramics	Remember
CO2	Preparation of thin films	Understand
CO3	Understanding of absorbance and FTIR spectroscopy	Apply
CO4	Phase transition studies in dielectrics	Analyse
CO5	Able to characterize the different types of materials	Apply

Mapping of Program Outcomes with Course Outcomes

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

SEMESTER - X

Courses:

PHY1101	Research Project	CC	12	24
PHY1102	DSE-IV	Internship	2	
PHYXXX	Self-Study Course	DSE	4	4

DISCIPLINE ELECTIVE COURSES:

1) ADVANCED MATHEMATICAL PHYSICS (PHYEC01)
2) ADVANCED PARTICLE PHYSICS (PHYEC02)
3) ADVANCED QUANTUM MECHANICS
4) ASTROPHYSICS
5) ATOMIC & MOLECULAR SPECTROSCOPY
6) CRYSTAL GROWTH AND THIN FILMS
7) DIGITAL ELECTRONICS & MICROPROCESSORS
8) GENERAL THEORY OF RELATIVITY & COSMOLOGY
9) INTRODUCTION TO NON-LINEAR DYNAMICS
10) LASER PHYSICS & ITS APPLICATIONS
11) MICROWAVE PHYSICS
12) NANOMATERIALS AND NANOTECHNOLOGY
13) NUMERICAL METHODS AND COMPUTER PROGRAMING
14) PHYSICS OF MAGNETISM & SPINTRONICS
15) PLASMA PHYSICS
16) PROPERTIES OF MATERIALS
17) QUANTUM OPTICS
18) QUANTUM COMPUTATION AND QUANTUM INFORMATION
19) QUANTUM FIELD THEORY
20) SEMICONDUCTOR PHYSICS
21) SOLAR ENERGY & ITS APPLICATIONS
22) VACUUM SCIENCE AND THIN FILM PHYSICS

Course Code: PHYEC01
Course Title: Advanced Mathematical Physics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Green's functions : Definitions and physical significance of Green's functions, Translational invariance, Green's function – expansion using eigen functions, Green's function for ordinary differential operators, first order and second order linear differential operators, solution of forced harmonic oscillator problem using Green's function, Green's function for Sturm-Liouville Problems – Initial value problems – Problems with mixed and unmixed boundary conditions, Green's functions for partial differential operators, solution of boundary value problems using Green's function for Laplace, Poisson and wave equations

Unit 2:
Variational Calculus: Functions and Functionals, Principles of Variational Calculus, Applications of variational calculus – minimal surface of revolution, geodesic on a surface of revolution, Brachistochrone Problem, Relation to the Sturm-Liouville Problem, The RayleighRitz Method, Adding constraints - method of Lagrange multipliers, Sturm-Liouville eigenvalue equation as a variational problem

(12 Hours)
Unit 3:
Integral Equations: Conversion of a differential equation into an integral equation, types of integral equation, linear integral operator, closed-form solutions, separable kernels, integral transform methods, solution of integral equation by differentiation, Neumann series, Fredholm theory, Schmidt–Hilbert theory
(12 Hours)

Unit 4:
Introduction to Non-Linear Equations: Introduction to linear and nonlinear differential equations with few illustrations – The notion of nonlinearity – Superposition principle and its validity – Autonomous and nonautonomous systems – Equilibrium points – Classification of equilibrium points – limit cycle motion – Lyaponov exponents – Poincaré surface of section.
(12 Hours)

Unit 5:
Introduction to Statistical Methods: Random variables, probability density functions (pdf), cumulative distribution functions, joint pdf, marginal pdf, conditional pdf, expectation values, variance, standard deviation, covariance and correlation and regression, correlation coefficient, error propagation, parameter estimation, maximum likelihood and least squares estimation**.**
(12 Hours)

Re Reference Books:
1.G.B. Arfken and, H.T.Weber, Mathematical methods for physicists, Academic Press; 7th edition, 2012
2. Tulsi Dass and Satish K Sharma, Mathematical methods in classical and quantum physics, Universities Press, First Edition, 1998
3.J.H. Heinbockel, Introduction to the Variational Calculus, Trafford Publishing, 2007.
4. K.F. Riley, M.P. Hobson, and S.J. Bence, Mathematical Methods for Physics and Engineering, Cambridge University Press, Third Edition, 2006.
5. M. Lakshmanan and S. Rajasekar, Nonlinear Dynamics, Integrability, Chaos and Patterns, Springer-Verlag, Berlin, 2003.
6. P.G. Drazin, Nonlinear systems, Cambridge University Press, Cambridge,1992.
7. G. Cowan, Statistical Data Analysis, Clarendon Press, Oxford, 1998
8. R.J. Barlow, Statistics, A Guide to the Use of Statistical in the Physical Sciences, John Wiley, 1989.
9. F. James, Statistical Methods in Experimental Physics, World Scientific, Second Edition, 2006.

Course Code: PHYEC02
Course Title: Advanced Particle Physics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Relativistic Kinematics: Lorentz transformations, four-vectors, relativistic collisions, Two nucleon state vectors, Isospin, Strangeness and Hypercharge, Lepton and Baryon number conservation, Yukawa's theory

(12 Hours)

Unit 2:
Parity, Parity conservation and nonconservation, Time reversal, Consequences of time reversal invariance, Charge conjugation, G-parity, Statement of CPT theorem and its consequences, Proof of equality of mass and life time for particle and antiparticle.

(12 Hours)

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

(12 Hours)

Unit 4:
Quantum Electrodynamics (QED) :
The S-matrix expansion, Time ordered product, Normal ordered product, Wick's theorem, Feynman diagrams in configuration and momentum space, First order terms in S-matrix, Compton scattering, Electron electron scattering, closed loop, Feynman rules (Decays and Scattering), QED Lagrangian and gauge invariance.

(12 Hours)

Unit 5:
QED processes in lowest order:
Lepton-pair production in electron-positron collisions, Bhabha scattering, Compton Scattering, Scattering by an external field and Mott Scattering Formula, Bremsstrahlung.

(12 Hours)

Reference Books::
1. Quantum Field Theory - F. Mandl and G. Shaw
2. Introduction to High Energy Physics - D. H. Perkins
3. Elementary Particle Physics - D.J.Griffiths
4. Quarks and Leptons – F.Halzen and A.D. Martin
5. Quantum Field Theory - M.Peskin and Schroeder

Course Code: PHYEC03
Course Title: Advanced Quantum Mechanics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Classical Fields: Brief introduction to Classical scalar fields, Classical Maxwell fields, Vector potential in quantum mechanics, Coulomb Gauge.
Quantum theory of radiation: Quantised radiation field, Rayleigh Scattering, Thomson scattering, Raman effect, Self-energy of a bound electron; the Lamb shift

(12 Hours)

Unit 2:
Relativistic Quantum Mechanics: Klein-Gordon equation and its drawbacks, Dirac equation, Properties of Dirac matrices, Non- relativistic reduction of Dirac equation, magnetic moment, Darwins term, Spin-Orbit coupling, Poincare transformation, Lorentz group, Covariant form of Dirac equation, Bilinear covariants, Gordon decomposition

(12 Hours)

Unit 3:
Free particle solution of Dirac equation, Projection operators for energy and spin, Physical interpretation of free particle solution, Zitter bewegung, Hole theory, Charge conjugation, space reflection and time reversal symmetries of Dirac equation. Continuous systems and fields. Transition from discrete to continuous systems, Lagrangian and Hamiltonian Formulations, Noether's theorem.

(12 Hours)

Unit 4:
Second quantization, Equal Time Commutators, Normal Ordering, covariant quantization of electromagnetic field, Quantization of scalar, e.m, and Dirac fields, Propagators for scalar, spinor and vector fields.

(12 Hours)

Unit 5:
Covariant Perturbation theory: Formulas and rules, S-matrix expansion; First order process: Mott scattering, Compton Scattering. Feynman's space-time approach to the electron propagator.

(12 Hours)

Reference Books:
1. Advanced Quantum Mechanics - J. J. Sakurai.
2. Relativistic Quantum Mechanics - J. D. Bjorken and S. D. Drell
3. Relativistic Quantum Fields - J. D. Bjorken and S. D. Drell
4. Quantum Field Theory - F. Mandl and G. Shaw
5. Quantum Field Theory - L. H .Ryder
6. Quantum Field Theory - S. Weinberg

Course Code: PHYEC04
Course Title: Astrophysics
Course Type: Theory (DSE)
Credits: 04

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

(12 Hours)

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

(12 Hours)

Unit 3:
Observing through the atmosphere- Atmospheric Windows, optical telescopes, Radio telescopes, telescope mountings, Magnification, Light gathering power, resolving power and diffraction limit, Detection limit of telescope. Derivation of Virial theorem, Basic equations of stellar structure, simple stellar models- Polytropic model, derivation of the Lane-Emden equation, analytic solution of Lane-Emden equation

(12 Hours)

Unit 4:
Morphological classification of the Galaxies. Basic structure and properties of the Milky way, Nature of rotation of the Milky Way- differential rotation of the Galaxy and Oort constants, rotation curve of the galaxy and the dark matter

(12 Hours)

Unit 5:
Cosmological observations, The cosmological principle, Homogeneous and isotropic universe, Friedmann model, Evolution of our universe

(12 Hours)

Reference Books:
1.Theoretical Astrophysics, Vol 1- T. Padmanabhan
2. Fundamental Astronomy, H. Karttunen et. al

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Course Code: PHYEC05
Course Title: Atomic & Molecular Spectroscopy
Course Type: Theory (Core)
Credits: 04

Unit 1:
General discussion in Hydrogen spectra, Relativistic correction to spectra of Hydrogen atom, Spectra of monovalent atoms, quantum defect, Introduction to electron spin, Spin-orbit interaction and fine structure, Zeeman effect, Stark effect, Spectra of divalent atoms: Singlet and triplet states of divalent atoms, LS and j-j coupling, Branching rule, Hyperfine structure in spectra of monovalent atoms.

(12 Hours)

Unit 2:
Energy and length scales in molecules, Molecular Binding: covalent bond, multipole interaction, van der Waals interaction, Morse potential, Born-Oppenheimer approximation, Pure rotational spectra of diatomic molecules, Non-rigid rotator, Poly-atomic molecules, Study of linear molecules and symmetric top molecules, Information from rotational spectra

(12 Hours)

Unit 3:
Vibrational spectroscopy of diatomic and simple polyatomic molecules, Harmonic Oscillator, Anharmonic Oscillator, Rotational vibrators, Normal modes of vibration of polyatomic molecules, IR spectrometer: FTIR Spectrometer, Applications of infrared spectroscopy: H_2O and CO_2 molecules.

(12 Hours)

Unit 4:
Raman effect, Classical and Quantum theory of Raman effect, Vibrational Raman spectra, Rotational Raman spectra, Vibrational-Rotational fine structure, Electronic structure of diatomic molecules, Intensity of spectral lines, Frank-Condon principle, Dissociation energy and dissociation products, Rotational fine structure of electronic-vibration transitions, P, Q, R branches, band origin

(12 Hours)

Unit 5:
Theory of NMR, Relaxation effect, Theory of dipolar interaction and chemical shifts, Indirect spin-spin interactions, Experimental set up of NMR, Applications of NMR to quantitative measurements (Idea only),

Quantum mechanical treatment of ESR, Nuclear interaction and hyperfine structure, Relaxation effects, ESR spectrometer, Applications of ESR method.

(12 Hours)

Reference Books::
1. Physics of Atoms and Molecules, Bransden and Joachain, Longman Scientific & Technical Group Ltd., 1983.
2. Atoms, Molecules and Photons, Wolfgang Demtroder, Springer, 2010.
3. Fundamentals of Molecular Spectroscopy, C. N. Banwell, McGraw-Hill Book Company, 1994.
4. Spectra of Atoms and Molecules, P. F. Bernath, Oxford University Press, 1995.
5. Atomic and Molecular Spectroscopy, Rita Kakkar, Cambridge University Press, 2019.

	Course Outcomes	Level
CO-1	Understanding basic atomic structure	**Remember**
CO-2	Understanding gross molecular structures and the effect of molecular rotation	**Apply**
CO-3	Knowing about vibrational spectroscopy	**Apply**
CO-4	Learning Raman spectroscopy and electronic spectroscopy	**Apply**
CO-5	Understanding the working principle of NMR and ESR	**Analyze**

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHYEC06
Course Title: Crystal Growth and Thin Films
Course Type: DSE
Credits: 04

Unit1:   **1:**
CRYSTAL GROWTH KINETICS: Basic Concepts, Nucleation and Kinetics of growth Ambient phase equilibrium - super saturation - equilibrium of finite phases equation of Thomson - Gibbs - Types of Nucleation - Formation of critical Nucleus- Classical theory of Nucleation - Homo and heterogeneous formation of 3D nuclei - rate of Nucleation - Growth from vapour phase solutions, solutions and melts - epitaxial growth - Growth mechanism and classification - Kinetics of growth of epitaxial films

(12 Hours)

Unit2:
CRYSTALLIZATION PRINCIPLES: Crystallization Principles and Growth techniques Classes of Crystal system - Crystal symmetry - Solvents and solutions - Solubility diagram - Super solubility - expression for supersaturation - Metastable zone and introduction period - Miers TC diagram - Solution growth - Low and high temperatures solution growth - Slow cooling and solvent evaporation methods - Constant temperature bath as a Crystallizer.

(12 Hours)

Unit3:   **3:**
GEL, MELT AND VAPOUR GROWTH: Gel, Melt and Vapour growth techniques Principle of Gel techniques - Various types of Gel - Structure and importance of Gel - Methods of Gel growth and advantages - Melt techniques - Czochralski growth - Floating zone - Bridgeman method - Horizontal gradient freeze - Flux growth - Hydrothermal growth - Vapour phase growth - Physical vapour deposition - Chemical vapour deposition - Stoichiometry

(12 Hours)

Unit 4:
THIN FILM DEPOSITION METHOD: Thin film deposition methods of thin film preparation, Thermal evaporation, Electron beam evaporation, pulsed LASER deposition, Cathodic sputtering, RF Magnetron sputtering, MBE, chemical vapour deposition methods, Sol Gel spin coating, Spray pyrolysis, Chemical   bath   deposition.
(12   Hours)

Unit 5:
THIN FILM FORMATION: Thin Film Formation and thickness Measurement Nucleation, Film growth and structure - Various stages in Thin Film formation, Thermodynamics of Nucleation, Nucleation theories, Capillarity model and Atomistic model and their comparison. Structure of Thin Film, Roll of substrat **(12 Hours)**

e, Roll of film thickness, Film thickness measurement - Interferometry, Ellipsometry, Micro balance, Quartz Crystal Oscillator techniques. **Text Books:**

1. V. Markov Crystal growth for beginners: Fundamentals of Nucleation, Crystal Growth and Epitaxy (2004) 2nd edition
2. A. Goswami, Thin Film Fundamentals (New Age, New Delhi, 2008)

3. M. Ohora and R. C. Reid, "Modeling of Crystal Growth Rates from Solution"
4. 4. D. Elwell and H. J. Scheel, "Crystal Growth from High Temperature Solution"
5. Heinz K. Henish, 1973, "Crystal Growth in Gels", Cambridge
   University Press. USA.

Reference Books:

1. J.C. Brice, Crystal Growth Process (John Wiley, New York, 1986)
2. P. Ramasamy and F. D. Gnanam, 1983, "UGC Summer School Notes".
3. P. Santhana Raghavan and P. Ramasamy, "Crystal Growth Processes", KRU Publications.
4. H.E. Buckley, 1951, Crystal Growth, John Wiley and Sons, New York
5. B.R. Pamplin, 1980, Crystal Growth, Pergman Press, London.

WEB SOURCES:
1. https://www.youtube.com/playlist?list=PLbMVogVj5nJRjLrXp3k MtrIO8kZl1D1Jp
2. https://www.youtube.com/playlist?list=PLFW6lRTa1g83HGEihgw cy7KeTLUuBu3WF
3. https://www.youtube.com/playlist?list=PLADLRin7kNjG1Dlna9M DA53CMKFHPSi9m
4. https://www.youtube.com/playlist?list=PLXHedI-xbyr8xIl_KQFs_R_oky3Yd1Emw
5. https://www.electrical4u.com/thermal-conductivity-of-metals/

COURSE OUTCOMES:
At the end of the course, the student will be able to:

	Acquire the Basic Concepts, Nucleation and Kinetics of crystal Growth	K1
CO2	Understand the Crystallization Principles and Growth techniques	K2, K4
CO3	Study various methods of Crystal growth techniques	K3
CO4	Understand the Thin film deposition methods	K2
CO5	Apply the techniques of Thin Film Formation and thickness Measurement	K3, K4
K1 - Remember; K2 – Understand; K3 - Apply; K4 - Analyze; K5 - Evaluate;		

MAPPING WITH PROGRAM OUTCOMES:

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

Course Code: PHYEC07
Course Title: Digital Electronics & Microprocessors
Course Type: Theory (DSE)
Credits: 04

Unit 1:
ACTIVE FILTERS & TIMER AND PHASE LOCKED LOOPS: Introduction, Butterworth filters – 1st order, 2nd order low pass and high pass filters, band pass, band reject and all pass filters. TIMER AND PHASE LOCKED LOOPS: Introduction to IC 555 timer, description of functional diagram, monostable and astable operations and applications, Schmitt trigger, PLL - introduction, basic principle, phase detector/comparator, voltage-controlled oscillator (IC 566), low pass filter, monolithic PLL and applications of PLL

(12 Hours)

Unit 2:
VOLTAGE REGULATOR & D-to-A AND A-to-D CONVERTERS: VOLTAGE REGULATOR: Introduction, Series Op-Amp regulator, IC Voltage Regulators, IC 723 general purpose regulators, Switching Regulator. D to A AND A to D CONVERTERS: Introduction, basic DAC techniques - weighted resistor DAC, R-2R ladder DAC, inverted R-2R DAC, A to D converters -parallel comparator type ADC, counter type ADC, successive approximation ADC and dual slope ADC, DAC and ADC Specifications.

(12 Hours)

Unit 3:
NUMBER SYSTEMS AND LOGICAL GATES: Decimal, binary, octal, hexadecimal numbers systems and their conversions – codes: BCD, gray and excess-3 codes –code conversions –complements (1's, 2's, 9's and 10's) –binary addition, binary subtraction using 1's & 2's complement methods – Boolean laws – De-Morgan's theorem –basic logic gates -universal logic gates (NAND & NOR) –standard representation of logic functions (SOP & POS) – minimization techniques (Karnaugh map: 2, 3, 4 variables). Adders: half & full adder, Subtractors: half &full subtractor –parallel binary adder – magnitude comparator – multiplexers (4:1) &demultiplexers (1:4), encoder (8-line-to-3- line) and decoder (3-line-to-8-line), BCD to seven segment decoder**.**

(12 Hours)

Unit 4:
SEQUENTIAL CIRCUITS AND LOGIC FAMILIES: S-R Flip-flop , J-K Flip-flop, T and D type flip-flops, master-slave flip-flop, truth tables, registers:- serial in serial out and parallel in and parallel out – counters asynchronous:-mod-8, mod-10, synchronous - 4-bit &ring counter – general memory operations, ROM, RAM (static and dynamic), PROM, EPROM, EEPROM, EAROM. IC – logic families: RTL, DTL, TTL logic, CMOS NAND & NOR Gates, CMOS Inverter, Programmable Logic Devices – Programmable Logic Array (PLA), Programmable Array Logic (PAL).

(12 Hours)

Unit 5:
MICROPROCESSOR & MICROCONTROLLER BASICS: introduction to microprocessor – INTEL 8085 architecture – register organization –pin configuration of 8085, interrupts and its priority – Program Status Word (PSW) –instruction set of 8085 –addressing modes of 8085 –assembly language programming using 8085 –programmes for addition (8-Bit & 16-Bit), subtraction (8-Bit & 16-Bit), multiplication (8- Bit), division (8- Bit) – largest and smallest number in an array – BCD to ASCII and ASCII to BCD.

(12 Hours)

Reference Books::
1. Modern Digital Electronics, 2/e (Tata McGraw Hill Education)
2. Digital Logic Design- Morries Mano, PHI.

3. Electronic devices and circuits,Jacob Millman, and C. C. Halkias, TMH Publications.
4. Linear Integrated Circuit, D. Roy Choudhury, Shail B. Jain,4th edition, New Age International Pvt. Ltd., New Delhi, India
5. OP-AMP and Linear Integrated Circuits, Ramakant A. Gayakwad, 4th edition, Prentice Hall / Pearson Education, New Delhi. Optics, Ajoy Ghatak (McGraw Hil)
6. A Textbook of Electrical technology, B.L. Theraja and A.K. Theraja, S. Chand & Co.
7. Digital Principles and Applications, Malvino and Leach 5th Edition, Tata McGraw Hill, New Delhi
8. Digital Fundamentals, Floyd, Jain 8th edition, Pearson Education, New Delhi.

Course Outcomes		Level
CO-1	Develop skills to design active filter circuits using operational amplifiers.	Remember
CO-2	Learn about various techniques to develop A/D and D/A converters	Uderstand
CO-3	Gain knowledge about logic gates and their implementation in construction of adders and substractors	Apply
CO-4	Acquire the knowledge about the logic, combinational and sequential circuit	Apply
CO-5	Assembly language programming on 8085 microprocessor	Skill

Mapping of Program Outcomes with Course Outcomes

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

Course Code: PHYEC08
Course Title: General Theory of Relativity & Cosmology
Course Type: Theory (DSE)
Credits: 04

Unit 1: Special relativity & Flat space-time, Equality of gravitational and intertial masses, Equivalence principle, Principle of general covariance.Tensor Analysis: covariant and contravariant tensors. Tensors of arbitrary rank. Metric tensor. Parallel transport and covariant differentiation. Affine connection and its relation to metric tensor. Curvature tensor and its symmetries. Bianchi identities. Weyl tensor and conformal invariance.

(12 Hours)

Unit 2: Energy momentum tensor for a perfect fluid, equation of motion from field equation for equation for dust. Action principle for field equations. Conservation laws in curved space and pseudo energy tensor for gravitational field

(12 Hours)

Unit 3: General static isotropic metric, Schwarzschild solution, Orbital equations, constants of motion, deflection of light by a mass object (sun), precision of perihelia, radar echo delay.

(12 Hours)

Unit 4: Cosmological principle, maximally symmetric spaces, Killing vectors, Robertson- Walker metric. Redshift of galaxies and Hubble's law. Magnitude-red shift relation, Measures of distances – parallax distance, luminosity distance, angular diameter distance, relation among the measures of distance, Horizons and the Hubble radius Hubble's constant and deceleration parameter, source counts. Einstein's equations, content of the universe – photons, baryons, dark matter neutrinos, dark energy- critical densities, pressure, matter-radiation equality, CMBR, problems of Friedmann cosmology, inflationary universe

(12 Hours)

Unit 5: Gravitational Radiation- Weak field approximation and linear wave equation. Plane waves, their polarization, helicity and energy momentum tensor. Emission of radiation by a rotating source. Effect of radiation on a test particle. Detection of gravitational radiation**.**

Reference Books::
1.Introducing Einstein's Relativity, Ray D'Inverno
2. Principles of Gravitation and Cosmology, M. Berry
3. Introduction to General Relativity & Cosmology, Steven Weinberg
4. The Classical Theory of Fields, L.D. Landau and E. M. Lifshitz
5. Classical Fields: General Relativity and Gauge Theory, Moshe Carmeli
6. General Theory of Relativity, P.A. M. Dirac
7. Introduction to Cosmology, J.V.Narlikar
8. Cosmology, S.Weinberg

Course Code: PHYEC09
Course Title: Introduction to Non-Linear Dynamics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Linear and Nonlinear systems - Mathematical models examples – Mathematical Implications of Nonlinearity: superposition principle and its validity - Examples and problems - linear and nonlinear oscillators - Resonance and Hysteresis - Examples and problems - Autonomous and nonautonomous systems - Phase plane trajectories - stability, attractors and repellers - limit cycle - Examples and problems - Phase space - classification of equilibrium points - stability of fixed points - Examples and problems.

(12 Hours)

Unit 2:
Bifurcation - the logistic map - period doubling phenomenon- onset of chaos- other routes to chaos -Lorentz systems - Sensitive dependence on initial condition - controlling of chaos - bifurcation scenario in Duffing oscillator- Examples and problems.

(12 Hours)

Unit 3:
Linear and nonlinear dispersive wave propagation - Fourier transformation and solution of initial value problem - wave packet and dispersion - Nonlinear dispersive system – Korteweg-de Vries equation and the solitary waves and Cnoidal waves - Scott Russel's phenomenon and Korteweg-de Vries equation - Fermi-Pasta-Ulam lattice problem - FPU recurrence phenomenon - numerical experiment of Zabusky and Kruskal - birth of soliton.

(12 Hours)

Unit 4:
Integrability and methods to solve soliton equations - The notion of integrability - multiple scale perturbation method - soliton solutions of perturbed nonlinear Schrödinger equation - Hirota's direct method and 'N' soliton solutions - Painleve analysis and its application to Korteweg-de Vries equation, nonlinear Schrödinger equation- Lax pair for Korteweg-de Vries equation.

(12 Hours)

Unit 5:
Applications of Nonlinear dynamics - soliton applications in all optical communication - Energy transfer in protein and DNA - Function of soliton in neuronal microtubules - Ionacoustic solitons in plasma: an application to Saturn's magnetosphere - Pulse solitons in blood circulatory systems

(12 Hours)

Reference Books::
1. M. Lakshmanan and S. Rajasekar, Nonlinear Dynamics, Integrability, Chaos and Patterns, Springer-Verlag, Berlin, 2003.
2. P.G. Drazin, Nonlinear systems, Cambridge University Press, Cambridge.
3. P.G. Drazin and R.S. Johnson, Solitons: An introduction Cambridge University Press, Cambridge, 1989.
4. M.J. Ablowitz and P.A. Clarkson, Solitons, Nonlinear Evolution Equations and Inverse Scattering, Cambridge University Press, Cambridge, 1991.
5. R. Dodd, J. Eilbeck, J. Gibbson and H. Morris, Solitons and Nonlinear Wave Equations, Academic, New York, 1982.

Course Code: PHYEC10
Course Title: LASER Physics & its applications
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Principles of Lasers: Interaction of radiation with matter – Absorption, spontaneous and stimulated emission – Einstein coefficients – relation between spontaneous and stimulated emission rates, Light amplification – Threshold condition for laser action, Line broadening mechanisms – Natural, Collision and Doppler broadening. Laser operations – Two level system, Population inversion in three level and four level systems- Threshold pump power, relative merits and de-merits of three and four level system.
(12 Hours)

Unit 2:
Laser Types - Mathematical description of Gaussian beams using Maxwell's equations. Propagation of Gaussian beams through optical elements. ABCD law for Gaussian beams. Hermite-Gaussian beams. Laser Systems - Gas lasers: He-Ne laser, Carbondioxide laser, Nitrogen gas laser, Argon ion gas laser – Solid state lasers: Ruby laser, Nd-YAG laser, Dye lasers - Optically pumped laser systems

(12 Hours)

Unit 3:
Laser Operations: Resonant cavities, modes of a rectangular cavity, quality factor of an optical resonator, ultimate laser line width , Longitudinal and Transverse mode selection, Pulsed lasers - Q-switching and Mode locking concepts and techniques. - Resonator configurations - Stability of resonators, - Characteristics of Gaussian beam.

(12 Hours)

Unit 4:
Fiber Lasers: Erbium doped fiber laser – basic equations for amplification and its steady state solutions, derivation for doped fiber length, threshold pump power and laser output power, Erbium doped fiber amplifier, mode locking using non-linear polarization, semiconductor lasers, optical gain in semiconductors, density of states, interaction of semiconductor with light, light amplifcation and gain coefficient in semiconductors, QuasiFermi levels, Gain in diode laser, Quantum-Well lasers – derivation for gain c

(12 Hours)

Unit 5:
Laser Applications: Holography, Basic Principle – Holographic interferometry – Speckle Metrology, Material processing- welding, cutting, and drilling. laser tracking, pollution monitoring using lasers, lasers in isotope separation, lasers in precision length measurement, lasers in information storage, bar-code scanner, Biological and Medical applications of lasers

(12 Hours)

Reference Books::
1. Lasers Theory and Applications: K. Thyagarajan and A.K. Ghatak (McMillan).
 2. C.O. Shea, W.R. Callen and N.T. Rhodes, "An Introduction to Lasers and their Applications'", Addison Wesley, 1969.
 3. J. Verdeyen, 'Laser Electronics', Second Edition, Prentice Hall, 1990.
 4. Goldman and Rockwell, 'Lasers in Medicine', Gordon and Breach, New York, 1985.
5. B.B. Laud, 'Laser and Non-Linear Optics', Second Edition, New Age International (p) Limited publishers, 1996.
6. Optics and Atomic Physics – B. P. Khandelwal (Siblal Agarwala).
7. Optical Electronic – A. K. Ghatak and K. Tyagrajan.
8. Introduction to Fibre Optics - R. A. Shotwell (EEE, Prentice Hall).

Course Code: PHYEC11
Course Title: Microwave Physics
Course Type: Theory (DSE)
Credits: 04

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

(12 Hours)

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

(12 Hours)

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

(12 Hours)

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

(12 Hours)

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

(12 Hours)

Reference Books::
1. Microwave Devices and Circuits – S Liao, Pearson Education India, 1990

Course Code: PHYEC12
Course Title: Nanomaterials and nanotechnology
Course Type: Theory (DSE)
Credits: 04

Unit 1:
 Introduction to nanotechnology, physics of low-dimensional materials, quantum effects, 1D, 2D and 3D confinement, Density of states, Excitons, Coulomb blockade, Zero-, One-, Two- and Three- dimensional

structure, Size control of metal nanoparticles and their properties: optical, electronic, magnetic properties; surface plasmon resonance, change of bandgap; Application: catalysis, electronic devices.

(12 Hours)

Unit 2:

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

(12 Hours)

Unit 3:

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

(12 Hours)

Unit 4:

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

(12 Hours)

Unit 5:

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

(12 Hours)

Reference Books::
1. Nanocomposite science and technology, Pulikel M. Ajayan, Wiley-VCH 2005
2. Nanolithography and patterning techniques in microelectronics, David G. Bucknall,   Wood head publishing 2005
3. Transport in Nanostructures, D.K. Ferry and S.M. Goodmick, Cambridge university press 1997.
4. Optical properties of solids, F. Wooten, Academic press 1972
5. Micro and Nanofabrication, Zheng Cui, Springer 2005
6. Nanostructured materials, Jackie Y. Ying, Academic press 2001
7. Nanotechnology and nanoelectronics, W.R, Fahrner, Springer 2005
8. Nanoengineering of structural, functional and smart materials, Mark J. Schulz, Taylor & Francis 2006.
9. Hand book of Nanoscience, Engineering, and Technology, William A. Goddard,   CRC press 2003.
10. Nanoelectronics and Information Technology, Rainer Waser, Wiley-VCH 2003.
11. The MEMS Handbook Frank Kreith, CRC press 2002.
12. Pradeep T "Nano: The Essentials", Mc Graw Hill Publishing Co. Ltd., 2007
13. Mick Wilson et al, "Nanotechnology", Overseas Press (India) Pvt. Ltd., 2005.
14. Charles P. Poole, Jr., Frank J. Owens, "Introduction to nano technology", Wiley, 2003.
15. Gunter Schmid, "Nanoparticles: From Theory to Applications", Wiley-VCH Verlag GmbH & Co., 2004.

Course Code: PHYEC13
Course Title: Numerical Methods and Computer Programing
Course Type: Theory (DSE)
Credits: 04

Unit I
Programming Language: Introduction to Unix System, and languages, variable types, operators, function, conditional statements (if, for loop, do while), array, for C++: pointer and references, basic idea of Class.)

Unit II
Approximations and round off errors: Significant digits, true/absolute and truncation errors, Taylor Series – Taylor polynomial error formula. Determination of roots of polynomials and transcendental equations: Bisection methods, Newton-Raphson method, Secant method and Bairstow's method.
(12 Hours)

Unit III
Solutions of linear simultaneous linear algebraic equations by Gauss Elimination and Gauss-Siedel iteration methods. **(12 Hours)**

Unit IV
Backward, Forward and Central difference relations and their uses in Numerical differentiation and integration, Application of difference relations in the solution of partial differential equations. Numerical solution of ordinary differential equations by Euler, Modified Euler, Runge-Kutta and Predictor-Corrector method. **(12 Hours)**

Unit V
Numerical integration: midpoint rule, trapezeoidal method, Simpson's method, Newton--Cotes method, Gaussian rules. Least squares approximation, fitting data to a straight line, fitting data to linear combinations of functions. Interpolation: Direct method, Newtons's divided difference method, Lagrange method.

(12 Hours)

Reference Books:

1. Venkatraman, M. K., "Numerical Methods in Science and Engineering", National Publishing Company, Madras, 1996.
2. Schaum's Outline of Programming with C++, McGraw-Hill; 2nd Edition
3. Numerical Recipes in C++: The Art of Scientific Computing , Cambridge University Press; 2nd
4. Numerical methods by Balaguruswami - TMH.

Course Code: PHYEC14
Course Title: Physics of magnetism & spintronics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Fundamental of Magnetism: Origin of permanent magnetic dipoles; Quantum theory of the magnetic moment; Hund's rules. Classical and quantum aspects of diamagnetism; paramagnetism; Curie law; formula of Van Vleck; Crystal field: d-f- metals, magnetic anisotropy; adiabatic demagnetization; Ferromagnetism; Weiss theory; domains; Bloch wall; Hysteresis.

(12 Hours)

Unit 2:
Magnetic Interactions and Relaxation: Exchange interaction, super-exchange, double exchange. Band magnetism. Collective excitation; Long-range order: Mean field theory: the theory of Weiss (Neel). Molecular field. Order parameter. Ferro-, antiferro-, iron-magnetism, other types of order. Spin glass, Magnetic domains. Hard & soft materials. Domain Theory; Exchange bias. Spin –latttice relaxation; spin-spin relaxation

(12 Hours)

Unit 3:
Nano-magnetism: Single-domain particle; Super-paramagnetism; Nanoparticles & molecular magnets.Stoner Wohlfarth model; Landau-Lifschitz-Gilbert Model; Neel-Brown model. Nanoscale magnetisam in small particles; thin films; wires; needles and bulk nanostructures

(12 Hours)

Unit 4:
Spintronics: Spin polarized currents; magnons; Spin-orbit interaction; Spin relaxation; Spin dependent Scattering and Transport; Spin dependent tunneling and Transport; Spin valve; Giant Magneto Resistance; Magnetic Random-Access Memory; spin torque; Spin transfer oscillators; spin transistors

(12 hours)

Unit 5:
Molecular magnetism: High-spin, low spin molecules; quantum theory of molecular magnetism: tunneling of magnetization; other functionalities of molecular nanomagnets: magneto caloric effect;

(12 Hours)

Reference Books::

Course Code: PHYEC15
Course Title: Plasma Physics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Basics of Plasma: Plasma as the fourth state of matter, macroscopic neutrality, Debye shielding, plasma frequency, the occurrence of plasma in nature, collisions, dc conductivity, ac conductivity, diffusion, production of plasma: dc discharge, rf discharge, using particle beam, laser produced plasma, overview of some plasma devices.

(12 Hours)

Unit 2:

Single particle motion: Motion of charged particle in electromagnetic field, Uniform E and B fields, Nonuniform fields, Diffusion across magnetic fields, Time varying E and B fields, Adiabatic invariants, First, second and third adiabatic invariant.

(12 Hours)

Unit 3:
Plasma as Fluids: Fluid description of plasma, equation of continuity, the fluid equation of motion, the convective derivative, the stress tensor, collisions, comparison with ordinary hydrodynamics, fluid drifts perpendicular to B, fluid drifts parallel to B, the plasma approximation

(12 Hours)

Unit 4:
Waves in Plasmas: Plasma oscillations, Electron plasma waves, sound waves, Ion acoustic wave, validity of the plasma approximation, phase velocity, group velocity, cut-offs, resonance for electromagnetic wave propagating parallel and perpendicular to the magnetic field, propagation through ionosphere and magnetosphere

(12 Hours)

Unit 5:
Laser plasma interaction: Ponderomotive energy, Keldysh parameter, multi-photon ionization, optical field ionization, high harmonic generation, Laser absorption processes: inverse bremsstrahlung, resonance absorption, Landau damping; Parametric decay processes, two plasmon decay, stimulated Brillouin scattering, stimulated Raman scattering.

(12 Hours)

Reference Books:

1.Principles of Plasma Physics, Nicholas A. Krall and Alvin W. Trivelpiece (McGraw-Hill Book Company).
2. Introduction to Plasma Physics and Controlled Fusion, Francis F. Chen (Springer).
3. The Physics of laser-plasma interaction, W. L. Kruer (Addison-Wesley Publishing Co.).
4. Short pulse laser interaction with matter- an introduction, Paul Gibbon (Imperial College Press).
5. Fundamentals of Plasma Physics, J. A. Bittencourt (Springer).
6. The Physics of Plasmas, T. J. M. Boyd and J. J. Sanderson (Cambridge University Press).

Course Code: PHYEC16
Course Title: Properties of materials
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Mechanical properties: Factors affecting mechanical properties - mechanical tests - tensile, hardness, impact, creep and fatigue - Plastic deformation by slip - shear strength - work hardening and recovery - fracture - Griffith's theory - slip and twinning - creep resistant materials - diffusion – Fick's law.
Electrical Properties: Electrical conductivity – Free electron theory of metals, effective mass, drift current, mobility and conductivity Drude-Lorentz theory of metals (qualitative), Fermi Dirac distribution - density of states - electronic specific heat. Boltzmann transport equation - Sommerfeld's theory of electrical conductivity. Review of Band theory of solids, distinction between conductor, semiconductor and insulator based on band theory. Factors affecting resistivity of metals - temperature, alloying, strain and magnetic field with respective applications. Hall effect - Band model of semiconductors - carrier concentrations in intrinsic and extrinsic semiconductors - effective mass - electron & holes mobilities, Fermi level - variation of conductivity and mobility with temperature.

(12 Hours)

Unit 2:
Thermal Properties: Thermal conduction - Thermal conductivity, Flow of heat through compound media. Determination of thermal conductivity of conductors by Forbe's method, Lattice vibrations, harmonic approximation, dispersion relations and normal modes, quantization of lattice vibrations and phonons. thermal expansion and need for anharmonicity. Transport properties of solids. Boltzmann transport equation. Wiedemann-Franz law. Lattice vibrations, phonons, adiabatic & harmonic approximations, lattice heat capacity, Einstein and Debye models,
Thermoelectricity : Seebeck, Peltier, and Thomson effects - laws of thermoelectricity - thermoelectric curve - neutral and inversion temperature, thermoelectric power **.**

(12 Hours)

Unit 3:
Dielectric and Ferroelectric Properties: Dielectric constant and polarizability - Static dielectric constant, electronic, ionic and orientation polarizations - Internal or local fields in dielectrics Clausius- Mossatti equation - complex dielectric constant - determination of dipole moment for polar substances - dielectric losses - frequency dependence of electronic, ionic, orientation polarisabilities - dielectric loss. General properties of ferroelectrics- Curie Weiss behavior - classification of ferro electric materials - dipole theory of ferro electricity - ferro electric domains - applications - piezoelectric and pyroelectric materials and applications.., Ferroelectric materials- Pervoskite crystal structure (eg.BaTiO3 and PZT).

(12 Hours)

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

(12 Hours)

Unit 5:
Optical Properties: Electrons in electromagnetic field, Optical absorption in insulators, semiconductors and metals – band to band absorption –Inter band and intra band transitions Charge injection and radiative recombination – The continuity equation: Diffusion length, Charge injection and band gap recombination. Excitonic effects and modulation of optical properties. Luminescence – photoconductivity, photoelectricity, LED and liquid crystal displays. Non-linear optics - wave propagation in Non-linear dielectrics - Electrooptic and Nonlinear optic co-efficients -The nonlinear susceptibility - Optical second Harmonic generation.

(12 Hours)

Reference Books::
1. V. Raghavan, "Materials Science and Engineering: A First Course", Prentice Hall, 2006.
2. S. O. Pillai," Solid state physics", New age International Pvt Ltd, 6th edition, 2005
3. Wahab, M. A.," Solid State Physics", Narosa Publishing, 2nd Edition, 2005
4. C. Kittel, "Introduction to Solid State Physics" Wiley Eastern Ltd., 2005.
5. N.W. Ashcroft and N.D. Mermin Solid state physics, India edition IE, Thomsom books, Reprint, 2007.
6. John Singleton: Band theory and Electronic properties of Solids (Oxford University Press; Oxford Master Series in Condensed Matter Physics).
7. Electricity and Magnetism: Brijlal & Subrahmanyam Ratan Prakashan Mandir Publishers -1995.
8. Harald Ibach and Hans Lüth " An Introduction to principles of Materials Science",
   Springer, 2003.
9. James D. Patterson, Bernard C. Bailey," Solid State Physics: Introduction to the theory", Springer-Verlag, edition 1, 2005

10. Jasprit Singh, "Semiconductor Optoelectronics Physics and Technology", McGraw Hill Co., 1998
11. H.P.Myers, Introductory Solid State Physics, 2nd edition, Viva Books Pvt. Ltd (1998)
12. M.Ali Omar, Elementary Solid State Physics, revised printing Pearson Education (2000)
13. M.S. Rogalski and S.B. Palmer, Solid Statae Physics, Gordon Breach Science Publishers (2000)
14. Y.K. Lim, Problems and solutions on Solid State Physics, Sarat Book Publishers (2002)
15. Fundamentals of Electricity and Magnetism: R.G.Mendiratta and B.K.Sawhney East - West Press(1976)
16. E. Lines and A.M.Glass, Principles and applications of ferroelectrics materials, Clarendon press, Oxford ,1979.
17. K.V.Keer, Principles of solid state physics, Wiley - Eastern, 1993.

Course Code: PHYEC17
Course Title: Quantum Optics
Course Type: Theory (DSE)
Credits: 04

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

(12 Hours)

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

(12 Hours)

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

(12 Hours)

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

(12 Hours)

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

(12 Hours)

Reference Books:
1. Christopher Gerry and Peter Knight, Introductory Quantum Optics, Cambridge University Press; First Edition, 2005.
2. Mark Fox, Quantum Optics An Introduction, Oxford University Press, First Edition, 2006.
3. Marlan O. Scully and M. Suhail Zubairy, Quantum Optics, Cambridge University Press, First Edition, 1997.
4. Girish S. Agarwal, Quantum Optics, Cambridge University Press, First Edition, 2013.
5. Michael A. Nielsen & Isaac L. Chuang, "Quantum Computation and Quantum Information", First Edition, Cambridge University Press, 2010.
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Course Code: PHYEC18
Course Title: Quantum Computation and Quantum Information
Course Type: Theory (DSE)
Credits: 04

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

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

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

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

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

Books Recommended:

1. Michael A. Nielsen & Isaac L. Chuang, "Quantum Computation and Quantum Information",

First Edition, Cambridge University Press, 2010.

2. Quantum Information and Computation, CIT Lecture Notes by J. Preskill

3. Asher Peres, "Quantum Theory: Concepts and Methods", Springer, 1995.

4. Ingemar Bengtsson and Karol Zyczkowski, "Geometry of Quantum States: An Introduction to Quantum Entanglement", First Edition, Cambridge University Press, 2007

5. Mark M. Wilde, "Quantum Information Theory", Second Edition, Cambridge UniversityPress, 2017.

6. Daniel A. Lidar and Todd A. Brun, "Quantum Error Correction", First Edition, Cambridge University Press, 2013.

Course Code: PHYEC19
Course Title: Quantum Field Theory
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Quantum mechanics of many particle systems the need for QFT (relativity, many-body and interactions) Review of Lagrangian of continuous systems. Canonical fields as generalized coordinates. Euler-Lagrange equations, Noether's theorem.

12 Hours

Unit 2:
Canonical quantization of the free scalar field Commutation relations, Energy-momentum tensor, Normal ordering Propagators, Causality n-point Green's function of elementary and composite operators.

12 Hours

Unit 3:
Interacting scalar fields Perturbation Expansion of correlation functions Time-ordering and Wick's theorem S-matrix and Cross-sections Feynman diagrams and calculation of cross-sections Crossing symmetry.

12 Hours

Unit 4:
Quantizing the Maxwell-field in a covariant gauge; physical state condition; spectrum; The Dirac field as a representation of SO(3,1) (notion of SL(2,C)) Weyl, Majorana and Dirac fermions Quantization of the Dirac field.

12 Hours

Unit 5:

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

Reference Books:

1. An Introduction To Quantum Field Theory by Peskin & Schroeder
2. Quantum Field Theory by Mandl and Shaw
3. Quantum Field Theory by I. Ryder

Course Code: PHYEC20
Course Title: Semiconductor Physics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Semiconducting Materials: Origin of band gap in solids - Concept of effective mass of electron and hole – carrier concentration in an intrinsic semiconductor – electrical conductivity – band gap determination – carrier concentration in n-type and p-type semiconductors – Fermi level – Variation of Fermi level with temperature and impurity concentration – Compound semiconductors – Hall effect – Determination of Hall coefficient. Semiconductor types: crystalline and amorphous, inorganic and organic, elemental and compound. Preparation and characteristics. Semiconductors – direct and indirect gaps – carrier statistics (intrinsic and extrinsic) – law of mass action and chemical potential of semiconductors. III - V and II – VI compound semiconductors**.**

(12 Hours)

Unit 2:
Band structure aspects: Band model of semiconductors - Effects of temperature and electric field on the band structure. Frank 'Keldysh effect. Localized states of impurities: theoretical models and experimental probes (Capacitive and spectroscopic techniques). Optical properties: allowed and forbidden . and phonon-assisted transitions and their spectral shapes. Burstein Moss effect. Excitons : free and bound excitons.

(12 Hours)

Unit 3:
Doping And Carrier Transport: Doping: Extrinsic carrier density – Heavily doped semiconductors – Modulation doping (MODFET) – Transport: Scattering of electrons – Photon and ionized impurity scattering – Low field and high field transport in Si and GaAs – Transport of holes – Very high field transport: Break down phenomena – Avalanche break down (APD) – Carrier transport by diffusion - generation and recombination processes, thermionic emission process, tunneling process.

(12 Hours)

Unit 4:
Metal-semiconductor contacts: Schottky barrier. P-N junctions: theory of carrier transport in p-n junctions. Characteristics of practical junctions and deviations from ideality. Capacitance effects: Space charge and diffusion capacitances. Impurity profiling through capacitance measurements. Tunnel diode and applications. , Physical model of p-n junction , junction capacitance and width , Breakdown phenomena , Metal-Semiconductor Junction , Rectification at metal-semiconductor Junction , Schottky-diffusion theory.

(12 Hours)

Unit 5:
Properties Of Semiconductors: Density of states for a 3 dimensional system and in sub 3 dimensional system – Holes in semiconductors, Band structures of some semiconductors. Modification of band structure by alloying and by hetero structures. Quantum well structures, Intrinsic carrier concentration, Electronic

properties of defects: shallow and deep impurity levels; Photoconductivity. Role of traps and recombination. Luminescence. Light emitting diodes and laser action in p-n junction diodes.

(12 Hours)

Reference Books::

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

Course Code: PHYEC21
Course Title: Solar Energy & its applications
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Introduction: Energy scenario current, energy future, energy sources - Energy demand and availability; Conventional, Nonconventional, and Renewable energy resources; Environmental impacts of conventional energy usage.

(15 Hours)

Unit 2:
Solar Collector, Thermal Technology, and Applications: Solar radiation and electromagnetic spectrum, solar radiation entering the earth system, Solar angle of incidence on tilted surface - measurement and estimation on horizontal and tilted surfaces - flat plate collector thermal analysis - testing methods - evacuated tubular collectors - concentrator collectors – compound parabolic concentrators - parabolic trough concentrators – performance of the collectors. Solar water heaters – Solar cooker – desalination - Solar Air heaters - Application of solar air heaters. Solar Drying with various driers – Heating and Drying of Agricultural products – moisture content and its measurement – solar ponds – Application of solar ponds – Solar pumping

(15 Hours)

Unit 3:
Solar Photovoltaic System and Applications: Basic principle of solar photovoltaic conversion, Solar cell parameters and characteristics. Block diagram of general PV conversion system and their characteristics,– Photovoltaic (PV) cell technologies - p-n junction under equilibrium and biasing, open circuit voltage and short circuit current, I-V and P-V curves, calibration and efficiency measurement – PV cell, modules, and array, - Array design, peak power point operation - Load estimation, Selection of inverters, Battery sizing, array sizing. Voltage regulation - maximum tracking - centralized and decentralized PV systems - stand alone - hybrid and grid connected system - System installation - operation and maintenances - field experience – Applications - PV market analysis and economics of PV systems.

(15 Hours)

Unit 4:
Solar refrigeration and Air-conditioning: Potential and scope of solar cooling, Types of solar cooling systems, solar collectors and storage systems for solar refrigeration and airconditioning, solar operation of vapor absorption cycle, temperature concentration diagram, enthalpy concentration diagram, steady flow process with binary mixtures, Energy balance for various components of vapor absorption cycle, Analysis

of absorption system using concentration chart. Solar Passive Architecture - passive cooling concepts: evaporative cooling - radiative cooling

(15 Hours)

Reference Books:
1. S.P. Sukhatme, Solar Energy, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1997. 42
2. S Sukhatme and J Nayak: Solar Energy: Principles of Thermal Collection and Storage, Third Edition (Tata McGraw Hill, 2008)
3. G.N.Tiwari, Solar Energy: Fundamentals, design, Modeling and Applications: 2002, Narosa Publishing house
4. Fonash Solar Cell Devices : (Academic Press, New York)(1981)
5. Stooker W.F, Refrigeration And Air Conditioning, Tata McGraw-Hill
6. C.P.Arora, Refrigeration And Air Conditioning Tata McGraw-Hill(2000)
7. Kreider, J.F. and Frank Kreith, Solar Energy Handbook, McGraw Hill, 1981.
8. Tiwari G.N., Tiwari A.K., Solar Distillation Practice, Anamaya Publishers, New Delhi
9. VVN Kishore, Renewable Energy Engineering and Technology – A Knowledge Compendium, ed. (TERI Press, 2008).
10. Goswami, D.Y., Kreider, J. F. and & Francis., Principles of Solar Engineering, 2000.
11. G.D. Rai, Non Conventional Energy Sources, Khanna Publishers, New Delhi, 1999.
12. G. D. Rai , Solar Energy Utilisation, ,, Khanna Publishers,Delhi.(1996)
13. Volker Quaschning, Understanding Renewable Energy Systems, Vol.1 (2005) 14. Marcelo Godoy Simmoes Renewable Energy Systems CRC Press (2004)
15. John Twidell Renewable Energy Resources Taylor and Francis (2006)
16. Renewable Energy Sources and Their Environmental Impact Abbasi & Abbasi Prentice Hall of India (2004).

Course Code: PHYEC22
Course Title: Vacuum Science and Thin Film Physics
Course Type: Theory (DSE)
Credits: 04

Unit 1:
Basic concepts of vacuum and its generation: Brief history of vacuum; kinetic theory; gas transport and pumping of gases; conductance; Physico and chemical phenomenon in vacuum; basic principles and processes for production of vacuum and ultra-high vacuum; vacuum generation; diaphragm pumps; vacuum blowers; vacuum jet pumps; cryogenic pumps; turbo molecular pumps etc

(12 Hours)

Unit 2:
Measurement of vacuum and leak detection: Mechanical gauges; gauges using liquids, molecular gauges, kundsenguage, thermal conductivity gauges; Ionization gauges; calibration of gauges; sealing techniques and leak detection

(12 Hours)

Unit 3:
Introduction and preparation of thin films: Crystal structures of thin films; defects in thin films (vacancies and interstitials, dislocations, grain boundaries etc.) nanocrystalline, polycrystalline and epitaxial thin films; thermal dynamics and diffusion mechanisms in thin films; thin film surface, nucleation and growth models (2D, 3D, and 2D-3D combination);preparation of thin films; physical vapor deposition techniques includes thermal evaporation, sputtering, pulsed laser deposition, molecular beam epitaxy; e-bean evaporation; chemical vapor deposition; solution based techniques.

Unit 4:
Characterization of thin films: Measurement of film thickness; structural characterization; x-ray diffraction, grazing incidence small angle x-ray scattering technique; transmission electron microscopy; scanning electron microscopy; ellipsometry; chemical characterization x-ray photoelectron spectroscopy; Rutherford back scattering; secondary ion mass spectroscopy

(12 Hours)

Unit 5:
Thin film properties and applications: Conduction in metallic thin films; electrical transport in insulating films; semiconductor contacts; superconductivity in thin films; magnetic film size effects; thin film optics; thin films for electrical and optical devices (LED), Solar Cells, thin film transistors and memories

(12 Hours)

Reference Books:
1. Hand book of thin film technology by H. Frey, H. R. Khan, 2015
2. Materials science of thin films: deposition and structure, by M. Ohring, 2002.
3. L.B. Freund and S. Suresh; Thin film materials: Stress, defect formation and surface evolution, 2004
4. Hand book of thin film deposition, third edition by Krishna Seshan 2012
5. Vacuum technology by A Roth 2012
6. Hand book of vacuum science and technology by D. Hoffman, B. Singh, J.H. Thomas 1997

OPEN ELECTIVE COURSES:

1. APPLIED OPTICS
2. INTRODUCTION TO ASTRONOMY & ASTROPHYSICS
3. GENDER CONCERNS IN STEM STUDIES
4. MEDICAL PHYSICS
5. PHYSICS OF ARTS

Course Code: PHYOE01
Course Title: Applied Optics
Course Type: Theory (OE)
Credits: 03

Unit 1:
Geometrical Optics I: What is light? The rectilinear propagation of light, the refractive index, optical path, introduction to geometrical optics, Fermat's principle, refraction and refraction, the principle of reversibility, color dispersion, paraxial approximation, ray theory, focusing and imaging, sign convention, thin lenses, real and virtual images, total internal reflection, Prisms, minimum deviation, combination of prisms

(09 Hours)

Unit 2:
Geometrical Optics II: Basics of mirrors, magnifiers, thick lenses, the composite lens, the eye, apertures, stops, pupils, windows, Matrix method in paraxial optics, thick and thin lenses, unit planes, nodal planes, system of thin lenses, microscopes, telescopes, Aberrations: chromatic, spherical, coma, astigmatism, distortion, curvature of field

(09 Hours)

Unit 3:
Wave Optics I: Introduction to wave theory of light, the wave equation, phasor representation, complex representation, Huygens' principle, superposition of waves, Interference of light waves, concept of coherence, Young's double slit experiment, interference with white light, Fresnel's biprism, interference by thin parallel films, anti-reflection coating, wedge shaped films, Newton's rings, Michelson interferometer and its applications

(09 Hours)

Unit 4:
Wave Optics II: Introduction to diffraction, Fraunhofer diffraction, single, double and multiple slit diffraction, diffraction at a rectangular and circular aperture, diffraction grating, resolving power, Fresnel

diffraction, Fresnel half period zones, vibration curve, circular obstacle, zone plates, Fresnel diffraction at a straight edge, diffraction by a narrow obstacle, Babinet's principle, transition from Fresnel to Fraunhofer diffraction

(09 Hours)

Unit 5:
Lasers and Fiberoptics: What is a laser? Properties of lasers, spot size, collimation, monochromaticity, tuning range, spectral width, efficiency, size and weight, operation of lasers, oscillators, amplifiers, generation of very short pulses, types of lasers, introduction to fiberoptics, light propagation in an optical fiber, Single mode and multimode propagation, Fiber amplifier, Fiberoptics applications in sensors and communications **(09 Hours)**

Reference Books:
1. Optics, Eugene Hecht (Addison Wesley)
2. Optics, Ajoy Ghatak (McGraw Hil)
3. Fundamentals of Optics, Jenkins & White (McGraw-Hill Primls Custom Publishing)
4. Introduction to Fiber Optics, Ghatak and Thyagarajan, (Cambridge University Press)

Course Code: PHYOE02
Course Title: Introduction to Astronomy & Astrophysics
Course Type: Theory (OE)
Credits: 03

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

(09 Hours)

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

(09 Hours)

Unit 3:
Observing through the atmosphere- Atmospheric Windows, optical telescopes, Radio telescopes, telescope mountings, Magnification, Light gathering power, Stellar Photometry - solid state, Photo-multiplier tube and CCD based photometers, Spectroscopy and Polarimetry using CCD detectors.

(09 Hours)

Unit 4:
Physical Characteristics of sun- basic data, solar rotation, solar magnetic fields, Photosphere - granulation, sunspots, Babcock model of sunspot formation, solar atmosphere – chromosphere and Corona, Solar activity- flares, prominences, solar wind, activity cycle, Helioseismology Morphological classification of the Galaxies. Basic structure and properties of the Milky way

(09 Hours)

Unit 5:

The Universe: Penzias, Wilson and the cosmic microwave background; corroboration of thermal history in big bang cosmology as predicted by Gamow and his collaborators; Big bang model, Zwicky and the dark matter; the observed large scale structure; evidence of dark matter from galactic rotation curves; Type Ia supernovae and accelerating universe; the puzzle of dark energy;

(09 Hours)

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

Course Code: PHYOE03
Course Title: Gender Concerns in STEM studies
Course Type: Theory (OE)
Credits: 03

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

(09 Hours)

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

(09 Hours)

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

(09 Hours)

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

(09 Hours)

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

(09 Hours)

Reference Books::
1. Kamala Bhasin, Understanding Gender : Gender Basics , New Delhi : Women Unlimited , 2004
2. Kamala Bhasin, Exploring Masculinity: Gender Basics , New Delhi: Women Unlimited, 2004 Londa Schiebinger(ed), Women and Gender in Science and Technology, Routledge,2014

• Francesca Bray, Gender and Technology, Annual Review of Anthropology, Vol. 36, 2007, pp. 37- 53
 • Namrata Gupta and A.K. Sharma, 'Gender inequality in the work environment at institutes of higher learning in science and technology in India', Work, Employment & Society, Vol. 17, No. 4 (December 2003), pp.597-616
3. Vineeta Bal, Women Scientists in India: Nowhere near the Glass Ceiling, Economic and Political Weekly, Vol. 39, No. 32 (Aug. 7-13, 2004), pp.3647- 3649+3651-3653
4. Vineeta Bal, Gendered Science: Women as Practitioners and as Targets of Research, Economic and Political Weekly, Vol. 37, No. 52 (Dec. 28, 2002 - Jan. 3, 2003), pp.5163-5167

Course Code: PHYOE04
Course Title: Medical Physics
Course Type: Theory (OE)
Credits: 03

Unit 1:
X-RAYS AND TRANSDUCERS: Electromagnetic Spectrum – Production of X-Rays – X-Ray Spectrum – Bremsstrahlung – Characteristic X-Ray – X-Ray Tubes – Coolidge Tube – XRay Tube Design – Thermistors – photo electric transducers – Photo voltaic cells – photo emissive cells –Photoconductive cells– piezoelectric transducer

(09 Hours)

Unit 2:
BLOODPRESSUREMEASUREMENTS: Introduction –sphygmomanometer – Measurement of heart rate – basic principles of electrocardiogram (ECG) –Basic principles of electroneurography (ENG) – Basic principles of magnetic resonance imaging (MRI).

(09 Hours)

Unit 3:
RADIATIONPHYSICS: Radiation Units – Exposure – Absorbed Dose – Rad to Gray – Kera Relative Biological Effectiveness –Effective Dose – Sievert (Sv) – Inverse Square Law – Interaction of radiation with Matter – Linear Attenuation Coefficient – Radiation Detectors –Thimble Chamber – Condenser Chambers – Geiger Counter – Scintillation Counter

(09 Hours)

Unit 4:
MEDICALIMAGINGPHYSICS: Radiological Imaging – Radiography – Filters – Grids – Cassette – X-Ray Film – Film processing – Fluoroscopy – Computed Tomography Scanner – Principal Function – Display – Mammography – Ultrasound Imaging – Magnetic Resonance Imaging – Thyroid Uptake System – Gamma Camera (Only Principle, Function and display).

(09 Hours)

Unit 5:
RADIATIONPROTECTION: Principles of Radiation Protection – Protective Materials – Radiation Effects – Somatic – Genetic Stochastic and Deterministic Effect – Personal Monitoring Devices – TLD Film Badge – Pocket Dosimeter

(09 Hours)

TEXT BOOKS
1. Dr. K. Thayalan, Basic Radiological Physics, Jayapee Brothers Medical Publishing Pvt. Ltd. New Delhi, 2003.
2. Curry, Dowdey and Murry, Christensen's Physics of Diagnostic Radiology: -LippincotWilliams and Wilkins, 1990.
3. FM Khan, Physics of Radiation Therapy, William and Wilkins, 3rd ed, 2003.

4. D. J. Dewhurst, An Introduction to Biomedical Instrumentation, 1st ed, Elsevier Science, 2014.
5. R.S. Khandpur, Hand Book of Biomedical Instrumentations, 1st ed, TMG, New Delhi, 2005.

Reference Books:
1. Muhammad Maqbool, An Introduction to Medical Physics, 1st ed, Springer International Publishing, 2017.
2. Daniel Jirák, FrantišekVítek, Basics of Medical Physics, 1st ed, Charles University, Karolinum Press, 2018
3. Anders Brahme, Comprehensive Biomedical Physics, Volume 1, 1st ed, Elsevier Science, 2014.
4. K. Venkata Ram, Bio-Medical Electronics and Instrumentation, 1st ed, Galgotia Publications, New Delhi, 2001. 96
5. John R. Cameron and James G. Skofronick, 2009, Medical Physics, John Wiley Interscience Publication, Canada, 2nd edition.

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Course Code: PHYOE05
Course Title: Physics of Arts
Course Type: Theory (OE)
Credits: 03

Unit 1:
Physics of Music: Introduction to music and its forms; Physics of pitch, loudness and timbre; melody, symphony and harmony – a basic understanding of western classical and Indian classical music; Time scales and rhythm in music and the handling of time in Physics; acoustics of auditoria – concepts of reverberation, echoes and good acoustics.

(15 Hours)

Unit 2:
Physics of Dance: History of dance; main elements of western classical dance, Indian classical dance and modern dance; Physics of rotations and their application in western classical dancing; role of centre of gravity in the basic stances (plie and ardhamandala/araimandi) of the two forms; tension and its resolution; projectiles and jumps – elements of velocity, friction and angular momentum.

(15 Hours)

Unit 3:
Physics of Paintings/Photography: Introduction to electromagnetic spectra; colours and wavelengths; colour wheel, mixing of colours and complementary colors; symmetry and its role in nature; role of symmetry in paintings; the golden ratio; introduction to the Physics of cameras – parts of a camera; lenses and their properties; aperture, shutter speed and iso.

(15 Hours)

VALUE ADDED COURSE

1. **Data Analysis Techniques**
2. **Computational Modeling Of Materials**

Course Code: PHYVA01
Course Title: Data Analysis Techniques
Course Type: VAC
Credits: 02

Unit 1:
Introduction to Statistics: Characteristics of a statistical distribution- Mean, variance, skewness, kurtosis, moments and cumulants, percentiles **(6 HOURS)**

Unit 2:
Probability theory, various probabilistic distributions (continuous and discrete), Central limit theorem.
(6 HOURS)

Unit 3:
Error analysis: Types of error in statistical analysis, error propagation, Sampling methods. **(6 HOURS)**

Unit 4:
Hypothesis testing, confidence interval and margin of error. **(6 HOURS)**

Unit 5:
Regression analysis and curve fitting. **(6 HOURS)**

Reference Books::
1. Statistical methods by N G Das, McGrawHill.
2. Statistical methods by S.P. Gupta, S. Chand Publication.
3. Statistical methods for Research Workers, R.A Fisher

Course Code: PHYVA02
Course Title: Computational Modeling Of Materials
Course Type: VAC
Credits: 02

Unit 1

Introduction to Computational Materials Science: Definitions and Terms-Force Field Methods-Molecular Mechanics - Quantum Mechanical Methods: Ab initio methods-Semi empirical methods - Density functional theory methods. **(6 HOURS)**

Unit 2

Ground-state calculations of condensed matter: The Hohenberg-Kohn Theorems – Self-consistent total energies, forces, stresses, Kohn-Sham orbitals - Separable norm-conserving and ultrasoft pseudo-potentials, Projector Augmented Waves - exchange-correlation functionals from LDA to generalized-gradient corrections. **(6 HOURS)**

Unit   **3**

Tutorial: Modeling of periodic solids: Visualization of crystal types – Miller Indices – Crystal planes – Optimization of energy, lattice parameters, volume – Finding optimum k-point grid – Electronic band structure and density of states plotting –Finding band-gap and identifying origin of bands – Electronic charge density visualization – Bonding analysis. **(6 HOURS)**

Unit 4

Tutorial: Modeling of Molecules: Optimization of molecular structure - Effect of different exchange-correlation functionals – Bonding and conformation analysis – HOMO-LUMO gaps – Visualization of electrostatic potential surface – Excited-state properties – Identification of functional groups. **(6 HOURS)**

Unit   **5**

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

(6 HOURS)

SKILL ENHANCEMENT COURSE

1. MACHINE SHOP
2. NANOSCIENCE AND NANOTECHNOLOGY
3. RENEWABLE ENERGY TECHNOLOGIES

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

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

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

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

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Course Code: PHYSE02
Course Title: Renewable Energy Technologies
Course Type: SEC
Credits: 03

Unit   -   I
Fossil fuels and Alternate Sources of energy   **(9 hours)**

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

Unit-II
Solar Energy

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

Unit-III
Wind Energy and Energy from Biomass

Basic principles of wind energy conversion – site selection considerations – Classification of wind energy conversion systems – types of wind machines – Performance analysis of wind machines – Schemes for electric generation – Applications of wind energy – Environmental aspects.- Biomass conversion technologies – Biomass as a source of energy – Methods for obtaining energy from biomass – Biogas generation – Biodegradation –– Biogas from waste – Community biogas plants – Thermal gasification of biomass.   **(18 hours)**

Unit-IV
Geothermal Energy and Energy from the Oceans

Nature of geothermal fields - Geothermal resources – Hot dry rock resources – Magma resources – Geothermal exploration – Advantages and disadvantages of geothermal energy – Applications of geothermal energy – Operational and environmental problems. Ocean thermal electric conversion (OTEC) – Introduction – Open cycle OTEC system - – Closed cycle OTEC system – Energy from Tides – Basic principle of tidal power – Operation methods of utilization
of tidal energy – Single cycle and double cycle systems – Advantages and limitations of tidal power generation - Ocean waves – Energy and power from the waves – Wave energy conversion devices - Advantages and limitations of wave energy.   **(9 hours)**

Unit V
Energy storage

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

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

20. http://en.wikipedia.org/wiki/Renewable_energy

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Course Code: PHYSE03
Course Title: Nanoscience and Nanotechnology
Course Type: SEC
Credits: 03

Unit-I
Basic Physical Properties of Nanostructures : Definition of nanoscience and nanotechnology – History of Nanotechnology- Nanostructures   Nanoparticles – Metal nanoclusters –Surface to volume ratio – Quantum confinement – Qualitative and Quantitative description – Size Dependence of Properties - Metal Nanoclusters –plasmonic effect - Magic Numbers -Electronic Structure - Reactivity -Fluctuations -Magnetic Clusters -Bulk to Nanotransition- Density of states of nanostructures – DOS of 3D Bulk solid- DOS of quantum wells - DOS of quantum wires - Excitons in Nano semiconductors - Natural Nanocrystals..

(9 hrs)

Unit-II
Quantum nanoparticles and Carbon Nanostructures : Semiconducting Nanoparticles - Size and Dimensionality Effects –Size Effects -Potential Wells-Partial Confinement -Conduction Electrons and Dimensionality   - Nanoparticles in Colloidal Suspensions -Photonic Crystals – Excitons. Carbon in nanotechnology – Graphite – Graphene –Fullerenes- Carbon nanotubes. Nanostructured Multilayers - Basics of Ferromagnetism - Dynamics of Nanomagnets -Nanopore Containment of Magnetic Particles - -Ferrofluids -Effect of Nanostructuring on Magnetic Properties - Giant and Colossal Magnetoresistance.

(9 hrs)

Unit-III
Synthesis of Nanostructures : Top-down and bottom up approaches - Methods of Synthesis - Synthesis of ultrafine/nano powders. RF Plasma - Chemical Methods -Thermolysis -Pulsed Laser Methods. Solid-State Reaction - Sol-Gel Technique - Hydrothermal growth - Ball Milling –Plasma arc discharge-sputtering-chemical vapour deposition-pulsed laser depositionmolecularbeam epitaxy- Electrochemical deposition - SILAR method. Combustion synthesis – Sonochemical method - Microwave synthesis – Coprecipitation.

(9 hrs)

Unit-IV
Characterization of Nanoparticles: Surface to volume ratio –Properties of Nanomaterials – wet chemical methods and its functionalizationTheoretical Modeling of Nanoparticles Particle Size Determination- Surface Structure-Microscopy-Transmission Electron Microscopy- Field Ion Microscopy- Scanning Electron Microscopy. Working principles and instrumentation – XRD – XPS – AES - SIMS - RBS – LEED - AFM – SEM – TEM – EDAX –STM.   **(9 hrs)**

Unit-V

Nanomachines and Nanodevices : Limitation of Moor's Law, understanding quantum transport in nanoscale transistors/Devices Microelectromechanical Systems (MEMSs) -Nanoelectromechanical Systems (NEMSs) -Fabrication Nanodevices and Nanomachines -Molecular and Supramolecular Switches. --Single-Electron Tunneling -Applications -Infrared Detectors - Quantum Dot Lasers. Carbon Molecules - Applications of Carbon Nanotubes -Computers -Fuel Cells -Chemical Sensors-Catalysis –Mechanical Reinforcement -Field Emission and Shielding.

(9 hrs)

References:

1. Introduction to Nanotechnology, Charles P. Poole, Jr. and Frank J. Owens, Wiley, 2003 & Study materials from the course.
2. MEMS/NEMS ; micro electro mechanical systems/nano electro mechanical systems Volume 1, Design Methods,, Cornelius T. Leondes, Springer, 2006.
3. Nano: the essentials, T. PRADEEP,TMH ,2007.
4. Nanoscale Materials ,Luis M. Liz-Marzan and Prashant V. Kamat, Kluwer Academic Publishers, 2003
5. Nanoscience,Nanotechnologies and Nanophysics, C. Dupas, P. Houdy and M. Lahmani,Springer-Verlag , 2007.
6. Nanotechnology 101, John Mongillo, Greenwood Press, 2007.
7. Semiconductor Nanostructures for Optoelectronic Applications, Todd Steiner, Artech House, 2004.
8. What is What in the Nanoworld,A Handbook on Nanoscience and Nanotechnology, Victor E. Borisenko and Stefano Ossicini , WILEY-VCH Verlag, 2008.
9. Nanotechnology and Nano-Interface Controlled Electronic Devices, M. Iwamoto,K.
10. Kaneto,S. Mashiko Elsevier Science, Elsevier Science, 2003.
    Semiconductors for Micro and Nanotechnology—An Introduction for Engineers
11. Jan G. Korvink and Andreas Greiner, WILEY-VCH Verlag ,2002.