COURSE STRUCTURE

For

M.Sc. PHYSICS

Based on CBCS & OBE model

Department of Physics
BIT Mesra, Ranchi
2021

Course Structure for

M.Sc.(Physics)

Level	Semester-I		Code no.	Name of the subjects	L	T	P	C
				THEORY				
4		PC	PH 401	Mathematical Method in Physics	3	0	0	3
			PH 402	Electrodynamics	3	0	0	3
			PH 403	Classical Mechanics	3	0	0	3
			PH 404	Quantum Mechanics	2	1	0	3
			PH 405	Modern Computational Techniques & Programming	2	0	0	2
		OE		Open Elective II	3	0	0	3
				LABORATORIES				
		PC	PH 406	Modern Computational Techniques & Programming Lab	0	0	4	2
			PH 407	Modern Physics Lab	0	0	4	2
2		MC	MT204	Constitution of India	2	0	0	Non-Credit
							Total	**21**

Level	Semester-II		Code no.	Name of the subjects	L	T	P	C
		Category		**THEORY**				
4		PC	PH 408	Statistical Physics	3	1	0	4
			PH 409	Atomic and Molecular Spectroscopy	3	1	0	4
			PH 410	Electronic Devices & Circuits	3	0	0	3
			PH 411	Condensed Matter Physics	3	0	0	3
		OE		Open Elective III	3	0	0	3
				SESSIONAL / LABORATORY				
		PC	PH 412	Electronics Lab	0	0	4	2
			PH 413	Condensed Matter Physics Lab	0	0	4	2
							Total	**21**

Level		Category	Code no.	Name of the subjects	L	T	P	C
5	Semester-III			**THEORY**				
		PC	PH 501	Nuclear and Particle Physics	**3**	**1**	**0**	**4**
			PH 502	Advanced Quantum Mechanics	**3**	**1**	**0**	**4**
			PH 503	Laser Physics and Applications	**3**	**1**	**0**	**4**
		PE	PH 504 to PH 512 **(Annexure II)**	PE- V One paper from Either Group A or B or C or D or E: Specialization	**4**	**0**	**0**	**4**
		PE	PH 500 **(Annexure II)**	Project (Phase-I) from Either Group A or B or C or D or E				**4**
				LABORATORIES				
		PC	PH 513	Laser Physics Lab	**0**	**0**	**4**	**2**
							Total	**22**

Level		Category	Code no.	Name of the subjects	L	T	P	C
5	Semester-IV			**THEORY**				
		PE	PH 513 to PH 530 **(Annexure II)**	**PE** - VI: One paper from Either Group A or B or C or D or E: Specialization	**4**	**0**	**0**	**4**
				PE - VII: One paper from Either Group A or B or C or D or E: Specialization	**4**	**0**	**0**	**4**
			PH 550	Project (Phase-II) from Either Group A or B or C or D or E				**8**
				Total				**16**

Total Credits of M.Sc. Physics (I to IV Semesters) = 80

<u>Note:</u> The contents of laboratory papers are designed to meet the course objectives and outcomes of their respective theory papers.

Annexure II

PE	Pre-requisites	Subjects	
PE -V	**One paper from Either Group A or B or C or D or E**	**Group A- Theoretical and Computational Physics:** • Numerical Methods for Physicists • Theory of Solids	 PH 504 PH 505
		Group B- Condensed Matter Physics: • Theory of Solids • Functional Materials	 PH 505 PH 506
		Group C – Photonics: • Fiber and Integrated Optics • Quantum & Nonlinear Optics	 PH 507 PH 508
		Group D- Electronics • Instrumentation and Control • Physics of Low dimensional Semiconductors Devices	 PH 509 PH 510
		Group E- Plasma Sciences: • Introduction to Plasma Physics • Plasma Processing of Materials	 PH 511 PH 512
PE -VI to VII	**Two papers from any group** (Papers shall be chosen from same group in IX and X Semesters)	**Group A- Theoretical and Computational Physics:** • Theoretical and Computational Fluid Dynamics • Theoretical and Computational Condensed Matter Physics • Nonlinear Dynamics and Chaos	 PH 514 PH 515 PH 516
		Group B- Condensed Matter Physics: • Nonconventional Energy Materials • Cryogenic Physics • Physics of Thin Films • Theory of Dielectrics and Ferroics • Theoretical and Computational Condensed Matter Physics	 PH 517 PH 518 PH 519 PH 520 PH 515
		Group C- Photonics: • Photonic and Optoelectronic Devices • Holography and Applications • Quantum photonics and applications • Introduction to Nanophotonics	 PH 521 PH 522 PH 523 PH 524
		Group D- Electronics: • Microprocessor and Microcontroller Applications • Integrated Electronics • Microwave Electronics	 PH 525 PH 526 PH 527
		Group E- Plasma Sciences: • Theory of Plasmas • Plasma Confinement • Waves and Instabilities in Plasma • Physics of Thin Films	 PH 528 PH 529 PH 530 PH 519

M.Sc. Physics (I -IV Semester)

Semester	Subjects	Credit	Total
I	Mathematical Method in Physics	3	**21**
	Electrodynamics	3	
	Classical Mechanics	3	
	Quantum Mechanics	3	
	Modern Computational Techniques & Programming	2	
	Open Elective I	3	
	Modern Computational Techniques & Programming Lab	2	
	Lab-II (Modern Physics Lab)	2	
II	Statistical Physics	4	**21**
	Atomic and Molecular Spectroscopy	4	
	Electronics Devices & Circuits	3	
	Condensed Matter Physics	3	
	Open Elective II (Other Dept)	3	
	Lab III (Electronics Lab)	2	
	Labs IV (Condensed Matter Physics Lab)	2	
III	Nuclear and Particle Physics	4	**22**
	Advanced Quantum Mechanics	4	
	Laser Physics and Applications	4	
	PE - V One paper from Either Group A or B or C or D or E: Specialization	4	**Papers shall be chosen from same group in I.MSc. IX and X Semesters**
	Project from Either Group A or B or C or D or E	4	
	Lab –V (Laser Physics Lab)	2	
IV	PE - VI One paper from the same Group A or B or C or D or E	4+4	**16**
	PE - VII One paper from the same Group A or B or C or D or E		
	Project (Phase-II) from Either Group A or B or C or D or E	8	
		Total	**80**

<u>Internship (In-house/External)</u> of at least 2 months should be done by the students (Non-credit)

Course Assessment tools & Evaluation procedure for Theory Papers

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Assessment tools & Evaluation procedure for Laboratory Papers

Assessment Tool	% Contribution
Progressive Evaluation	60 (Day to day performance: 30, Quiz: 10, Viva: 20)
End Sem Examination	40 (Experiment Performance: 30, Quiz: 10)

Semester I

COURSE INFORMATION SHEET

Course code: PH 401
Course title: Mathematical Methods in Physics
Pre-requisite(s): Mathematical Physics
Co- requisite(s):
Credits: **3** L: 3 T: 0 P: 0
Class schedule per week:
Class: M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Code: PH 401	Title: Mathematical Methods in Physics	L-T-P-C [3-0-0-3]

Course Objectives: The objectives of the course are

1.	To train the students to solve problems related to complex variables which contain real and imaginary parts.
2.	To teach the use of different special functions in solving physical problems.
3.	To provide an understanding of Integral Transform and Probability.
4.	To teach about an understanding of Tensors.
5.	To give the basic knowledge of Group theory.

Course Outcomes: After completion of the course students should be able to

1.	The students will be able to solve different physical problems which contain complex variables.
2.	They will be familiarized with different special functions like Associated Legendre Polynomials, Polynomials, etc. and their solutions in solving different physical problems.
3.	This module will be helpful to obtain knowledge of Fourier and Laplace Transforms in solving different problems of Mechanics and Electronics etc. The module will also impart some basic knowledge of Probability.
4.	Students will be able to learn about the concept and uses of Tensors.
5.	Useful to obtain the basic knowledge of Group theory and its applications.

Module-1	**Complex variables** Analytic functions, Cauchy-Riemann conditions, Cauchy's Integral theorem and Integral formula, Laurent expansion, Singularities, Evaluation of residues, Residue theorem.	**[6]**
Module-2	**Special Functions** Associated Legendre Polynomials, Recurrence relations, Rodrigue's formula, Orthogonality of Legendre Polynomials, Hermite Polynomials, Green's function.	**[8]**
Module-3	**Integral Transform** Laplace Transform, Inversion, Applications of Laplace Transform; Fourier Transform, Inversion, Fourier Sine and Cosine transform, Convolution Theorem, Fourier transforms of derivatives, Applications of Fourier Transform. **Probability** Elementary probability theory, simple properties, random variables, binomial and normal distribution , centre limit theorem	**[10]**
Module-4	**Tensors** Covariant, Contravariant and Mixed tensors, Tensors of rank 2, Algebra of tensors: Sum, Difference & Product of Two Tensors, Contraction, Quotient Law of Tensors, Pseudotensors, dual tensors, Tensors in General Coordinates, Tensor derivative operators, Jacobians, Inverse of Jacobians. Diad and Triad.	**[8]**
Module-5	**Introductory group theory** Review of sets, Mapping and Binary Operations, Relation, Types of Relations, Groups: Elementary properties of groups, uniqueness of solution, Subgroup, Centre of a group, Co-sets of a subgroup: SU(2), O(3).	**[8]**

Text books:

T1: Hans J. Weber George B. Arfken, Mathematical Methods for Physicists, (2005), Academic Press.
T2: L. A. Pipes, Applied Mathematics for Engineering and Physics (1958) McGraw-Hill.
T3: Elements of Group Theory for Physicists by A. W. Joshi, 1997, John Wiley.

Reference books:

R1: Charlie Harper, Introduction to Mathematical Physics (2003), Prentice-Hall India.
R2: Erwin Kreyszig, Advanced Engineering Mathematics (1999), Wiley.
R3: N. P. Bali, A. Saxena and N.C. S. W. Iyengar, A Text Book of Engineering Mathematics (1996), Laxmi Publications (P) Ltd.
R4: Group Theory and its Applications to Physical Problems by Morton Hamermesh, 1989, Dover

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
End Sem Examination Marks	√	√	√	√	√
Quiz 1	√	√			
Quiz 2			√		
Quiz 3				√	

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Objectives onto Course Outcomes

Course Outcome #	Program Outcomes				
	a	b	c	d	e
1	H	L	L	L	L
2	L	H	L	L	L
3	L	L	H	L	L
4	L	L	L	H	L
5	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	M	H	H
2	H	H	H	M	H	H
3	H	H	H	M	H	H
4	H	H	H	M	H	H
5	H	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1-2	L1-L6			Analytic functions, Cauchy-Riemann conditions, Cauchy's Integral theorem and Integral formula, Laurent expansion, Singularities, Evaluation of residues, Residue theorem.	T1, R1	1		PPT Digi Class/ Chock -Board	
3-5	L7-L14			Associated Legendre Polynomials, Recurrence relations, Rodrigue's formula, Orthogonality of Legendre Polynomials, Hermite Polynomials, Green's function.	T1, T2, R2	2			
5-7	L15-L20			Laplace Transform, Inversion, Applications of Laplace Transform; Fourier Transform, Inversion, Fourier Sine and Cosine transform, Convolution Theorem, Fourier transforms of derivatives, Applications of Fourier Transform.	T1,R3	3			
7-8	L21-L24			Elementary probability theory, simple properties, random variables, binomial and normal distribution, central limit theorem	T2, R2	3			

9-11	L25-L32			Covariant, Contravariant and Mixed tensors, Tensors of rank 2, Algebra of tensors: Sum, Difference & Product of Two Tensors, Contraction, Quotient Law of Tensors, Pseudo tensors, dual tensors, Tensors in General Coordinates, Tensor derivative operators, Jacobians, Inverse of Jacobians. Diad and Triad.	T1, T2	4			
11-14				Review of sets, Mapping and Binary Operations, Relation, Types of Relations, Groups: Elementary properties of groups, uniqueness of solution, Subgroup, Centre of a group, Co-sets of a subgroup: SU(2), O(3).	T3, R4	5			

<u>**COURSE INFORMATION SHEET**</u>

Course code: PH 402
Course title: Electrodynamics
Pre-requisite(s): Electricity and Magnetism
Co- requisite(s):
Credits: **3** L: 3 T: 0 P: 0
Class schedule per week:
Class: M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Code: PH 402	**Title: Electrodynamics**	**L-T-P-C [3-0-0-3]**

Course Objectives

This course enables the students:

A.	Introducing the mathematical tools used in electrodynamics.
B.	Review of electrostatics and magnetostatics in matter.
C.	Providing easy headway into the covariant formulation of Maxwell's equations.
D.	Teaching basic principles of waveguides and transmission lines.
E.	Rendering insights into fields generated by oscillating sources, and their applications.

Course Outcomes

After the completion of this course, students will be:

1.	Ability to use basic mathematical tools to solve problems in electrodynamics.
2.	Gaining proficiency in electrostatics and magnetostatics.
3.	Obtaining command on four-vector and tensor notations.
4.	Learning about TM, TE and TEM modes in waveguides.
5.	Understanding radiations by moving charges.

Module-1	The concept of a scalar potential. Poisson's and Laplace's equations for scalar potential. Green's theorem, Electrostatic field energy density. Solutions of Laplace's equation in rectangular, spherical and cylindrical coordinates using the method of separation of variables, Method of images, Multipole expansion of potential due to a localized charge distribution.	**[8]**
Module-2	Electrostatics in matter; Polarization and electric displacement vector. Electric field at the boundary of an interface, Linear dielectrics. Magnetostatics, Biot-Savart Law, Ampere's Law, Scalar and Vector potentials, Magnetic moment of a current distribution. Macroscopic magnetostatics, Magnetization. M and H vectors, Boundary conditions.	**[8]**
Module-3	Electromagnetic induction, Faraday's Law, Maxwell's equations, Maxwell's equations in matter, Conservation of charge, Poynting's theorem, Solutions of Maxwell's Equations, Covariant formulation of electrodynamics, Inhomogeneous wave equations and their solutions.	**[8]**
Module-4	Electromagnetic waves in matter, Reflection and refraction at a plane interface between dielectrics, Fresnel's equations. Phase velocity and group velocity, spreading of a pulse propagating in a dispersive medium, propagation in a conductor, skin depth. Transmission lines and wave guides; Dynamics of charged particles in static and uniform electromagnetic fields.	**[8]**
Module-5	EM Field of a localized oscillating source. Fields and radiation in dipole and quadrupole approximations. Antenna; Radiation by moving charges, Lienard-Wiechert potentials, total power radiated by an accelerated charge, Lorentz formula.	**[8]**

References:

1. Introduction to Electrodynamics by D. J. Griffiths
2. Classical Electrodynamics by J. D. Jackson
3. Lectures on Electromagnetism by A. Das

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks					
End Sem Examination Marks					
Quiz I					
Quiz II					

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	-	M	L
B	H	H	-	L	-
C	H	M	H	H	M
D	H	L	-	H	L
E	H	L	M	M	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	H	H	H
2	H	H	H	H	H	H
3	H	H	H	H	H	H
4	H	H	H	H	H	H
5	H	H	H	H	H	H

Lecture wise Lesson planning Details.

Week No.	Lect.No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COsmapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L4			The concept of a scalar potential. Poisson's and Laplace's equations for scalar potential. Green's theorem, Electrostatic field energy density. Solutions of Laplace's equation in rectangular coordinates	T1,T3	1			

2	L5-L8			Laplace's equation in spherical and cylindrical coordinates using the method of separation of variables, Method of images, Multipole expansion of potential due to a localized charge distribution.	T1,T3	1			
3	L9-L12			Electrostatics in matter; Polarization and electric displacement vector. Electric field at the boundary of an interface, Linear dielectrics. Magnetostatics, Biot-Savart Law, Ampere's Law,	T1,T3	2			
4	L13-L16			Scalar and Vector potentials, Magnetic moment of a current distribution. Macroscopic magnetostatics, Magnetization. M and H vectors, Boundary conditions.	T1,T3	2			
5	L17-L20			Electromagnetic induction, Faraday's Law, Maxwell's equations, Maxwell's equations in matter, Conservation of charge, Poynting's theorem,	T1,T3	3			
6	L21-L24			Solutions of Maxwell's Equations, Covariant formulation of electrodynamics, Inhomogeneous wave equations and their solutions.	T1,T3	3			
7	L25-L28			Electromagnetic waves in matter, Reflection and refraction at a plane interface between dielectrics, Fresnel's equations. Phase velocity and group velocity, spreading of a pulse propagating in a dispersive medium,	T1,T3	4			
8	L29-32			propagation in a conductor, skin depth. Transmission lines and wave guides; Dynamics of charged particles in static and uniform electromagnetic fields.	T1,T3	4			
9	L33-L36			EM Field of a localized oscillating source. Fields and radiation in dipole and quadrupole approximations.	T1,T3	5			
10	L37-L40			Antenna; Radiation by moving charges, Lienard-Wiechert potentials, total power radiated by an accelerated charge, Lorentz formula.	T1,T3	5			

COURSE INFORMATION SHEET

Course code: PH 403
Course title: Classical Mechanics
Pre-requisite(s):): Classical Dynamics (or similar papers) Or Mechanics and Electricity & Magnetism at UG level
Co- requisite(s):
Credits: **3** L: 3 T: 0 P: 0
Class schedule per week:
Class: M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Code: PH 403	**Title: Classical Mechanics**	**L-T-P-C [3-0-0-3]**

Course Objectives

This course enables the students:

A.	To define the concepts of Langrangian Mechanics.
B.	To interpret the concepts of Hamiltonian Mechanics.
C.	To explain generating function, canonical transformation & Poisson brackets.
D.	To illustrate the dynamics of a rigid body and non-inertial frames of reference.
E.	To formulate the concepts of coupled oscillators.

Course Outcomes

After the completion of this course, students will be able to:

1.	Formulate the Lagrangian mechanics concepts and solve the problems with the help of Lagrangian mechanics.
2.	Compare the formulation of Hamiltonianand Lagrangian mechanics and solve the problems of classical and relativistic mechanics
3.	Solve the problems of generating function, canonical transformation & Poisson brackets.
4.	Formulate the equations of rigid body dynamics and demonstrate the examples of non-inertial frames of reference.
5.	Solve the equations of coupled oscillator and to examine the two coupled pendulums, and double pendulum related problems.

Module-1	Constraints, classification of constraints, generalized coordinates, principal of virtual work, D Alembert's principal, Langrange's equations of motion, properties of kinetic energy function, theorem on total energy, generalized momenta, cyclic-coordinates, integrals of motion, Jacobi integrals and energy conservation, concept of symmetry, invariance under Galilean transformation, velocity dependent potential. Two body central force problem: reduction of two body problem to equivalent one body problem, equation of motion under central force and first integrals, differential equation for an orbit, Kepler's law, stability of orbits, virial theorem, scattering in a central force field.	**[10]**
Module-2	Hamilton's function and Hamilton's equation of motion, configuration space, phase space and state space, Lagrangian and Hamiltonian of relativistic particles, Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.	**[7]**
Module-3	Generating function, Conditions for canonical transformation and problem. Poisson Brackets , its definitions, identities, Poisson theorem, Jacobi-Poisson theorem, Jacobi identity, invariance of PB under canonical transformation. Lagrange bracket.	**[5]**
Module-4	Dynamics of a Rigid Body: Rigid body and space reference system, Euler's angles, angular momentum and inertia tensor, principal moment of inertia, rotational kinetic energy of rigid body, symmetric bodies, moments of inertia for different body system, Euler's equation of motion for a rigid body by Newtonian method and Lagrange's method Non-inertial frames of reference, fictitious force, uniformly rotating frames, coriolis force, Foucault's pendulum, Larmor precession, effects of Coriolis force on: river flow on the surface of the earth, air flow on the surface of the earth, projectile motion	**[10]**
Module-5	Coupled Oscillator: Potential energy and equilibrium of one dimensional oscillator, differential equations for coupled oscillator, kinetic and potential energies of the coupled oscillators, theory of small oscillations, examples of coupled oscillator: two coupled pendulums, double pendulum	**[8]**

Reference books:

1. Classical Mechanics by H. Goldstein, Pearson Education Asia.
2. Classical Dynamics of Particles and Systems by Marion and Thomtron, Third Edition, Horoloma Book Jovanovich College Publisher.
3. Classical Mechanics by P. V. Panat, Narosa Publishing Home,, New Delhi.
4. Classical Mechanics by N. C. Rana and P. S. Joag, Tata Mc-Graw Hill Publishing Company Limited, New Delhi.
5. Introduction to Classical Mechanics by R. G. Takwale and P. S. Puranik, Tata Mc-Graw Hill Publishing Company Limited, New Delhi.
6. Landau and Lifsitz

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination	√	√	√		
End Sem Examination	√	√	√	√	√
Quiz I	√	√	√		
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome
3. Teacher's assessment

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

	Course Outcomes				
Course Objectives	**1**	**2**	**3**	**4**	**5**
A	H	M	M	L	L
B	H	H	M	L	L
C	M	M	H	L	L
D	L	L	L	H	L
E	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	H	H	H
2	H	H	H	H	H	H
3	H	M	M	H	H	M
4	H	L	L	M	H	M
5	H	M	H	M	H	M

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
	L1-L3			Constraints, classification of constraints, generalized coordinates, principal of virtual work, D Alembert's principal, Langrange's equations of motion	T1 T2				
	L4-L6			properties of kinetic energy function, theorem on total energy, generalized momenta, cyclic-coordinates, integrals of motion, Jacobi integrals and energy conservation, concept of symmetry	T1 T2				
	L7-L10			invariance under Galilean transformation, velocity dependent potential. Two body central force problem: reduction of two body problem to equivalent one body problem, equation of motion under central force and first integrals, differential	T1 T2				

				equation for an orbit, Kepler's law, stability of orbits, virial theorem, scattering in a central force field					
	L11-L13			Hamilton's function and Hamilton's equation of motion	T1 T2				
	L14			configuration space, phase space and state space	T1 T2				
	L15-L17			Lagrangian and Hamiltonian of relativistic particles, Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.	T1 T2				
	L18, L19			Generating function, Conditions for canonical transformation and problem.	T1 T2				
	L20-L22			Poisson Brackets, its definitions, identities, Poisson theorem, Jacobi-Poisson theorem, Jacobi identity, invariance of PB under canonical transformation. Lagrange bracket.	T1 T2				
	L23-L27			Dynamics of a Rigid Body: Rigid body and space reference system, Euler's angles, angular momentum and inertia tensor, principal moment of inertia, rotational kinetic energy of rigid body, symmetric bodies, moments of inertia for different body system, Euler's equation of motion for a rigid body by Newtonian method and Lagrange's method	T1 T2				
	L28-L32			Non-inertial frames of reference, fictitious force, uniformly rotating frames, coriolis force, Foucault's pendulum, Larmor precession, effects of Coriolis force on: river flow on the surface of the earth, air flow on the surface of the earth, projectile motion.	T1 T2				

	L32, L33			Coupled Oscillator: Potential energy and equilibrium of one dimensional oscillator,	T1 T2				
	L34-L38			differential equations for coupled oscillator, kinetic and potential energies of the coupled oscillators, theory of small oscillations,	T1 T2				
	L39, L40			examples of coupled oscillator: two coupled pendulums, double pendulum.	T1 T2				

<u>**COURSE INFORMATION SHEET**</u>

Course code: PH 404
Course title: Quantum Mechanics
Pre-requisite(s): Previous papers of Quantum Mechanics
Co- requisite(s):
Credits: **3**L: 2 T:1 P: 0
Class schedule per week:
Class: M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Code: PH 404	**Title: Quantum Mechanics**	**L-T-P-C [2-1-0-3]**

Course Objectives

This course enables the students to:

A. define Heisenberg & Dirac formulation of quantum mechanics and explain their importance.-Outline the basics of crystallography and define various types of imperfections in crystals.
B. demonstrate the linear harmonic oscillator and hydrogen-like atom using Dirac formulation-Explain elastic and plastic deformation in solids and summarize the strain hardening mechanisms.
C. explain the angular momentum operators associated with spherical and symmetrical systems-Define ceramics and explain its types and applications.
D. illustrate scattering theory and determine the scattering parameters.-Define polymers and composites and categorize them on the basis of their applications.
E. formulate the approximation methods to solve real problems which are insolvable analytically-Define Nanotechnology and outline the various properties of nano materials and their fabrication techniques.

Course Outcomes

After the completion of this course, students will be able to:

1. formulate the Heisenberg & Dirac formulation of quantum mechanics-explain various types of imperfections in crystals.
2. solve the linear harmonic oscillator and hydrogen-like atom problems using Dirac formulation-analyze the mechanisms behind elastic and plastic deformation is solids and compare different strengthening techniques.
3. demonstrate angular momentum operators associated with spherical and symmetrical systems.-summarize ceramics and its types and relate their applications with properties.
4. explain scattering theory, formulate and solve scattering equation-classify polymers and composites based on their properties and applications.
5. apply the Variational principle and WKB Approximation to solve the real problems-Classify nanomaterials, their fabrication techniques and co relate the effects of confinement to nanoscale on their properties.

Module-1	**Introduction to Dirac and Heisenberg Formulation:** Linear vector space, Dirac Bra-Ket notations. Determination of eigen-values and eigen-functions using matrix representations. Coordinate and momentum representation. Uncertainty principle.	**[10]**
Module-2	**Harmonic Oscillator and Hydrogen atom problem:** Linear harmonic oscillator, Heisenberg and quantum mechanical treatments. Asymptotic behaviour, energy levels, correspondence with classical theory. Spherically symmetric potential in three dimensions, hydrogen atom, wave functions, eigenvalues, degeneracy, etc.	**[10]**
Module-3	**Angular momentum and its addition:** Theory of angular momentum, symmetry, invariance and conservation laws, relation between rotation and angular momentum. Commutation rules, eigenvalues and eigen functions of the angular momentum. Stern-Gerlach experiment, spin, spin operators, Pauli's spin matrices. Spin states of two spin-1/2 particles. Addition of angular momenta, Clebsch-Gordon coefficients. Principle of indistinguishablity of identical	**[10]**

	particles, Pauli's exclusion principle.	
Module-4	**Scattering theory:** Scattering Theory, differential and total scattering cross-section laws, partial wave analysis and application to simple cases; Integral form of scattering equation, Born approximation validity and simple applications.	**[5]**
Module-5	**Approximation Methods:** Variational Principle, WKB approximation, solution near a turning point, connection formula, tunnelling through barrier. boundary conditions in the quasi classical case.	**[5]**

Text books:

1. J. J. Sakurai, Modern Quantum Mechanics , Addison-Wesley Publishing Company, 1994.
2. Nouredine Zettili, Qunatum Mechanics: Concepts and Application, Wiley Publications 2016.
3. R. Shankar, Principles of Quantum Mechanics, Plenum Press, 1994.

Reference books:

1. L. I. Schiff, Quantum Mechanics, Tata McGraw Hill, New Delhi
2. L. D. Landau and E. M. Lifshitz, Quantum Mechanics, Pergamon, Berlin.

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	No
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

AssessmentCompoents	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid Sem Examination Marks	Yes	Yes	Yes	No	No
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment	Yes	Yes	Yes	Yes	Yes

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	L	M	L
2	H	H	M	L	L	L
3	H	M	M	L	L	L
4	H	M	M	L	L	L
5	H	H	H	L	H	L

Course Outcome #	Course Objectives				
	a	b	c	d	e
1	H	M	M	M	L
2	M	H	M	M	L
3	M	M	H	L	L
4	M	M	H	L	L
5	M	M	L	L	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD8
CD2	Tutorials/Assignments		CO2	CD1, CD2 and CD8
CD3	Seminars		CO3	CD1, CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Module No.	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1		I	Linear vector space	T2	CO-1		PPT Digi Class/Chalk Board	
	L2-L3			Dirac Bra-Ket notations	T2	CO-1		PPT Digi Class/Chalk-Board	
2	L4-6			Determination of eigen-values and eigen-functions using matrix epresentations.	T1	CO-1		PPT Digi Class/Chalk-Board	
3	L7-8			Coordinate and	T1	CO-1		PPT Digi Class/Chal	

				momentum representation				k-Board	
3-4	L9-L10			Uncertainty principle	T3	CO-1		PPT Digi Class/Chalk-Board	
4	L11		II	Linear harmonic oscillator	T3	CO-2		PPT Digi Class/Chalk-Board	
4-5	L12-13			Heisenberg and quantum mechanical treatments.	T3	CO-2		PPT Digi Class/Chalk-Board	
5	L14			Asymptotic behaviour, energy levels,	T1	CO-2		PPT Digi Class/Chalk-Board	
5	L15			correspondence with classical theory.	T1	CO-2		PPT Digi Class/Chalk-Board	
6	L16-17			Spherically symmetric potential in three dimensions,		CO-2		PPT Digi Class/Chalk-Board	
6-7	L18-19			hydrogen atom, wave functions, eigenvalues, degeneracy, etc.	T1, T2, T3	CO-2		PPT Digi Class/Chalk-Board	
7	L20-21		III	Theory of angular momentum, symmetry, invariance and conservation laws,	T2	CO-3		PPT Digi Class/Chalk-Board	
8	L22-23			relation between rotation and angular momentum.	T2	CO-3		PPT Digi Class/Chalk-Board	
8-9	L24-25			Commutation rules, eigenvalues and eigen functions of the angular momentum.	T1	CO-3		PPT Digi Class/Chalk-Board	
9	L26-27			Stern-Gerlach experiment, spin, spin operators	T1	CO-3		PPT Digi Class/Chalk-Board	
10	L28			Pauli's spin matrices. Spin states of two spin-1/2 particles.	T1, T2, T3	CO-3		PPT Digi Class/Chalk-Board	
10	L29			Addition of angular momenta, Clebsch-Gordon coefficients.	T1, T2, T3	CO-3		PPT Digi Class/Chalk-Board	
10	L30			Principle of indistinguishablity of identical particles,	T1, T2, T3	CO-3		PPT Digi Class/Chalk-Board	
11	L31			Pauli's exclusion principle	T3	CO-3		PPT Digi Class/Chal	

								k-Board	
11	L29		IV	Scattering Theory, differential and total scattering cross-section laws	T2	CO-4		PPT Digi Class/Chalk-Board	
11	L30			partial wave analysis and application to simple cases	T2	CO-4		PPT Digi Class/Chalk-Board	
12	L31			Integral form of scattering equation	T1	CO-4		PPT Digi Class/Chalk-Board	
12	L32-33			Born approximation validity and simple applications	T2	CO-4		PPT Digi Class/Chalk-Board	
13	L34		V	Variational Principle, WKB approximation	T2	CO-5		PPT Digi Class/Chalk-Board	
13	L35			solution near a turning point	T2	CO-5		PPT Digi Class/Chalk-Board	
13	L36			connection formula, tunnelling through barrier	T2	CO-5		PPT Digi Class/Chalk-Board	
14	L37			boundary conditions in the quasi classical case	T2	CO-5		PPT Digi Class/Chalk-Board	

COURSE INFORMATION SHEET

Course code: PH 405
Course title: Modern Computational Techniques & Programming
Pre-requisite(s): Mathematical Physics
Co- requisite(s):
Credits: **2** L: 2 T: 0 P: 0
Class schedule per week:
Class: M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Code: PH405	**Title: Modern Computational Techniques & Programming**	**L-T-P-C [2-0-0-2]**
Course Objectives: The idea behind the course is to teach students to solve problem in physics using MAPLE and MATLAB. In this regard the objectives are to 1. Teach to calculate various errors which arise while solving different equations. 2. Train them to solve systems of linear equations. 3. Teach them the concept of interpolation. 4. Instruct them to calculate integrals and differentials using different numerical methods. 5. Train them to solve partial differential equations numerically. **Program Outcomes:** After completion of the course, students should be able to 1. Estimate errors while solving equations. 2. Effectively use methods like matrix inversion, Gauss elimination and LU decomposition to solve linear equations. 3. Enrich a given set of data points using interpolation methods like cubic spline, Newton's divided difference, etc. 4. Numerically differentiate and integrate expressions. 5. Solve equations from physics like heat equation, diffusion equation, etc. numerically.		
Module-1	Approximation Methods, Errors and Roots of Equations, Accuracy and precision, Truncation and round-off errors, Bracketing Methods (false position, bisection), Iteration Methods (Newton-Raphson and secant).	**[8]**
Module-2	Systems of linear algebraic equations Gauss elimination, matrix inversion and LU decomposition methods.	**[4]**
Module-3	Curve fitting and Interpolation Least squares regression, Linear, multiple linear and nonlinear regressions, Cubic spline. Newton's divided difference and Lagrange interpolating polynomials.	**[6]**
Module-4	Numerical differentiation and integration, Divided difference method for differentiation, Newton-Cotes formula, Trapezoidal and Simpson's rules, Romberg and Gauss quadrature methods.	**[5]**
Module-5	Ordinary and Partial differential equations , Euler's method and its modifications, Runge-Kutta methods, Boundary value and Eigen value problems. Finite difference equations, Elliptic equations, Laplace's equation and solutions, Parabolic equations, Solution of the heat conduction equation	**[12]**

Text books:

T1: Introductory Methods of Numerical Analysis, S.S. Sastry, Prentice Hall of India (1983)

Reference books:

R1: Numerical Analysis, V. Rajaraman
R2: Numerical Methods for Engineering, S.C. Chopra and R.C. Canale, McGraw-Hill (1989).
R3: Numerical Methods for Scientists and Engineers, Prentice Hall of India (1988).

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	Y

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	C05
End Sem Examination Marks	√	√	√	√	√
Quiz 1	√	√			
Quiz 2			√		
Quiz 3				√	

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Objectives onto Course Outcomes

Course Outcome #	Program Outcomes				
	a	b	c	d	e
1	H	L	L	L	L
2	L	H	L	L	L
3	L	L	H	L	L
4	L	L	L	H	L
5	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	M	H	H
2	H	H	H	M	H	H
3	H	H	H	M	H	H
4	H	H	H	M	H	H
5	H	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD9
CD2	Tutorials/Assignments		CO2	CD1 , CD2and CD9
CD3	Seminars		CO3	CD1, CD2 and CD9
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD9
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD9
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1-3	L1-L12			Approximation Methods, Errors and Roots of Equations, Accuracy and precision, Truncation and round-off errors, Bracketing Methods (false position, bisection), Iteration Methods (Newton-Raphson and secant).	T1, R1	1		PPT Digi Class/Chock -Board	
3-5	L13-L24			Systems of linear algebraic equations Gauss elimination, matrix inversion and LU decomposition methods.	T1	2			
5-8	L25-LL36			Curve fitting and Interpolation Least squares regression, Linear, multiple linear and nonlinear regressions, Cubic spline. Newton's divided difference and Lagrange interpolating polynomials.	T1, R2	3			
8-10	L37-L48			Numerical differentiation and integration, Divided difference method for differentiation, Newton-Cotes formula,	T1, R1	4			

				Trapezoidal and Simpson's rules, Romberg and Gauss quadrature methods.					
10-14	L49-L60			Ordinary and Partial differential equations , Euler's method and its modifications, Runge-Kutta methods, Boundary value and Eigen value problems. Finite difference equations, Elliptic equations, Laplace's equation and solutions, Parabolic equations, Solution of the heat conduction equation	T1, R3	5			

COURSE INFORMATION SHEET

Course code: PH 406
Course title: Modern Computational Techniques & Programming Lab
Pre-requisite(s): Mathematical Physics
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week:
Class: M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Title: Modern Computational Techniques & Programming Lab **L-T-P-C [0-0-4-2]**

1. Evaluate $f(0.8)$ using Taylor's series for $f(x)$, where
$f(x) = 5x^4 - 2x^2 + 3x - 2$

2. Find the truncation error by comparing the following functions with their values calculated using zeroth, first,...,seventh order Taylor's expansion:

a) $sin(\pi/3)$

b) $\frac{1}{1-0.1}$

3. Let $u = \frac{5xy^3}{z^2}$. If $\Delta x = \Delta y = \Delta z = 0.01$ and $x = y = z = 2$, calculate the maximum relative and absolute errors.

4. Find the roots of the function
$10\sin(x) = 2x^2 + 1.$

Maple is not able to find an exact (symbolic) solution of the equation. There are two general approaches to obtaining an approximate solution that you might consider in a case like this; graphical and numerical.

5. Solve the following set of linear equation by
(i) Gauss elimination
(ii) Matrix inversion and
(iii) LU decomposition methods.

$$x + 3y - 2z = 10$$
$$3x + 5y + 6z = 7$$
$$2x + 4y + 3z = 8$$

6. Fit the given set of data points to a gaussian function of the form $a_0 * exp^{-(x^2-a_1)}$:

(-3, 0.0188), (-2.68, 0.1112), (-2.37, 0.5468), (-2.05, 2.2223), (-1.74, 7.3486), (-1.42, 19.8502), (-1.11, 43.9048), (-0.79, 79.6264), (-0.47, 118.49122), (-0.16, 144.6785), (0.16, 144.6785), (0.4737, 118.4912), (0.7895, 79.6264), (1.11, 43.9048), (1.42, 19.8502), (1.74 7.3486), (2.05, 2.2223),(2.37, 0.5468), (2.68, 0.1112), (3, 0.01877)

Find the values of a_0 and a_1.

7. Using the table below, find $f(x)$ as a polynomial in x for data points provided below:
(-1,5), (2,-6), (5,4), (6, 9), (7,10), (9,13), (11, 16), (13,18)

8. Using the values of x and y provided in the table below, obtain dy/dx and d^2x/d^2y for $x = 1.2$.

x	Y
1.0	2.7188
1.2	3.3289
1.4	4.0068
1.6	4.9538
1.8	6.0489
2.0	7.4567
2.2	9.2258
2.4	11.8976

9. Evaluate the integral $\int_0^1 \frac{x^3}{e^x - 1}$ using trapezoidal and Simpson's rules correct to five decimal places. Which method gives the most accurate result?

10. A solid of revolution is formed by rotating about the x-axis the area between the x-axis, the lines $x = 0$ and $x = 1$, and a curve through the points with the following coordinates:

x	Y
0.00	1.0000
0.25	0.9900
0.50	9600
0.75	0.9100
1.00	0.8400

11. Solve the following differential equation (overdamped Langevin equation):

$\gamma \frac{dx}{dt} = -kx + \sqrt{2k_B T}\, \xi(t),$

where , T and k are constants, and $\xi(t)$ is a random variable sampled from a normal distribution. Take $k_B = 1$. Start with the initial condition $x(t = 0) = 0$.

12. Solve Laplace equation in Cartesian coordinates, in a region defined by a parallelepiped of dimensions L_1, L_2 and L_3. The equation is

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0.$$

The potential vanishes on 5 faces of the parallelepiped. On the 6th face at $z = L_3$, the potential is a known function $f(x, y)$.

13. Solve the heat equation

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$$

Subject to the initial conditions: $u = sin(\pi x)$ at $t = 0$ for $0 \leq x \leq 1$ and $u = 0$ at $x = 0$ and $x = 1$ for $t > 0$.

14. Consider a system of 100 identical particles interacting via a Lennard-Jones potential:

$$U_{LJ}(r) = 4\epsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6}\right] .$$

which is terminated and shifted at $r = r_{Cut} = 2.5\sigma$, so that the truncated potential $\bar{U}_{LJ}$ is defined as,

$$\bar{U}_{LJ}(r) = \begin{cases} U_{LJ}(r) - U_{LJ}(r_{Cut}) & \text{if } r < r_{Cut} \\ 0 & \text{if } r > r_{Cut} \end{cases}$$

All the quantities are defined in terms of reduced Lennard-Jones units with mass m, interaction parameter ϵ and length scale σ having unit values. Using NVT simulations, plot the equilibrium energy of the system against temperature.

References:

1. Numerical Mathematical Analysis, J.B. Scarborough, John Hopkins (1966).
2. Introductory Methods of Numerical Analysis, S.S. Sastry, Prentice Hall of India (1983)
3. Numerical Methods for Engineering, S.C. Chopra and R.C. Canale, McGraw-Hill (1989).
4. Numerical Methods for Scientists and Engineers, Prentice Hall of India (1988).
5. Electromagnetics and Calculation of Fields, Nathan P-Ida and J.P.A. Bastos, Springer-Verlag (1992).

Course Assessment tools & Evaluation procedure

Assessment Tool	% Contribution
Progressive Evaluation	60 (Day to day performance: 30, Quiz: 10, Viva: 20)
End Sem Examination	40 (Experiment Performance: 30, Quiz: 10)

COURSE INFORMATION SHEET

Course code: PH 407
Course title: Modern Physics Lab
Pre-requisite(s):
Co- requisite(s):
Credits: **2**L: 0 T: 0 P: 4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: VII / I
Branch: PHYSICS
Name of Teacher:

Modern Physics Lab L-T-P-C [0-0-4-2] **Name of the Experiment**
1. To determine specific charge of electron by Thomson's method/circular trajectory method. (Thomson's experiment) 2. To Verify the inverse Square law using Planck's constant measuring instrument.(Inverse square law) 3. Determination of Planck's constant using Light Emitting Diode (LEDs) (Planck's constant) 4. Verification of energy quantisation by Franck-Hertz Experiment. (Franck-Hertz Experiment) 5. Study of the voltage and current of the solar cells in series and parallel combinations. (Characteristic of Solar cell) 6. To measure the charge of electron and show that it is quantised with the smallest value of 1.6× 10-19 coulombs (Millikan's oil drop experiment) 7. To study the variation of count rate with applied voltage and thereby determine the plateau, the operating voltage and slope of plateau (G M Counter) 8. To observe the dielectric constant by comparison of electrical conductivity of different materials to that of a metal.(Dielectric constant)

Course Assessment tools & Evaluation procedure

Assessment Tool	% Contribution
Progressive Evaluation	60 (Day to day performance: 30, Quiz: 10, Viva: 20)
End Sem Examination	40 (Experiment Performance: 30, Quiz: 10)

Semester II

COURSE INFORMATION SHEET

Course code: PH 408
Course title: Statistical Physics
Pre-requisite(s): Mathematical Physics
Co- requisite(s): Quantum Physics
Credits: **4**L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: II
Branch: PHYSICS
Name of Teacher:

Code: PH 408	Title: Statistical Physics	L-T-P-C [3-1-0-4]

Course Objectives

1. To understand the dependence of equilibrium properties of various systems on their microscopic constituents and compute thermodynamic parameters by using classical statistics.
2. To learn to use methods of quantum statistics to obtain properties of systems made of microscopic particles which either obey Fermi-Dirac statistics or Bose-Einstein statistics.
3. To grasp the concepts of first order and second order phase transitions and critical phenomena.
4. To understand phase transition arising in Ising model.
5. To learn to obtain the properties of out-of-equilibrium systems using concepts from equilibrium physics.

Course Outcomes: Students should be able to

1. Use various ensemble theories to calculate the thermodynamic properties of different systems.
2. Compute properties of systems behaving as ideal Fermi gas or ideal Bose gas.
3. Classify transitions as first order or second order.
4. The student should be able to reproduce the exact solution of Ising model in one dimension and solve it using mean field theory.
5. Understand the approach required to predict the evolution of non-equilibrium systems.

Module-1	**Formalism of Equilibrium Statistical Mechanics** Concept of phase space, Liouville's theorem, basic postulates of statistical mechanics, ensembles: microcanonical, canonical, grand canonical and their partition functions, connection to thermodynamics, fluctuations, applications of various ensembles, equation of state for a non-ideal gas, Van der Waals' equation of state, Meyer cluster expansion, virial coefficients.	**[8]**
Module-2	**Quantum Statistics** Formalism of Fermi-Dirac and Bose-Einstein statistics. Applications of the formalism to: (a) Ideal Bose gas, Debye theory of specific heat, properties of black-body radiation, Bose-Einstein condensation, degeneracy, BEC in a harmonic potential. (b) Ideal Fermi gas, properties of simple metals, Pauli paramagnetism, electronic specific heat	**[8]**
Module-3	**Phase Transitions and Critical Phenomena** First and Second order Phase transitions, Diamagnetism, paramagnetism, and ferromagnetism, Landau theory, critical phenomena, Critical exponents, scaling hypothesis.	**[8]**
Module-4	**Ising Model :** Ising Model, mean-field theory, exact solution in one dimension.	**[6]**
Module-5	**Nonequilibrium Systems:** Correlation of space-time dependent fluctuations, fluctuations and transport phenomena, Diffusion equation, Random walk and Brownian motion, Langevin theory, fluctuation dissipation theorem, Fokker-Planck equation.	**[10]**

Text books:

T1: Statistical Physics, Landau and Lifshitz, Pergamon Press

Reference books:

R1: Statistical Physics, R. K. Patharia, Pergamon Press

R2: Statistical Physics, Kerson Huang, John Wiley and Sons R3: Statistical Physics, S. K. Ma, World Scientific Publishing, Singapore

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	C05
End Sem Examination Marks	√	√	√	√	√
Quiz 1	√	√			
Quiz 2			√		
Quiz 3				√	

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Objectives onto Course Outcomes

Course Outcome #	Program Outcomes				
	a	b	c	d	e
1	H	L	L	L	L
2	L	H	L	L	L
3	L	L	H	L	L
4	L	L	L	H	L
5	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	M	H	H
2	H	H	H	M	H	H

3	H	H	H	M	H	H
4	H	H	H	M	H	H
5	H	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 andCD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1-3	L1-L8			Concept of phase space, Liouville's theorem, basic postulates of statistical mechanics, ensembles: microcanonical, canonical, grand canonical and their partition functions, connection to thermodynamics, fluctuations, applications of various ensembles, equation of state for a non-ideal gas, Van der Waals' equation of state, Meyer cluster expansion, virial coefficients.	T1	1		PPT Digi Class/Chock -Board	
3-6	L9-L16			Formalism of Fermi-Dirac and Bose-Einstein statistics. Applications of the formalism to: (a) Ideal Bose gas, Debye theory of specific heat, properties of black-body radiation, Bose-Einstein condensation, degeneracy, BEC in a harmonic potential. (b) Ideal Fermi gas, properties of simple metals, Pauli paramagnetism, electronic specific heat	T1, R1, R2	2			
6-8	L17-L24			First and Second order Phase transitions, Diamagnetism,	T1,R2 3	3			

				paramagnetism, and ferromagnetism, Landau theory, critical phenomena, Critical exponents, scaling hypothesis.						
8-10	L25-L30			Ising Model, mean-field theory, exact solution in one dimension.	T1, R3	4				
11-14	L31-L40			Correlation of space-time dependent fluctuations, fluctuations and transport phenomena, Diffusion equation, Random walk and Brownian motion, Langevin theory, fluctuation dissipation theorem, Fokker-Planck equation.	T1, R3	5				

COURSE INFORMATION SHEET

Course code: PH 409
Course title: Atomic and Molecular Spectroscopy
Pre-requisite(s): Modern Physics
Co- requisite(s):
Credits: 4L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: VIII / II
Branch: PHYSICS
Name of Teacher:

Code: PH 409	Title: Atomic and Molecular Spectroscopy	L-T-P-C [3-1-0-4]

Course Objectives

This course enables the students:

A.	To learn about the intricacies of spectra of Hydrogen-like atoms
B.	To understand the details of rotational, vibrational and Raman spectra of molecules.
C.	To know about the different regions of spectra, and the corresponding instrumentations.
D.	To learn about NMR spectra and its application
E.	To get a feeling of the principles of mass spectroscopy and ionization methods.

Course Outcomes

After the completion of this course, students will be:

1.	Able to deal with problems related to Hydrogen-like atomic spectra
2.	Having knowledge about the rotational, vibrational and Raman spectroscopy of molecules
3.	Able to comprehend the instrumentation techniques that are used in different regions of spectra
4.	Understanding NMR spectra and visualize the physical phenomenon
5.	Learning about mass spectroscopy and its usage

Module-1	Atomic Physics: Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen, helium and alkali atoms; Relativistic corrections for energy levels of hydrogen; Hyperfine structure and isotopic shift; Spectral terms, L-S and J-J coupling schemes, Singlet-Triplet separation for interaction energy of L-S coupling. Lande Interval rule, Zeeman, Paschen Back & Stark effect; width of spectral lines	**[10]**
Module-2	Molecular Spectroscopy: Types of molecular spectroscopy, applications, Rotational, vibrational and electronic spectra of diatomic and polyatomic molecules; Born Oppenheimer approximation, Frank – Condon principle and selection rules. Molecular hydrogen, Fluorescence and Phosphorescence, Instrumentations of IR and Microwave Spectroscopy and Applications. Raman Effect, Rotational Raman spectra. Vibrational Raman spectra. Stokes and anti-Stokes lines and their Intensity difference, Instrumentation and applications.	**[12]**
Module-3	Characterization of electromagnetic radiation, regions of spectrums, spectra representation, basic elements if practical spectroscopy, resolving power, width and intensity of spectral transition, Fourier transform spectroscopy, concept of stimulated emission.	**[10]**
Module-4	NMR Spectroscopy: Nuclear spin, nuclear resonance, saturation, spin-spin and spin-lattice relaxations, chemical shift, de shielding, coupling constant, instrumentation and applications.	**[8]**
Module-5	Principle and applications of Mass Spectroscopy, Thomson's method of determining e/m of electrons, Aston mass spectrograph, Dempster's mass spectrometer, Ionization Methods, instrumentation and applications.	**[10]**

Text books:

1. Introduction to Atomic Spectra", H.E. White, McGraw-Hill.
2. Fundamentals of Molecular Spectroscopy" C. N. Banwell, Tata McGraw-Hill
3. Atomic Physics", G. P. Harnwell & W.E. Stephens, McGraw-Hills Book Company, Inc.
4. Modern Spectroscopy", J. M. Hollas, John Wiley

Reference books:

1. "Physics of Atoms and Molecules" by Bransden & Joachain, Pearson
2. "Introduction to Spectroscopy" by Pavia et. al., Cengage Learning India Pvt. Ltd.

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

_Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks					
End Sem Examination Marks					
Quiz I					
Quiz II					

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	-	L	L	-
B	-	H	H	-	-
C	L	H	H	-	-
D	-	-	L	H	-
E	-	-	-	-	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	M	H	M	L	M
2	H	H	H	M	H	M
3	L	H	M	M	H	M
4	L	M	M	M	H	M
5	M	M	M	M	M	M

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L3			Atomic Physics: Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen, helium and alkali atoms; Relativistic corrections for energy levels of hydrogen	T2, R1	1		PPT Digi Class/Chock -Board	
2	L4-L6			Hyperfine structure and isotopic shift; Spectral terms, L-S and J-J coupling schemes, Singlet-Triplet separation for interaction energy of L-S coupling	T2, R1	1			
3	L7-L9			Lande Interval rule, Zeeman, Paschen Back & Stark effect; width of spectral lines	T2, R1	1			
4	L10-L12			Molecular Spectroscopy: Types of molecular spectroscopy, applications, Rotational, vibrational and electronic spectra of diatomic and polyatomic molecules; Born Oppenheimer approximation, Frank – Condon principle and selection rules.	T2, R1	2			
5	L13-L15			Molecular hydrogen, Fluorescence and Phosphorescence, Instrumentations of IR and Microwave Spectroscopy and Applications. Raman Effect	T2, R1	2			

6	L16-L19			Rotational Raman spectra. Vibrational Raman spectra. Stokes and anti-Stokes lines and their Intensity difference, Instrumentation and applications.	T2, R1	2			
7	L20-L22			Characterization of electromagnetic radiation, regions of spectrums, spectra representation, basic elements if practical spectroscopy	T2, R1	3			
8	L23-L25			resolving power, width and intensity of spectral transition, Fourier transform spectroscopy, concept of stimulated emission.	T2	3			
9	L26-L29			NMR Spectroscopy: Nuclear spin, nuclear resonance, saturation, spin-spin and spin-lattice relaxations	T2, R2	4			
10	L30-L33			chemical shift, de shielding, coupling constant, instrumentation and applications.	T2, R2	4			
11	L34-L37			Principle and applications of Mass Spectroscopy, Thomson's method of determining e/m of electrons, Aston mass spectrograph,	R2	5			
12	L38-L41			Dempster's mass spectrometer, Ionization Methods, instrumentation and applications.	R2	5			

COURSE INFORMATION SHEET

Course code: PH 410
Course title: Electronic Devices & Circuits
Pre-requisite(s): Digital and Analog Systems
Co- requisite(s):
Credits: **3**L: 3 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: VIII / II
Branch: PHYSICS
Name of Teacher:

Code: PH 410	**Title: Electronic Devices & Circuits**	**L-T-P-C [3-0-0-3]**
Course Objectives: • To impart knowledge about a To impart knowledge about a variety of special, power and microwave solid state electronic devices, their structure and the underlying physical principles. • To expose the students to the integrated circuit chip development technologies and associated processes • Amplifiers would be dealt with in all its expanse and rigor to give a good feel of the associated design and mathematical intricacies. • A rigorous treatment on integrated circuit operational amplifiers is to be delivered to supplement their understanding on amplifiers • Linear and non-linear applications of op-amps are introduced to add to the knowledge on the variety of circuits encompassing all major class of applications. • Nanoelectronic devices and concepts are introduced to give a feel of the future electronics devices and the quantum effects that manifest. **Course Outcomes:** • Understanding the physics of the devices their characteristics and applications, to be able to use them in electronic circuits • Students would develop an insight into the technologies that go into an IC chip that they would be extensively using during and after the course • In depth understanding would enable the students to appreciate the beauty of the subject and design amplifiers that are technically sound. • Students would develop a comprehensive understanding of contemporary integrated circuit amplifier design. • Students would be aware of various signal conditioning, processing and generation techniques thus being better equipped to understand their use in larger and complex systems. • Students would enjoy the new and stimulating ideas behind the future novel devices and would also appreciate the link between electronics and the quantum effects that come into play.		
Module-1	**Electronic Devices** Varactor diode, photo-diode, Schottky diode, solar cell, Principle of Operation and I-V Characteristics of JFET, MOSFET. Thyristors (SCR, LASCR, Triac and Diac) Microwave semiconductor devices: Tunnel diode, IMPATT, Gunn effect and Gunn diode.	8
Module-2	**Integrated circuits:** Monolithic lC's, Hybrid lC's. Materials for IC fabrication (Si and GaAs), Crystal growth and wafer preparation, processes Epitaxy, Vapour phase epitaxy (VPE), Molecular beam epitaxy (BME), MOCVD Oxidation, Ion implantation, Optical lithography, electron beam lithography, Etching processes.	8
Module-3	**Amplifiers using discrete devices** Amplifiers using BJTs, FETs, MOSFETs and their analysis. Feedback in amplifiers, characteristics of negative feedback amplifiers, input resistance, output resistance, method of analysis of a feedback amplifier, feedback types and their analyses, Bode plots, two-pole and three–pole transfer function with Feedback, approximate analysis of a multipole feedback amplifier, stability, gain and phase margins, compensation, dominant-pole compensation, pole-zero compensation.	12
Module 4	**Operational amplifiers** Differential Amplifier, emitter-coupled differential amplifier, transfer characteristics of a differential amplifier, current mirror and active load, Measurement of op-amps parameters, frequency response of op-amps, dominant–pole compensation, pole-zero compensation, lead	10

	compensation, step response of op-amps.	
Module 5	**Applications of Op-Amps** **Linear:** instrumentation amplifier, precision rectifiers, active filters (low-pass, high-pass, band-pass, band-reject/ notch), Analog computation circuits **Nonlinear:** Comparators, Schmitt trigger, multivibrators, AMV and MMV using 555 timer, waveform generation, D/A converters, binary weighted, A/D converters, simultaneous, counter type, dual slope converter. **Single electron devices:** Quantum point contact, Coulomb blockade, Resonant tunneling transistor, Single electron transistor (SET).	12

Text books:

T1: Physics of Semiconductor Devices- S. M. Sze
T2: Solid State Electronic Devices- B. G. Streetman, PHI
T3: VLSI Technology, S. M. Sze Mc Graw Hill
T4: Integrated Electronics, Jacob Millman and Christos Halkias, -Tata McGraw Hill Publication
T5: Thomas L. Floyd. ELECTRONIC. DEVICES. 9th Edition. Prentice Hall.
T6: Louis Nashelsky and Robert Boylestad, Electronic Devices and Circuit Theory
T7: Khan and Dey, A First course in Electronics, PHI
T8: Operational amplifiers and Linear Integrated Circuits- R. A. Gayakwad, PHI.
T9: Linear Integrated Circuits- D. R. Choudhary and S. B. Jain, New Age Publications

Reference books:

R1: Operational amplifier and Linear Integrated Circuits- R. F. Coughlin, F. F. Driscoll, PHI

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5	CO6	CO7
Quiz-I	√	√	√				
Quiz-II	√			√	√		
Quiz-III	√					√	√
Assignment	√	√	√	√			
End Sem Exam	√	√	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	**1**	**2**	**3**	**4**	**5**	**6**
A	H	H	H	H	H	H
B	H	H	H	L	H	H
C	H	L	H	L	M	L
D	H	M	M	H	H	M
E	H	H	H	H	H	M
F	H	H	H	L	M	H
G	H	H	L	M	L	L

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	**Program Outcomes**						
	a	b	c	d	e	f	g
1	H	H	H	H	H	M	H
2	H	H	H	H	H	M	H
3	H	H	H	H	H	M	H
4	H	H	H	H	H	M	H
5	H	H	H	H	H	M	H

Mapping Between COs and Course Delivery (CD) methods

CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		CO6	CD1 and CD2
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	**Lect. No.**	**Tentative Date**	**Ch. No.**	**Topics to be covered**	**Text Book / References**	**COs mapped**	**Actual Content covered**	**Methodology used**	**Remarks by faculty if any**
1	L1		Module-1	Varactor diode, Schottky diode,	T1				
	L2			photo-diode,	T1				
	L3			solar cell,	T1				
	L4			Principle of Operation and I-V Characteristics of JFET, MOSFET.	T1, T2, T4				
	L5								
	L6			Thyristors (SCR, LASCR, Triac and Diac)	T1, T4				
	L7								

	L8			Tunnel diode, IMPATT, Gunn effect and Gunn diode.	T1				
	L9		Module-II	**Integrated circuits:** Monolithic lC's, Hybrid lC's. Materials for IC fabrication (Si and GaAs)	T1, T3				
	L10			Crystal growth and wafer preparation, processes Epitaxy, Vapour phase epitaxy (VPE)	T1, T3				
	L11			Molecular beam epitaxy (BME), MOCVD Oxidation	T1, T3				
	L12			Ion implantation	T1, T3				
	L13			Optical lithography	T1, T3				
	L14			electron beam lithography, Etching processes	T1, T3				
	L15		Module-III	**Amplifiers using discrete devices** Amplifiers using BJTs	T4, T5, T6				
	L16			Amplifiers using FETs, MOSFETs and their analysis	T4, T5, T6				
	L17			Feedback in amplifiers, characteristics of negative feedback amplifiers	T4, T5, T6				
	L18			input resistance, output resistance,	T4, T5, T6				
	L19			method of analysis of a feedback amplifier	T4, T5, T6				
	L20			feedback types and their analyses, Bode plots, two-pole and three–pole transfer function with Feedback, approximate analysis of a multipole feedback amplifier	T4, T5, T6				
	L21			stability, gain and phase margins	T4, T5, T6				

	L22			compensation, dominant-pole compensation, pole-zero compensation	T4, T5, T6				
	L23		Module-IV	**Operational amplifiers** Differential Amplifier,	T4, T7				
	L24			emitter-coupled differential amplifier	T4, T7				
	L25								
	L26								
	L27			current mirror and active load	T7, T9				
	L28			transfer characteristics of a differential amplifier	T4, T7				
	L29			Measurement of op-amps parameters, frequency response of op-amps	T4, T7				
	L30			dominant–pole compensation, pole-zero compensation, lead compensation, step response of op-amps.	T4, T9				
	L31		Module-V	**Applications of Op-Amps** **Linear:** instrumentation amplifier	T5				
	L32			Precision rectifiers	T5,T9				
	L33			Active filters (low-pass, high-pass, band-pass, band-reject/ notch), Analog computation circuits	T5,T9				
	L34			**Nonlinear:** Comparators, Schmitt trigger	T5,T9				
	L35			multivibrators, AMV and MMV using 555 timer	T5,T9				
	L36			Waveform generation, D/A converters, binary weighted, A/D converters, simultaneous, counter type, dual slope converter.	T5,T9				

	L37		Module-VI	**Single electron devices:** Quantum point contact	T2, T1				
	L38			Coulomb blockade	T2, T1				
	L39			Resonant tunneling transistor	T2, T1				
	L40			Single electron transistor (SET).	T2, T1				

COURSE INFORMATION SHEET

Course code: PH 411
Course title: Condensed Matter Physics
Pre-requisite(s): Quantum Mechanics
Co- requisite(s):
Credits: **3** L: 3 T: 0 P: 0
Class schedule per week:
Class: M.Sc.
Semester / Level: II
Branch: PHYSICS
Name of Teacher: Dr S K Rout

Course Objectives

This course enables the students:

A.	To relate crystal structure to symmetry, recognize the correspondence between real and reciprocal space.
B.	Acquire knowledge of the behaviour of electrons in solids based on classical and quantum theories.
C.	To become familiar with the different types of magnetism and magnetism based phenomenon.
D.	To develop an understanding of the dielectric properties and ordering of dipoles in ferroelectrics.
E.	To get familiarized with the different parameters associated with superconductivity and the theory of superconductivity.

Course Outcomes

After the completion of this course, students will be:

1.	Able to correlate the X-ray diffraction pattern for a given crystal structure based on the corresponding reciprocal lattice.
2.	Able to explain how the predicted electronic properties of solids differ in the classical free electron theory, quantum free electron theory and the nearly free electron model.
3.	Able to explain various magnetic phenomena and describe the different types of magnetic ordering based on the exchange interaction.
4.	Able to differentiate between ferroelectric, anti-ferroelectric, piezoelectric and pyroelectric materials.
5.	Able to differentiate between type-I and type-II superconductors and their theories.

Code:PH 411	**Title : Condensed Matter Physics**	**L-T-P-C [3-0-0-3]**
Module-1	**CRYSTAL DIFFRACTION AND RECIPROCAL LATTICE** Revision of concepts, crystal structure, Bravais Lattice, lattice translation vector, symmetry operations, simple crystal structures, Miller indices, lattice planes, Braggs' law, reciprocal lattice to SC, BCC, FCC, Laue's equation and Bragg's law in terms of reciprocal lattice vector, diffraction and the structure factor, Ewald’s construction, structure determination using Laue's method, powder crystal diffraction, rotating crystal method, scattered wave amplitude, Fourier analysis of the basis, structure factor of lattices (sc, bcc, fcc), atomic form factor.	**[8]**
Module-2	**ENERGY BAND THEORY** Classical free electron theory, wave mechanical treatment of electron in 1D and 3D well, Wiedemann-Franz law, quantum theory of thermal conductivity, failure of free electron theory, density of states, Fermi-Dirac statistics, effect of temperature on Fermi distribution function, electrons in a periodic potential, Bloch’s theorem, Kronig Penney Model, construction of Brillouin zone, reduced zone scheme, concept of energy band, energy band structure of conductors, semiconductors and insulators.	**[8]**
Module-3	**MAGNETISM** Magnetic Susceptibility, diamagnetism, paramagnetism, the ground state of an ion and Hund's rules, adiabatic demagnetization, crystal fields, orbital quenching, Jahn-Teller effect, nuclear magnetic resonance, electron spin resonance, Mossbauer spectroscopy, magnetic dipolar interaction, exchange interaction, ferromagnetism, antiferromagnetism, ferrimagnetism, spin glasses.	**[8]**
Module-4	**DIELECTRICS AND FERROELECTRICS**	**[8]**

	Macroscopic Maxwell equation of electrostatics, theory of local field, theory of polarisability, dielectric constant, Claussius-Mosotti relation, optical properties of ionic crystals, dielectric breakdown, dielectric losses, ferroelectric, anti-ferroelectric, piezoelectric, pyroelectric, frequency dependence of dielectric properties, classification of ferroelectric crystal, ferroelectric phase transitions, relaxor ferroelectrics.	
Module-5	**SUPERCONDUCTIVITY** Basic properties of superconductors, phenomenological thermodynamic treatment, London equation, penetration depth, superconducting transitions, order parameter, Ginzburg-Landau theory, Cooper pair, electron-phonon interaction, BCS theory, coherence length, flux quantization, Josephson junction, high T_c superconductors, mixed state.	**[8]**

Textbooks:

1. Introduction to Solid State Physics 8thEdition , Charles Kittel, John Wiley and Sons, 2005.
2. Solid State Physics, Neil W. Ashcroft, N. David Mermin, Saunders College Publishing, 1976.

References:

1. Condensed Matter Physics 2nd Edition, Michael. P Marder, John Wiley and Sons, 2010.
2. Magnetism in Condensed Matter, Oxford Master Series in Condensed Matter Physics 4, Stephen Blundell, Oxford University Press, 2001.

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	Yes
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	Yes	Yes	Yes	No	No
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment	Yes	Yes	Yes	Yes	Yes

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	L	L	M
2	H	H	H	L	M	L
3	H	H	H	L	M	L
4	M	H	M	L	M	L
5	M	H	H	L	L	L

Course Outcome #	Course Objective				
	a	b	c	d	e
1	H	L	M	M	M
2	L	H	M	M	L
3	L	M	H	L	M
4	L	L	M	H	L
5	L	M	M	L	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1,CD2 and CD8
CD2	Tutorials/Assignments		CO2	CD1,CD2 and CD8
CD3	Seminars		CO3	CD1,CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1,CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1,CD2 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Module No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1		I	Revision of concepts, crystal structure, Bravais Lattice,	T1, T2	1, 2		PPT Digi Class/Chalk -Board	
1	L2			lattice translation vector, symmetry operations, simple crystal structures, Miller indices, lattice planes, Braggs' law,	T1, T2			PPT Digi Class/Chalk -Board	
1	L3-L4			reciprocal lattice to SC, BCC, FCC, Laue's equation and Bragg's law in terms of reciprocal lattice vector,	T1, T2			PPT Digi Class/Chalk -Board	

2	L5			diffraction and the structure factor,	T1, T2			PPT Digi Class/Chalk -Board	
2	L6			Ewald's construction,	T1, T2			PPT Digi Class/Chalk -Board	
2	L7			structure determination using Laue's method, powder crystal diffraction, rotating crystal method,	T1, T2			PPT Digi Class/Chalk -Board	
3	L8			scattered wave amplitude, Fourier analysis of the basis, structure factor of lattices (sc, bcc,fcc), atomic form factor.	T1, T2			PPT Digi Class/Chalk -Board	
4	L11		II	Classical free electron theory, wave mechanical treatment of electron in 1D and 3D well Wiedemann-Franz law, quantum theory of thermal conductivity, failure of free electron theory	T1, T2			PPT Digi Class/Chalk -Board	
4	L12-13			density of states, Fermi-Dirac statistics, effect of temperature on Fermi distribution function	T1, T2			PPT Digi Class/Chalk -Board	
5	L14-15			electrons in a periodic potential, Bloch's theorem, Kronig Penney Model, construction of Brillouin zone, reduced zone scheme, concept of energy band,	T1, T2			PPT Digi Class/Chalk -Board	
5	L16			Energy band structure of conductors, semiconductors and insulators.	T1, T2			PPT Digi Class/Chalk -Board	
	L17		III	Magnetic Susceptibility, diamagnetism, Paramagnetism, The ground state of an ion and Hund's rules, adiabatic demagnetization	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L18			Crystal fields, orbital quenching	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L19			Jahn-Teller effect Nuclear magnetic resonance	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L20-21			Electron spin resonance Mossbauer spectroscopy,	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L22			Magnetic dipolar interaction, Exchange interaction,	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L23-L24			Ferromagnetism, anti-ferromagnetism,Ferrimagnetisms, Spin glasses.	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L25		IV	Macroscopic Maxwell equation of electrostatics	T1, T2, R1			PPT Digi Class/Chalk -Board	

	L26			Theory of local field, theory of Polarisability, dielectric constant, Claussius-Mosotti relation	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L27			Optical properties of ionic crystals.	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L28-29			Dielectric breakdown, dielectric losses, ferroelectric, anti-ferroelectric.	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L30-31			Piezoelectric, Pyroelectric, frequency dependence of dielectric properties.	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L32			Classification of ferroelectric crystal, ferroelectric phase transitions, relaxor ferroelectrics.	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L33		V	Basic properties of Superconductors, Phenomenological thermodynamic treatment	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L34-35			London equation, penetration depth	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L36			Superconducting transitions, order parameter, Ginzburg-Landau theory	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L37			Cooper pair, electron-phonon interaction, BCS theory	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L38			Josephson junction	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L39			Coherence length, Flux quantization	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L40			High T_c superconductors, mixed state.	T1, T2, R1			PPT Digi Class/Chalk -Board	

COURSE INFORMATION SHEET

Course code: PH 412
Course title: Electronics Lab
Pre-requisite(s):
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Electronics Lab

L-T-P-C
[0-0-4-2]

List of Experiments:

1. Verification of truth tables of OR, NOT and AND gates using NAND gates
2. Verification of truth tables of OR, NOT and AND gates using NOR gates
3. Realization of XOR and XNOR gates using NAND and NOR gates
4. Design and verification of a 2 bit binary half adder
5. Design and verification of a 2- bit binary full adder
6. Design of a half subtractor and verification of its truth table
7. Design of a half subtractor and verification of its truth table
8. Design and implementation of clocked R-S flipflops using NAND gates
9. Design and implementation of clocked J-K flipflops using NAND gates
10. Design and testing of monostable vibrator using IC 555 timer
11. Design and testing of astable multivibrator using IC 555 timer
12. Design and testing of Schmidt Trigger using IC 741
13. Design and testing of modulo 9 ripple counter using IC CD4029.
14. Design and testing of CMOS switch and 2:1 multiplexer using IC 4066.

Course Assessment tools & Evaluation procedure

Assessment Tool	% Contribution
Progressive Evaluation	60 (Day to day performance: 30, Quiz: 10, Viva: 20)
End Sem Examination	40 (Experiment Performance: 30, Quiz: 10)

COURSE INFORMATION SHEET

Course code: PH 413
Course title: Condensed Matter Physics Lab
Pre-requisite(s):
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher:

Condensed Matter Physics Lab

L-T-P-C
[0-0-4-2]

List of experiments:

1. To study the permeability of a ferrite substance as a function of frequency. (Take atleast 20 data)
2. To study the relative permittivity of a dielectric material as a function of temperature. (Take atleast 20 data).
3. Analysis of XRD data using JCPDS software.
4. Analysis of FESEM data using ImageJ software to calculate density function.
5. Analysis of XRD data using CheckCell software.
6. Measurement of resistance of a semiconductor as a function of temperature.
7. Measurement of susceptibility using lock in amplifier.
8. Synthesis of a ceramic sample using a programmable furnace.
9. Analysis of XRD data using FullProf software.
10. Design of crystal structure using VESTA software.

Course Assessment tools & Evaluation procedure

Assessment Tool	% Contribution
Progressive Evaluation	60 (Day to day performance: 30, Quiz: 10, Viva: 20)
End Sem Examination	40 (Experiment Performance: 30, Quiz: 10)

Semester III

COURSE INFORMATION SHEET

Course code: PH 501
Course title: Nuclear and Particle Physics
Pre-requisite(s): Modern Physics
Co- requisite(s):
Credits: 4 L: 3 T:1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: IX / III
Branch: PHYSICS
Name of Teacher:

Code: PH 501	**Title: Nuclear and Particle Physics**	**L-T-P-C [3-1-0-4]**

Module	**Course Objective:**
1	To impart the knowledge regarding the fundamental and basics of Nucleus and its models.
2	To provide the knowledge of the Two-nucleus problem, concept of nuclear force.
3	To acquire knowledge about the nucleus by the study of scattering of particles.
4	To have a good understanding of interaction of charged particles with matter.
5	To have an elementary idea of particles and their classification.

Course Name : Nuclear and Particle Physics	
Module	**Course Outcome:**
1	Student will have an idea developed about the nucleus.
2	Student will have a concept and nature of nuclear force.
3	Student will learn about the method and analysis of Scattering process.
4	Student will have an idea about the interaction of particles with matter.
5	Student will understand te nature, interaction etc.. of the elementary particles.

Module-1	Nuclear Models Liquid drop Model, semi-empirical mass formula, transitions between odd A isobars, transitions between even isobars, odd-even effects and magic numbers, Shell model, collective model.	
Module-2	Two nucleon problem, The deuteron, ground state of deuteron, nature of nuclear forces, excited state of deuteron, spin dependence of nuclear force, meson theory of nuclear force	
Module-3	Scattering, Cross section, differential cross section, scattering cross section, nucleon nucleon scattering, proton-proton and neutron-neutron scattering at low energies.	
Module-4	Interaction of radiation with matter, Interaction of charged particles with matter, stopping power of heavy charged particles, energy loss of electrons, absorption of gamma rays, photoelectric effect, Compton effect and pair production.	
Module-5	Classification of elementary particle, Eightfold way, Baryon octate and meson octate, Quark model, Baryon Decuplet, meson nonlet, Intermediate vector Boson, Strong electromagnetic and week interactions, standard model, lepton classification and quark classification.	

References

1. Nuclear Theory-Roy and Nigam
2. Introductory Nuclear Physics- Kenneth S-Krane
3. Nuclear Physics: D. Halliday
4. Elements of Nuclear Physics: Pandya and Yadav
5. Introduction to Elementary Particle: David Griffiths

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks					
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	L	L	L
B	M	H	L	L	L
C	M	L	H	L	L
D	L	L	L	H	L
E	L	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes											
	A	b	c	D	E	f	g	h	I	J	k	l
1	H	H	L	M	M	M						
2	H	H	L	M	M	H						
3	H	H	M	M	M	H						

4	H	H	M	M	M	H						
5	H	H	L	M	M	H						

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 CD2
CD2	Tutorials/Assignments		CO2	CD1 CD2
CD3	Seminars		CO3	CD1 CD2
CD4	Mini projects/Projects		CO4	CD1 CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology Used	Remarks by faculty if any
1	L1-L2			Nuclear Models Liquid drop Model, semi-empirical mass formula,	T1 R1				
	L3-L4			transitions between odd A isobars, transitions between even isobars,	T1 R1				
	L5-L8			odd-even effects and magic numbers, Shell model, collective model. L	T1 R1				
	L9-L11			Two nucleon problem, The deuteron, ground state of deuteron,	T1 T2				
	L12-L13			nature of nuclear forces, excited state of deuteron,	T1-T2				
	L14-L15			spin dependence of nuclear force,	T1 T2				
	L-16			meson theory of nuclear force	T1 T2				
	L17-L20			Scattering, Cross section,	T1 T2 R1				

				differential cross section, scattering cross section,					
	L20-L24			nucleon nucleon scattering, proton-proton and neutron-neutron scattering at low energies	T1 T2 R1				
	L25-L28			Interaction of radiation with matter, Interaction of charged particles with matter,	T1 R1				
	L29-L32			stopping power of heavy charged particles, energy loss of electrons, absorption of gamma rays, photoelectric effect, Compton effect and pair production	T1 R1				
	L33-L35			Classification of elementary particle,	T1 T3				
	L36-L38			Eightfold way, Baryon octate and meson octate, Quark model, Baryon Decuplet, meson nonlet, Intermediate vector Boson	T1 T3				
	L39-L40			Strong electromagnetic and week interactions, standard model, lepton classification and quark classification.	T1 T3				

COURSE INFORMATION SHEET

Course code: PH 502
Course title: Advanced Quantum Mechanics
Pre-requisite(s): Quantum Mechanics
Co- requisite(s):
Credits: **4**L: 3 T:1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level:IX / III
Branch: PHYSICS
Name of Teacher:

Code: PH 502	**Title: Advanced Quantum Mechanics**	**[L-T-P-C [3-1-0-4]**
Module	**Course Objective:**	
1	To learn how to apply Perturbation Theory (Time Independent) in non-degenerate and degenerate situations.	
2	To apply approximate method in Quantum Mechanics to treat molecules.	
3	To learn how to apply semi-classical method to treat the interaction of atoms with field.	
4	To learn how to treat Two –level systems Quantum Mechanically.	
5	To learn the basics of relativistic quantum Mechanics.	
Module	**Course Outcome:**	
1	Will be able to solve and analyse various quantum mechanical problem related to Time Independent Perturbation Theory.	
2	Will be able to treat molecules quantum mechanically .	
3	Will be able to apply semi-classical method to treat atom field interactions.	
4	Will be able to treat Two- Level System Quantum Mechanically.	
5	Will be able to understand the central concept and principles of relativistic Quantum Mechanics.	
Module-1	Perturbation theory, time-independent perturbation theory (non-degenerate and degenerate) and applications. Stark effect and other simple cases. Relativistic perturbation to hydrogen atom. Energy levels of hydrogen including fine structure, Lamb shift and hyperfine splitting . Zeeman effect (normal and anomalous) time, first and second order, the effect of the electric field on the energy levels of an atom (**Stark effect)**	15
Module-2	Quantum mechanics of molecules, Born-Oppenheimer approximation	5
Module-3	Time-dependent perturbations, first order transitions, Semi- classical theory of interaction of atoms with field. Quantization of radiation field. Hamiltonian of field and atom, Fermi golden rule, the Einstein's A & B coefficients.	10
Module-4	Atom field interaction, density matrix equation, closed and open two-level atoms, Rabi oscillations.	10
Module-5	Relativistic wave equations: Klein-Gordon equation for a free particle and particle under the influence of an electromagnetic potential, Dirac's relativistic Hamiltonian, Dirac's relativistic wave equation, positive and negative energy states, significance of negative energy states.	10

Book:

1. Quantum Mechanics by L. I. Schiff. (Tata McGraw Hill, New Delhi)

References:

1. Quantum Mechanics by L. D. Landau and E. M. Lifshitz (Pergamon, Berlin)
2. Quantum Mechanics by A. K. Ghatak and S. Lokanathan (McMillan India)
3. A Textbook of Quantum Mechanics by P. T. Mathews (Tata McGraw Hill)

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Sem Examination Marks	25
End SemExamination Marks	50
Quiz	10+10
Teacher's assessment	5

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	L	M	M	L
B	L	H	L	L	L
C	M	L	H	M	L
D	M	L	M	H	L
E	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes										
	a	B	c	d	e	f		h	i	j	k	l
1	H	H	**H**	M	H	H						
2	H	H	**H**	M	H	H						
3	H	H	**H**	M	H	H						
4	H	H	H	M	L	H						
5	H	H	H	M	M	H						

Mapping Between COs and Course Delivery (CD) methods				
CD	Course Delivery methods		Course Outcome	Course Delivery Method

CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 CD2
CD2	Tutorials/Assignments		CO2	CD1 CD2
CD3	Seminars		CO3	CD1 CD2
CD4	Mini projects/Projects		CO4	CD1 CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology Used	Remarks by faculty if any
1	L1-L6			Perturbation theory, time-independent perturbation theory (non-degenerate and degenerate) and applications.	T1-T2-R1				
	L7-L9			Stark effect and other simple cases. Relativistic perturbation to hydrogen atom.	T1-T2_R1				
	L10-L12			Energy levels of hydrogen including fine structure, Lamb shift and hyperfine splitting	T1 T2 R1				
	L13-L15			Zeeman effect (normal and anomalous) time, first and second order, the effect of the electric field on the energy levels of an atom (**Stark effect)**	T1 T2 R1				
	L16-L20			Quantum mechanics of molecules, Born-Oppenheimer approximation	T1 T3 R1				
	L21-L24			Time-dependent perturbations, first order transitions, Semi-classical theory of interaction of atoms with field.	T1 T3 R1				
	L25-L28			Quantization of radiation field. Hamiltonian of field and atom,	T1 T2 R1				
	L29-L30			Fermi golden rule, the Einstein's A & B coefficients.	T1 T2				
	L31-L34			Atom field interaction, density matrix equation,	T1 T2				
	L35-L38			closed and open two-level atoms, Rabi oscillations.	T1 T2 T3				
	L39-L44			Relativistic wave equations: Klein-Gordon equation for a free particle and particle under the influence of an electromagnetic potential,	T1 T2 T3				
	L44-			, Dirac's relativistic Hamiltonian,	T1 T2				

	L50			Dirac's relativistic wave equation, positive and negative energy states, significance of negative energy states.	T3				

<u>**COURSE INFORMATION SHEET**</u>

Course code: PH 503
Course title: Lasers Physics and Applications
Pre-requisite(s): Waves and Optics
Co- requisite(s):
Credits: 3 L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: IX / III
Branch: PHYSICS
Name of Teacher:

Code: PH 503	Title: Lasers Physics and Applications	L-T-P-C [3-1-0-4]

Course Objectives

This course enables the students:

A.	To identify conditions for lasing phenomenon and properties of the laser.
B.	To discuss stable, unstable resonators and cavity modes.
C.	To compare continuous and pulsed lasers.
D.	To classify different types of lasers with respect to design and working principles
E	To illustrate various applications of laser e.g. holographic non-destructive testing.

Course Outcomes

After the completion of this course, students will be:

1.	To evaluate conditions for lasing phenomenon and properties of the laser.
2.	To calculate cavity modes of a given cavity and identify the given resonator is stable or unstable one.
3.	To evaluate Q-switching and the mode-locked lasing phenomenon.
4.	To appraise different type of lasers with respect to design and working principles.
5.	To assess applications of a laser for measurement of distance, holography and medical surgeries etc.

Module-1	Interaction of radiations with atoms and ions: Spontaneous and Stimulated emissions, Stimulated absorption. Population inversion, gain oscillation, gain saturation, threshold, rate equation, 3 and 4 level systems, laser line shape, hole burning, Lamb dip, output power. Properties of laser: coherence, monochromaticity, divergence.	**[15]**
Module-2	Theory of resonator. Stable and unstable resonator, Optical cavities, Cavity modes, longitudinal and transverse modes of the cavity.	**[10]**
Module-3	Continuous wave, Pulsed, Q- switched and Modelocked lasers.	**[5]**
Module-4	Different type of lasers, design (in brief) and functioning of different lasers - Ruby laser, Nd: YAG laser, He-Ne laser, CO_2 laser, Argon ion laser, Dye laser, Excimer laser. Free electron laser	**[10]**
Module-5	Measurement with laser, alignment, targeting, tracking, velocity measurement, surface quality measurement. Measurement of distance (interferometric, pulse echo, Beam modulation). laser gyroscope, Holographic nondestructive testing (NDT). Application in communication. Material Processing: cutting, welding, drilling and surface treatment. Medical Applications, Laser trapping.	**[10]**

<u>**Book:**</u>

T1: O. Svelto; Principles of Lasers, Springer (2004)
T2: Laser Fundamentsls: William T. Silfvast, Cambridge University Press (1998)
R1 K. Shimoda, Introduction to laser Physics, Springer Verlag, Berlin (1984)
R2: Laser Electronics: J.T.Verdeyen, 3rdEd, Prentice Hall (1994)
R3 Laser Applications in Surface Science and Technology; H.G.Rubahn; John Wiley & Sons (1999)
1. R4 Optical Methods in Engineering Metrology: Ed D.C.Williams; Chapman &Hall

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	M	L	M
B	M	H	M	L	L
C	L	L	H	L	L
D	-	L	L	H	L
E	L	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	H	L	H
2	H	H	H	H	M	H
3	H	H	H	M	L	M
4	H		H	H	L	M
5	M	H	H	H	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L2		1	Interaction of radiations with atoms and ions	T1, T2,	1,2		PPT Digi Class/Chock -Board	
	L3-L7			Spontaneous and Stimulated emissions, Stimulated absorption. Population inversion, gain oscillation		1,		Digi Class/Chock -Board	
	L8-L10			gain saturation, threshold, rate equation, 3 and 4 level systems,		1,2		Digi Class/Chock -Board	
	L11-L14			laser line shape, hole burning, Lamb dip, output power.		1,2,3		Digi Class/Chock -Board	
	L15			Properties of laser: coherence, monochromaticity, divergence.		1,2		Digi Class/Chock -Board	
	L16-L18			Theory of resonator. Stable and unstable resonator,		1		Digi Class/Chock -Board	
	L19-L25			Optical cavities, Cavity modes, longitudinal and transverse modes of the cavity.		2		Digi Class/Chock -Board	
	L26-L30			Continuous wave, Pulsed, Q- switched and Modelocked lasers.		3		Digi Class/Chock -Board	
	L31-35			Different type of lasers, design (in brief) and functioning of different lasers -		4		Digi Class/Chock -Board	

		L36-L40		Ruby laser, Nd: YAG laser, He-Ne laser, CO_2 laser, Argon ion laser, Dye laser, Excimer laser. Free electron laser		4		Digi Class/Chock-Board	
		L41-L45		Measurement with laser, alignment, targeting, tracking, velocity measurement, surface quality measurement.		5		Digi Class/Chock-Board	
		L46-L50		Measurement of distance (interferometric, pulse echo, Beam modulation). laser gyroscope, Holographic nondestructive testing (NDT). Application in communication. Material Processing: cutting, welding, drilling and surface treatment. Medical Applications, Laser trapping.				Digi Class/Chock-Board	

COURSE INFORMATION SHEET

Course code: PH 513
Course title: Laser Physics Lab
Pre-requisite(s): Laser Physics and Applications
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: I
Branch: PHYSICS
Name of Teacher: Dr K. Bose

Laser Physics Lab

L-T-P-C
[0-0-4-2]

1. To determine the wavelength of sodium light using Michelson Interferometer
2. Demonstrate interference fringe pattern using Mach Zhender interferometer.
3. Study of mercury spectrum using grating and spectrometer.
4. Determine the coherence length of a diode laser using a Michelson Interferometer.
5. Perform Faraday Effect experiment and find verdet constant of flint glass.
6. To study the birefringence with respect to applied voltage in an electro optic crystal.
7. To determine the Kerr constant of the liquid (Nitro Benzene)
8. Study of hydrogen spectrum using grating and spectrometer.
9. To find the velocity of ultrasonic wave in a liquid using ultrasonic diffraction apparatus.

Course Assessment tools & Evaluation procedure

Assessment Tool	% Contribution
Progressive Evaluation	60 (Day to day performance: 30, Quiz: 10, Viva: 20)
End Sem Examination	40 (Experiment Performance: 30, Quiz: 10)

Semester IV

PE- VI & VII Two papers from the same Group A or B or C or D or E
Project from the same Group A or B or C or D or E

PE-V

Group A- **Theoretical and Computational Physics:**
1. Numerical Methods for Physicists 2. Theory of Solids

COURSE INFORMATION SHEET

Course code: PH 504
Course title: Numerical Methods for Physicists
Pre-requisite(s): Mathematical Physics
Co- requisite(s):
Credits: **4**L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher:

Group : A **Option 1**

Code: PH 504	**Title: Numerical Methods for Physicists** Theory &Programming using C for solving problems on following topics**:**	**L-T-P-C [4- 0-0- 4]**

Course Objectives

This course enables the students:

A.	To learn about optimization techniques
B.	To understand the concepts of functional approximations
C.	To know about algebraic eigenvalue problems
D.	To gain knowledge on integral equations
E.	To gain familiarity with the numerical solutions of partial differental equations

Course Outcomes

After the completion of this course, students will be:

1.	Able to perform optimization via coding
2.	Able to do construct programs on functional approximations
3.	Solving eigenvalue problems numerically
4.	Comfortable in dealing with integral equations
5.	Numerically able to solve partial differential equations

Module-1	**Optimization** Golden Section Search, Brent's Method, Methods Using Derivative, Minimization in Several Dimensions, Quasi-Newton Methods, Direction Set Methods, Linear Programming	**[10]**
Module-2	**Functional Approximations** Choice of Norm and Model, Linear Least Squares, Nonlinear Least Squares, Discrete Fourier Transform, Fast Fourier Transform (FFT), FFT in Two or More Dimensions, Functional Approximations	**[10]**
Module-3	**Algebraic Eigenvalue Problems** Introduction,Power Method, Inverse Iteration, Eigenvalue Problem for a Real Symmetric Matrix , QL Algorithm for a Symmetric Tridiagonal Matrix, Algebraic Eigenvalue Problem	**[10]**
Module-4	**Integral Equations** Introduction, Fredholm Equations of the Second Kind, Expansion Methods, Eigenvalue Problem, Fredholm Equations of the First Kind, Volterra Equations of the Second Kind, Volterra Equations of the First Kind	**[10]**

Module-5	**Partial Differential Equations** Wave Equation in Two Dimensions, General Hyperbolic Equations, Elliptic Equations , Successive Over-Relaxation Method, Alternating Direction Method, Fourier Transform Method, Finite Element Methods, Algorithms for Vector and Parallel Computers	**[10]**

References

1. "Numerical methods for Scientists and Engineers" by H. M. Antia, Springer Science and Business Media.
2. "Numerical Recipes in C" by William H. Press, Saul A. Teukolsky, William T. Vetterling & Brian P. Flannery, Cambridge University Press.
3. "Programming in C# A Primer" by E Balagurusamy, McGraw Hill Education.

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks					
End Sem Examination Marks					
Quiz I					
Quiz II					

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	L	-	-	-
B	M	H	L	-	M
C	M	L	H	-	M
D	M	L	L	H	M
E	M	L	L	L	H

Course Outcome #	**Program Outcomes**					
	a	**b**	**c**	**d**	**e**	**f**
1	**L**	**M**	**M**	**M**	**L**	**M**
2	**L**	**M**	**M**	**M**	**L**	**M**
3	**L**	**H**	**M**	**M**	**L**	**M**
4	**L**	**H**	**M**	**M**	**H**	**M**
5	**L**	**H**	**M**	**M**	**H**	**M**

Lecture wise Lesson planning Details.

Week No.	Lect No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodologyused	Remarks by faculty if any
1	L1-L3			Golden Section Search, Brent's Method, Methods Using Derivative	T1,T2,T3	1		Board, Computers	
2	L4-L6			inimization in Several Dimensions, Quasi-Newton Methods	T1,T2,T3	1		Board, Computers	
3	L7-L9			Direction Set Methods, Linear Programming	T1,T2,T3	1		Board, Computers	
4	L10-L12			Choice of Norm and Model, Linear Least Squares, Nonlinear Least Squares	T1,T2,T3	2		Board, Computers	
5	L13-L15			Discrete Fourier Transform, Fast Fourier Transform (FFT),	T1,T2,T3	2		Board, Computers	
6	L16-L18			FFT in Two or More Dimensions, Functional Approximations	T1,T2,T3	2		Board, Computers	
7	L19-L21			Introduction,Power Method, Inverse Iteration,	T1,T2,T3	3		Board, Computers	
8	L22-L24			Eigenvalue Problem for a Real Symmetric Matrix , QL Algorithm for a Symmetric Tridiagonal Matrix	T1,T2,T3	3		Board, Computers	
9	L25-L27			Algebraic Eigenvalue Problem	T1,T2,T3	3		Board, Computers	
10	L28-L30			Introduction, Fredholm Equations of the Second Kind, Expansion Methods	T1,T2,T3	4		Board, Computers	
11	L31-L33			Eigenvalue Problem, Fredholm Equations of the First Kind	T1,T2,T3	4		Board, Computers	
12	L34-L36			Volterra Equations of the Second Kind, Volterra Equations of the First Kind	T1,T2,T3	4		Board, Computers	
13[T1,T2,T3]	L37-L39			Wave Equation in Two Dimensions, General Hyperbolic Equations, Elliptic Equations	T1,T2,T3	5		Board, Computers	
14	L40-L42			Successive Over-Relaxation Method, Alternating Direction Method, Fourier Transform Method	T1,T2,T3	5		Board, Computers	
15	L43-L45			Finite Element Methods, Algorithms for Vector and	T1,T2,T3	5		Board, Computers	

				Parallel Computers					

<u>**COURSE INFORMATION SHEET**</u>

Course code: PH 505
Course title: Theory of Solids
Pre-requisite(s): Condensed Matter Physics
Co- requisite(s):
Credits: **4**L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher:

Group A **Option 3**

Code: PH 505	Title: Theory of Solids	L-T-P-C [4-0-0-4]

Course Objectives : This course enables the students

A.	To become familiar with classification of solids using band theory.
B.	To be familiarized with the change in density of states as a function of physical dimension of solids.
C.	To become familiar with the electrical behaviour of dielectric materials and understand the field charge induced by dielectrics.
D.	To become familiar with the theory behind the magnetic properties of materials.
E.	To understand the different optical processes and photophysical properties of solids.

Course Outcomes : After the completion of this course, students will be

1.	Able to classify materials as metals, insulators and semiconductors and sketch the band diagram for each.
2.	Able to classify material as 0D, 1D, 2D and 3D on the basis of density of states and correlate the physical properties with physical dimensions.
3.	Able to describe the different dielectric properties and be familiar with the experimental methods for investigation of dielectrics.
4.	Able to apply the theories to estimate the magnetic properties of materials.
5.	Able to correlate the results of different optical experiments with the theory.

Module-1	**Band Theory** Review of Concepts: (Bloch theorem and Bloch function, Kronig Penney model), Construction of Brillouin zones (1 and 2 dimensions), Extended, reduced and periodic zone scheme, Effective mass of an electron, Nearly free electron model, Tight binding approximation, Orthogonalized plane wave method, Pseudo-potential method, Classification of conductor, semiconductor and insulators.	**[8]**
Module-2	**Electron Statistics** Fermi-Dirac distribution, Fermi energy, Density of States, Classification of solids (0D, 1D, 2D, 3D) on the basis of density of states and k-space, effect of temperature on Fermi distribution function.	**[6]**
Module-3	**Dielectrics** Matter in a.c. field, Propagation of e.m. wave in matter on the basis of Maxwell's equation, Relaxations and resonances, Kramer's-Kronig relation, Mechanical analogue of relaxation, Debye relation, Argand diagram, Influence of local field and d.c. conductivity and multiple relaxation times, Special diagram (cole-cole arc), Heterogeneous dielectrics (Maxwell-Wagner effect), Dipole relaxation of defects in crystal lattices, Space charge polarization and relaxation, Resonances: Linear oscillator model and one dimensional polar lattices, Ferroelectricity, Microscopic theory of Ferroelectricity, Phase transition of ferroelectrics (1^{st}, 2^{nd} and relaxor kind), Hysteresis loop, Recoverable energy, Piezoelectricity and transducers.	**[10]**
Module-4	**Magnetism** Magnetic interactions, Exchange interaction, Direct exchange, Indirect exchange, Double exchange, Helical order, Frustration, Spin glasses, Landau theory of ferromagnetism, Heisenberg and Ising models, Excitations, Magnons, Bloch $T^{3/2}$ law, Measurement of spin waves, Magnetism of the electron gas, Spin density waves, Kondo effect.	**[8]**

Module-5	**Optical properties** Classification of optical process, optical coefficient, complex refractive index, propagation of light in a dense optical medium, atomic oscillator, vibrational oscillator, free electron oscillator, dipole oscillator model, inter band absorptions, excitons, concept of excitons, free excitons, free excitons in external field, luminescence, light emission from solids, interband luminescence, photoluminescence, electroluminescence, luminescence centres, phonons, optical properties of metals.	**[8]**

Text book

1. Introduction to Solid State Physics 8thEdition , Charles Kittel, John Wiley and Sons, 2005.
2. Solid State Physics, Neil W. Ashcroft, N. David Mermin, Saunders College Publishing, 1976

References:

1. Optical properties of Solids: Anthony Mark Fox, Oxford Master Series in Physics, Oxford University Press (2001).
2. Magnetism in Condensed Matter, Oxford Master Series in Condensed Matter Physics 4, Stephen Blundell, Oxford University Press (2001).

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	Yes
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	Yes	Yes	Yes	No	No
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment	Yes	Yes	Yes	Yes	Yes

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes

	a	b	c	d	e	f
1	H	M	M	L	M	L
2	H	M	M	L	L	L
3	M	H	H	L	M	M
4	H	H	H	L	M	M
5	M	H	H	L	M	M

Course Outcome #	**Course Objectives**				
	a	b	c	d	e
1	H	M	L	L	M
2	M	H	L	L	L
3	L	L	H	L	M
4	L	L	L	H	L
5	M	L	M	M	H

Mapping Between COs and Course Delivery (CD) methods

CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD8
CD2	Tutorials/Assignments		CO2	CD1, CD2 and CD8
CD3	Seminars		CO3	CD1, CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	**Lect. No.**	**Tentative Date**	**Module No.**	**Topics to be covered**	**Text Book / References**	**COs mapped**	**Actual Content covered**	**Methodology used**	**Remarks by faculty if any**
1	L1-L2		I	Review of Concepts: (Bloch theorem and Bloch function,	T1, T2	1, 2		PPT Digi Class/Chalk -Board	
1	L3			Kronig Penney model)Construction of Brillouin zones (1 and 2 dimensions)	T1, T2			PPT Digi Class/Chalk -Board	
1	L4-L5			Extended, reduced and periodic zone scheme Effective mass of an electron,	T1, T2			PPT Digi Class/Chalk -Board	
2	L6			Nearly free electron model	T1, T2			PPT Digi Class/Chalk -Board	

2	L7			Tight binding approximation	T1, T2			PPT Digi Class/Chalk -Board	
2	L8-L9			Orthogonalized plane wave method,Pseudo-potential method	T1, T2			PPT Digi Class/Chalk -Board	
3	L10			Classification of conductor, semiconductor and insulators	T1, T2			PPT Digi Class/Chalk -Board	
4	L11		II	Fermi-Dirac distribution	T1, T2			PPT Digi Class/Chalk -Board	
4	L12-13			Fermi energy	T1, T2			PPT Digi Class/Chalk -Board	
5	L14-16			Density of States, Classification of solids (0D, 1D, 2D, 3D) on the basis of density of states	T1, T2			PPT Digi Class/Chalk -Board	
5	L17			k-space	T1, T2			PPT Digi Class/Chalk -Board	
6-7	L18-20			Effect of temperature on Fermi distribution function.	T1, T2			PPT Digi Class/Chalk -Board	
	L21		III	Matter in a.c. field, Propagation of e.m. wave in matter on the basis of Maxwell's equation	T1, T2			PPT Digi Class/Chalk -Board	
	L22			Relaxations and resonances	T1, T2			PPT Digi Class/Chalk -Board	
	L23			Kramer's-Kronig relation, Mechanical analogue of relaxation	T1, T2			PPT Digi Class/Chalk -Board	
	L24			Debye relation, Argand diagram	T1, T2			PPT Digi Class/Chalk -Board	
	L25			Influence of local field and d.c. conductivity and multiple relaxation times	T1, T2			PPT Digi Class/Chalk -Board	
	L26			Special diagram (cole-cole arc), Heterogeneous dielectrics (Maxwell-Wagner effect)	T1, T2			PPT Digi Class/Chalk -Board	
	L27			Ferroelectricity, Microscopic theory of Ferroelectricity	T1, T2			PPT Digi Class/Chalk -Board	
	L28			Phase transition of ferroelectrics (1^{st}, 2^{nd} and relaxor kind),	T1, T2			PPT Digi Class/Chalk -Board	

	L29			Hysteresis loop, Recoverable energy,	T1, T2			PPT Digi Class/Chalk -Board	
	L30			Piezoelectricity and transducers.	T1, T2			PPT Digi Class/Chalk -Board	
	L31		IV	Magnetic interactions, Exchange interaction	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L32			Direct exchange, Indirect exchange	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L33-34			Double exchange, Helical order, Frustration, Spin glasses	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L35			Landau theory of ferromagnetism,	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L36-37			Heisenberg and Ising models, Excitations,	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L38			Magnons, Bloch $T^{3/2}$ law,	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L39			Measurement of spin waves	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L40			Spin density waves, Kondo effect.	T1, T2, R2			PPT Digi Class/Chalk -Board	
	L41		V	Classification of optical process, optical coefficient	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L42			complex refractive index, propagation of light in a dense optical medium	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L43			atomic oscillator, vibrational oscillator	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L44-45			free electron oscillator, dipole oscillator model	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L46			inter band absorptions,excitons, concept of excitons, free excitons, free excitons in external field	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L47			luminescence, light emission from solids	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L48			interband luminescence, photoluminescence	T1, T2, R1			PPT Digi Class/Chalk -Board	

	L49			electroluminescence,luminescence centres	T1, T2, R1			PPT Digi Class/Chalk -Board	
	L50			phonons, optical properties of metals.	T1, T2, R1			PPT Digi Class/Chalk -Board	

Group B- <u>Condensed Matter Physics:</u>

1. Theory of Solids
2. Functional Materials

COURSE INFORMATION SHEET

Course code: PH 505
Course title: Theory of Solids
Pre-requisite(s): Condensed Matter Physics
Co- requisite(s):
Credits: 4 L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher:

Group B **Option 1**

Same given As above(in Group A)

COURSE INFORMATION SHEET

Course code: PH 506
Course title: Functional Materials
Pre-requisite(s): Condensed Matter Physics
Co- requisite(s):
Credits: 4L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher:

Option 2

Group : B

Code: PH 506	**Title: Functional Materials**	**L-T-P-C [4-0-0-4]**
Module-1	Introduction to Metals, Alloys, Ceramics, Polymers and Composites, Phase rules Fe-C phase diagram, Steels, cold, hot working of metals, recovery, recrystallization and grain growth, Structure, properties.	**[8]**
Module-2	Processing and applications of ceramics. Classification of polymers, polymerization, structure, properties, additives, products, processing and applications. Quasicrystals, Conducting Polymers; Properties and applications composites.	**[12]**
Module-3	Advanced Materials: Smart materials, ferroelectric, piezoelectric, biomaterials (some basic information),superalloys, aerospace materials, shape memory alloys, optoelectronic materials, Materials for photodiode, light emitting diode (LED), Photovoltaic/Solar cell and meta materials	**[10]**
Module-4	Nanostructured Materials: Nanomaterials classification (Gleiter's Classification)–property changes done to size effects, Quantum dot, wire and well, synthesis of nanomaterials, ball milling.	**[8]**
Module-5	Liquid state processing -Sol-gel process, Vapour state processing –CVD, MBE, Aerosol processing, fullerene and tubules, formation and characterization of fullerenes and tubules, single wall and multiwall carbon tubules, electronic properties of tubules, applications: optical lithography, MOCVD, super hard coating.	**[12]**

Text books:

1. T1: Structure and properties of engineering materials, fifth edition, Henkel and Pense, McGraw Hill, 2002
2. T2: Biomaterials Science, An Introduction to Materials in Medicine , Edited by B.D. Ratner, A.S. Hoffman, F.J. Sckoen, and J.E.L Emons, Academic Press, second edition, 2004

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	Yes
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Assessment Components	CO1	CO2	CO3	CO4	CO5
Quizes	Yes	Yes	Yes	Yes	Yes
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment					

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	L	M	L
2	M	H	H	L	L	L
3	H	M	M	M	M	M
4	M	H	M	M	H	M
5	H	H	H	L	H	L

Course Outcome #	Course Objectives				
	A	B	C	D	E
1	H	M	M	M	M
2	L	H	L	L	M
3	L	M	H	M	M
4	H	L	H	H	L
5	H	M	M	L	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD8
CD2	Tutorials/Assignments		CO2	CD1, CD2 and CD8
CD3	Seminars		CO3	CD1, CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Module. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any

1	L1		I	Introduction to Metals, Alloys	T1			PPT Digi Class/Chalk-Board	
1	L2			Ceramics	T1, T2			PPT Digi Class/Chalk-Board	
1	L3-L4			Polymers and Composites, Phase rules	T1, T2			PPT Digi Class/Chalk-Board	
2	L5			Fe-C phase diagram	T1			PPT Digi Class/Chalk-Board	
2	L6-L8			Steels, cold, hot working of metals, recovery, recrystallization and grain growth, Structure, properties.	T1			PPT Digi Class/Chalk-Board	
2	L9-L10		II	Processing and applications of ceramics.	T1			PPT Digi Class/Chalk-Board	
3	L11-L13			Classification of polymers, polymerization, structure, properties	T1			PPT Digi Class/Chalk-Board	
3	L14-L16			additives, products, processing and applications.	T1			PPT Digi Class/Chalk-Board	
3	L17-L18			Quasicrystals	T1			PPT Digi Class/Chalk-Board	
4	L19-L20			Conducting Polymers; Properties and applications composites.	T1			PPT Digi Class/Chalk-Board	
4	L21-22		III	Advanced Materials: Smart materials,	T1			PPT Digi Class/Chalk-Board	
5	L23-24			Ferroelectric, piezoelectric,	T1			PPT Digi Class/Chalk-Board	
5	L25-L26			Biomaterials (some basic information), superalloys,	T2			PPT Digi Class/Chalk-Board	
6	L27-L28			Aerospace materials, shape memory alloys,	T1			PPT Digi Class/Chalk-Board	
6-7	L29-L30			Optoelectronic materials, Materials for photodiode, light emitting diode (LED), Photovoltaic/Solar cell and meta materials	T1			PPT Digi Class/Chalk-Board	
	L31-L32		IV	Nanostructured Materials: Nanomaterials classification (Gleiter's Classification)	T1			PPT Digi Class/Chalk-Board	
	L33-L35			Property changes done to size effects,	T1			PPT Digi Class/Chalk-Board	
	L36-			Quantum dot, wire and well,	T1			PPT Digi	

	L38							Class/Chalk-Board	
	L39-L40		V	synthesis of nanomaterials, ball milling.	T2			PPT Digi Class/Chalk-Board	
	L41-L43			Liquid state processing -Sol-gel process, electronic properties of tubules, applications	T1, T2			PPT Digi Class/Chalk-Board	
	L44-L46			Vapour state processing –CVD, MBE	T1			PPT Digi Class/Chalk-Board	
	L47-L48			Aerosol processing, fullerene and tubules,	T1			PPT Digi Class/Chalk-Board	
	L49-L50			Formation and characterization of fullerenes and tubules, single wall and multiwall carbon tubules	T1			PPT Digi Class/Chalk-Board	

Group C – Photonics:

1. Fiber and Integrated Optics
2. Quantum & Nonlinear Optics

COURSE INFORMATION SHEET

Course code: PH 507
Course title: Fiber and Integrated Optics
Pre-requisite(s): Waves and Optics
Co- requisite(s):
Credits: **4**L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher:

Group C **Option : 1**

Code: PH 507	Title: Fiber and Integrated Optics	L-T-P-C [4-0-0-4]

Course Objectives : This course enables the students:

A.	To understand the light propagation phenomenon through fiber optic cable
B.	To understand various loss mechanism of signal while travelling through an optical fiber.
C.	To understand the basic working principle of waveguides and its design parameters.
D.	To identify waveguides for applications in fiber optics communication systems
E	To understand the principle of working of fiber based sensors for various application purposes.

Course Outcomes : After the completion of this course, students will be:

1.	Able to illustrate the principle of fiber optics communications.
2.	Able to distinguish between various loss mechanism in fiber optics communication system.
3.	Able to utilize the idea of waveguide for different application purpose.
4.	Able to categorise different waveguides for the utilization in optics communication system
5.	Able to interpret different fiber sensors and their respective application and can recommend this technique for other new application.

Module-1	Principle of light propagation in fibers, step-index and graded index fibers; single mode, multimode and W-profile fibers. Ray optics representation, meridional and skew rays. Numerical aperture and acceptance angle.	**5**
Module-2	Dispersion, combined effects of material and other dispersions - RMS pulse widths and frequency response, birefringence. Attenuation in optical fibers. Material dispersion and waveguide dispersion in single-mode fibers, Inter and intramodal dispersion in graded-index fibers. .	**10**
Module-3	Theory of optical waveguides, planar, rectangular, symmetric and asymmetric waveguides, channel and strip loaded waveguides. Anisotropic and segmented waveguides. Step-index and graded index waveguides, guided and radiation modes. Arrayed waveguide devices. Fabrication of integrated optical waveguides and devices.	**12**
Module-4	Wave guide couplers, transverse couplers, grating couplers, tapered couplers, prism couplers, fiber to waveguide couplers. Multilayer planar waveguide couplers, dual channel directional couplers, Butt coupled ridge waveguides, Branching waveguide couplers. Directional couplers, optical switch; phase and amplitude modulators, filters, etc. Y-junction, power splitters.. .	**13**
Module-5	Fiber optics sensors, intensity modulation, phase modulation sensors, fiber Bragg grating sensors. Measurement of current, pressure, strain, temperature, refractive index, liquid level etc. Time domain and frequency domain dispersion measurement, fibre lasers and fibre gyroscope.	**12**

Text books:
T1: Introduction to Fiber Optics: A.K. Ghatak and K. Thayagarajan, Cambridge University press
T2: Integrated Optics: Theory and Technology; R. G. Hunsperger; Springer
T3: Optical Fiber Sensors, John Dakin and Brain Culshaw, Arctech House Inc
Reference books: R1:

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	M	M	L
B	M	H	M	M	--
C	M	M	H	M	L
D	L	M	H	H	M
E	M	M	H	H	H

Mapping of Course Outcomes onto Program Outcomes

Course	Program Outcomes

Outcome #	a	b	c	d	e	f
1	M	H	H		L	H
2	M	H	M		M	H
3	M	H	H	L	L	M
4	M	M	H	L	M	M
5	M	M	M	L	H	H

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book/ References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
	L1-L2			Principle of light propagation in fibers, step-index and graded index fibers; single mode, multimode and W-profile fibers	T1, T2	CO1		PPT Digi Class/Chock-oard	
	L3-L5			Ray optics representation, meridional and skew rays. Numerical aperture and acceptance angle.	T1, T2	CO1		PPT Digi Class/Chock-Board	
	L6-L7			Dispersion, combined effects of material and other dispersions	T1, T2	CO2		PPT Digi Class/Chock-Board	
	L8-L11			RMS pulse widths and frequency response, birefringence. Attenuation in optical fibers.	T1, T2	CO2		PPT Digi Class/Chock-oard	
	L12-L15			Material dispersion and waveguide dispersion in single-mode fibers, Inter and intramodal dispersion in graded-index fibers	T1, T2	CO2		PPT Digi Class/Chock-Board	
	L16-			Theory of optical	T1, T2	CO3		PPT Digi	

	L19			waveguides, planar, rectangular, symmetric and asymmetric waveguides, channel and strip loaded waveguides				Class/Chock-Board	
	L20-L23			Anisotropic and segmented waveguides. Step-index and graded index waveguides, guided and radiation modes	T1, T2	CO3		PPT Digi Class/Chock-Board	
	L24-L27			Arrayed waveguide devices. Fabrication of integrated optical waveguides and devices.	T1, T2	CO3		PPT Digi Class/Chock-Board	
	L28-L31			Wave guide couplers, transverse couplers, grating couplers, tapered couplers, prism couplers, fiber to waveguide couplers	T1, T2	CO4		PPT Digi Class/Chock-Board	
	L32-L35			Multilayer planar waveguide couplers, dual channel directional couplers , Butt coupled ridge waveguides , Branching waveguide couplers	T1, T2	CO4		PPT Digi Class/Chock-Board	
	L36-L39			Directional couplers optical switch; phase and amplitude modulators	T1, T2	CO4		PPT Digi Class/Chock-Board	
	L40			filters, Y-junction, power splitters	T1, T2	CO4		PPT Digi Class/Chock-Board	
	L41-L44			Fiber optics sensors, intensity modulation, phase modulation sensors, fiber Bragg grating sensors	T3	CO5		PPT Digi Class/Chock-Board	
	L45-L48			Measurement of current, pressure, strain, temperature, refractive index, liquid level etc.	T3	CO5		PPT Digi Class/Chock-Board	
	L49-L52			Time domain and frequency domain dispersion measurement, fibre lasers and fibre gyroscope.	T3	CO5		PPT Digi Class/Chock-Board	

COURSE INFORMATION SHEET

Course code: PH 508
Course title: Quantum and Nonlinear Optics
Pre-requisite(s): Waves and Optics
Co- requisite(s):
Credits: **4**L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher
Group C **Option 2**

Course Delivery methods	

Code: PH 508	**Titles: Quantum and Nonlinear Optics**	**L-T-P-C [4-0-0-4]**

This course enables the students:

A.	To identify the phenomenon of the nonlinear optical interaction of light with matter
B.	To examine higher harmonic generations, two-photon absorption and stimulated scattering phenomenon
C.	To formulate nonlinear optics in two-level approximations
D.	To analyse intensity dependent phenomenon
E	To identify nonlinear optical phenomenon for applications in optical devices

Course Outcomes After the completion of this course, students will be:

1.	Able to judge non-linear optical phenomenon
2.	Apply knowledge of nonlinear optical phenomena in higher harmonic generations, two-photon absorption and stimulated scattering phenomenon
3.	To solve nonlinear optical interaction problem in two-level system
4.	To evaluate intensity dependent material properties like refractive indices and self-focussing
5.	To design non-linear optical devices

Module-1	Nonlinear Optical Phenomena: Introduction to nonlinear optics, description of nonlinear optical interaction, phenomenological theory of nonlinearity, nonlinear optical susceptibilities. Sum and difference frequency generation, second harmonic generation, coupled wave equation	**10**
Module-2	Manley-Rowe relations, phase matching of SHG, quasi phase matching, electric field induced SHG (EIFISH), optical parametric amplification, third harmonic generation, two-photon absorption. Stimulated Raman scattering and stimulated Brillouin scattering.	**10**
Module-3	Two level atoms: nonlinear optics in two level approximations, density matrix equation, closed and open two-level atoms, steady state response in monochromatic field, Rabi oscillations, dressedatomic state, optical wave mixing in two level systems, photon echo, self-induced transparency, optical nutation, free induction decay.	**10**
Module-4	tensity dependent phenomena: intensity dependent refractive index, self-focusing, self-phase modulation, spectral broadening, optical continuum generation by short optical pulse. Optical phase conjugation, application of OPC in signal processing. Self-induced transparency, spatial and temporal solitons, solitons in Kerr media, photorefractive and quadratic solitons, Soliton pulses, optical vortices. Pulse compression. .	**12**
Module-5	Nonlinear guided wave optical devices: nonlinear planar waveguide, nonlinear channel waveguide, nonlinear directional coupler, nonlinear mode sorter, nonlinear Mach-Zehnder interferometer and logic gate, Nonlinear loop mirror	**8**

Book:

T1. Fundamentals of Nonlinear Optics; P.E.Powers, CRC Press Francis and Taylor (2011)
T2. Principles of Nonlinear Optics; Y.R.Shen
T3. Nonlinear Optics: Robert Boyd, Academic press
R1. Physics of Nonlinar Optics: Guang- Sheng –He and So ng-Hao Lin; World scientific.
R2. Two Level Resonances in Atoms; Allen and J.H. Emberly, John Wiley.

Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	M	L	M
B	M	H	M	L	L
C	L	L	H	L	L
D	-	L	L	H	L
E	L	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	H	L	H
2	H	H	H	H	M	H
3	H	H	H	M	L	M
4	H	M	H	H	L	M
5	M	H	H	H	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No	Topics to be covered	Text Book / Refere Nces	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L10		1	Nonlinear Optical Phenomena: Introduction to nonlinear optics, description of nonlinear optical interaction, phenomenological theory of nonlinearity, nonlinear optical susceptibilities. Sum and difference frequency generation, second harmonic generation, coupled wave equation	T1, T2,	1,2		PPT Digi Class/Chock -Board	
	L11-L20			Manley-Rowe relations, phase matching of SHG, quasi phase matching, electric field induced		2		Digi Class/Chock -Board	

				SHG (EIFISH), optical parametric amplification, third harmonic generation, two-photon absorption. Stimulated Raman scattering and stimulated Brillouin scattering.					
	L21-L30			Two level atoms: nonlinear optics in two level approximations, density matrix equation, closed and open two-level atoms, steady state response in monochromatic field, Rabi oscillations, dressed atomic state, optical wave mixing in two level systems, photon echo, self-induced transparency, optical nutation, free induction decay..		3		Digi Class/Chock -Board	
	L31-L42			Intensity dependent phenomena: intensity dependent refractive index, self-focusing, self-phase modulation, spectral broadening, optical continuum generation by short optical pulse. Optical phase conjugation, application of OPC in signal processing. Self-induced transparency, spatial and temporal solitons, solitons in Kerr media, photorefractive and quadratic solitons, Soliton pulses, optical vortices. Pulse compression		4		Digi Class/Chock -Board	
	L43-L50			Nonlinear guided wave optical devices: nonlinear planar waveguide, nonlinear channel waveguide, nonlinear directional coupler, nonlinear mode sorter, nonlinear Mach-Zehnder interferometer and logic gate, Nonlinear loop mirror		5		Digi Class/Chock -Board	

Group D – <u>Electronics:</u> 1. **Instrumentation and Control** 2. **Physics of Low dimensional Semiconductors**

<u>COURSE INFORMATION SHEET</u>

Course code: PH 509
Course title: Instrumentation and Control
Pre-requisite(s):
Co- requisite(s):
Credits: **4** L: 4 T:0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher: Dr. Dilip Kumar Singh

Group : D **<u>Option 1</u>**

Code: **PH 509**	**Title: Instrumentation and Control**	**L-T-P-C** **4-0-0-4**

Course Objectives
This course enables the students:

A.	Course on *Instrumentation and control* intends to impart knowledge of measurement, data acquisition and control for experiments.
B.	The first module of the course addresses basics of measurements like range, resolution, reproducibility, accuracy and precision.
C.	Module-2 of the course introduces various types of sensors and their working to record changes in the different physical parameters.
D.	The techniques of signal conditioning and noise reductions for acquired data are subject of Module-3.
E.	Last two units covers working and theory of different types of correction and regulating elements used in control systems.

Course Outcomes
After the completion of this course, students will be:

1.	Learners would develop understanding of various experimental parameters of measurements like range, resolution, reproducibility and precision.
2.	Through this course, students would develop an insight into fundamentals of sensors / transducers, data acquisition and processing, noise minimization and control systems for automation.
3.	This course is expected to enable students to design and understand hardwares used for developing equipment for data acquisition, data conditioning and control.
4.	Course would enable students to grasp understanding of instrumentation for automation of various physical process monitoring and control.

Module-1	**Measurement basics:** Range, resolution, linearity, hysteresis, reproducibility and drift, calibration, accuracy and precision.	5
Module-2	**Sensors** Sensor Systems, characteristics, Instrument Selection, Measurement Issues and Criteria, Acceleration, Shock and Vibration Sensors,	10

	Interfacing and Designs, Capacitive and Inductive Displacement Sensors, Magnetic Field Sensors, Flow and Level Sensors, Load Sensors, Strain gauges, Humidity Sensors, Accelerometers, Photosensors, Thermal Infrared Detectors, Contact and Non-contact Position sensors, Motion Sensors, Piezoresistive and Piezoelectric Pressure Sensors, Sensors for Mechanical Shock, Temperature Sensors (contact and non-contact)	
Module-3	**Signal conditioning** Types of signal conditioning, Amplification, Isolation, Filtering, Linearization, Classes of signal conditioning, Sensor Signal Conditioning, Conditioning Bridge Circuits, D/A and A/D converters for signal conditioning, Signal Conditioning for high impedance sensors Grounded and floating signal sources, single-ended and differential measurement, measuring grounded signal sources, ground loops, signal circuit isolation, measuring ungrounded signal sources, system isolation techniques, errors, noise and interference in measurements, types of noise, noise minimization techniques	15
Module-4	**Actuators** Correction and regulating elements used in control systems, pneumatic, hydraulic and electric correction elements.	4
Module-5	**Control System** Open loop and closed loop (feedback) systems and stability analysis of these systems, Signal flow graphs and their use in determining transfer functions of systems; transient and steady state analysis of linear time invariant (LTI) control systems and frequency response. Tools and techniques for LTI control system analysis: root loci, Routh-Hurwitz criterion, Bode and Nyquist plots. Control system compensators: elements of lead and lag compensation, elements of Proportional-Integral-Derivative (PID) control. State variable representation and solution of state equation of LTI control systems.	16
Text books: T1. Electronic Instrumentation -H. S. Kalsi, Tata McGraw-Hill Education, 2010 T2. Electronic Instrumentation -W. Bolton T3. Instrumentation: Electrical and Electronic Measurements and Instrumentation -A. K. Sawhney, T4. Modern Electronic Instrumentation & Measurement Techniques -Helfrick & Cooper		

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	Y
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment

Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I	√	√	√		
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4
A	H	H	H	H
B	H	H	L	L
C	H	H	H	L
D	H	L	H	L
E	H	H	H	L
F	H	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	L	H	H
2	H	H	H	L	H	H
3	H	H	H	L	H	H
4	H	H	H	L	H	M

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		CO6	CD1 and CD2
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch No	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1			**Measurement basics:** Range, resolution, linearity,	T1, T4				
	L2				T1, T4				
	L3			hysteresis, reproducibility	T1, T4				
	L4			drift, calibration,	T1, T4				
	L5			accuracy and precision.	T1, T4				
	L6			**Sensors** Sensor Systems, characteristics,	T1, T4				
	L7			Instrument Selection, Measurement Issues and Criteria,	T1, T4				
	L8			Acceleration, Shock and Vibration Sensors, Interfacing and Designs,	T1, T4				
	L9			Capacitive and Inductive Displacement Sensors, Magnetic Field Sensors,	T1, T4				
	L10			Flow and Level Sensors, Load Sensors, Strain gauges, Humidity Sensors, Accelerometers,	T1, T4				
	L11			Photosensors, Thermal Infrared Detectors,	T1, T4				
	L12			Contact and Non-contact Position sensors, Motion Sensors,	T1, T4				
	L13			Piezoresistive and Piezoelectric	T1, T4				
	L14			Pressure Sensors, Sensors for Mechanical Shock,	T1, T4				
	L15			Temperature Sensors (contact and non-contact)	T1, T4				
	L16			**Signal conditioning** Types of signal conditioning, Amplification, Isolation,	T1, T4				
	L17				T1, T4				
	L18				T1, T4				
	L19				T1, T4				
	L20			Filtering, Linearization,	T1, T4				
	L21			Classes of signal conditioning, Sensor Signal Conditioning,	T1, T4				
	L22			Conditioning Bridge Circuits,	T1, T4				
	L23			D/A converters	T1, T4				
	L24			and A/D converters for signal conditioning,	T1, T4				
	L25			Signal Conditioning for high impedance sensors Grounded and floating signal sources,	T1, T4				
	L26			single-ended and differential	T1, T4				

				measurement,					
	L27			measuring grounded signal sources, ground loops, signal circuit isolation,	T1, T4				
	L28			measuring ungrounded signal sources,	T1, T4				
	L29			system isolation techniques, errors, noise and interference in measurements,	T1, T4				
	L30			types of noise, noise minimization techniques	T1, T4				
	L31			**Actuators** Correction and regulating	T1, T4				
	L32			elements used in control systems,	T1, T4				
	L33			pneumatic, hydraulic and electric correction elements.	T1, T4				
	L34				T1, T4				
	L35			**Control System** Open loop and closed loop (feedback) systems	T1, T4				
	L36			stability analysis of these systems,	T1, T4				
	L37			Signal flow graphs and their use in determining transfer functions of systems;	T1, T4				
	L38			transient and steady state analysis of linear time invariant (LTI) control systems and frequency response.	T1, T4				
	L39				T1, T4				
	L40			Tools and techniques for LTI control system analysis: root loci, Routh-Hurwitz criterion	T1, T4				
	L41				T1, T4				
	L42				T1, T4				
	L43			Bode and Nyquist plots.	T1, T4				
	L44				T1, T4				
	L45			Control system compensators: elements of lead and lag compensation,	T1, T4				
	L46				T1, T4				
	L47				T1, T4				
	L48			elements of Proportional-Integral-Derivative (PID) control.	T1, T4				
	L49				T1, T4				
	L50			State variable representation and solution of state equation of LTI control systems.	T1, T4				

COURSE INFORMATION SHEET

Course code: PH 510
Course title: Physics of Low dimensional Semiconductors Devices
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher:
Group : D

Option 2

Code: PH 510	**Title: Physics of Low dimensional Semiconductors Devices**	L-T-P-C 4-0-0-4

Course Objectives

This course enables the students:

	Course on "Physics of Low dimensional Semiconductors" contains information about functionality and working of devices with miniaturized size.
	The first module includes introduction to various types of semiconductor nanostructures and effect of dimension on their properties.
	The properties, growth and band-engineering of heterostrcutres is planned to be covered in Unit-2.
	Unit-3 contains Quantum wells and Low-dimensional systems, while Unit-4 addresses physics of Tunneling transport and Low-dimensional systems.
	The electronic and optical properties of Two-dimensional electron gas (2DEG) and their applications is subject of Unit-5.

Course Outcomes

After the completion of this course, students will be:

1.	Learners would gain knowledge about working and application of various Low-dimensional Semiconductors.
2.	An understanding about Heterostructures, Quantum wells: Low-dimensional systems, Tunneling transport, Quantum-Hall effect and their electronic and optical applications would update learners with recent electronic and optical technologies in use.
3.	Knowledge about Physics and applications of Two-dimensional electron gas (2-DEG) would enable them to grasp the pace of advancing field of 2D-Semiconductors and their applications for ultrathin devices.

Module-1	**Introduction to Semiconductor Nanostructures** Introduction, Semiconductor quantum dot and quantum wire, Density of states for 0-D, 1D and 2D nanostructures. Two-dimensional semiconductors.	**6**
Module-2	**Hetrostructures** General properties and growth of hetrostructures, Band engineering, Layered structures, Quantum wells and barriers, Doped hetrostructures, Wires and dots, Optical confinement, Effective mass approximation and Effective mass theory in hetrostructures.	**8**

Module-3	**Quantum wells and Low-Dimensional Systems** Infinite deep square well, square well of finite depth, parabolic well, triangular well, Low-dimensional systems, Occupation of subbands, Quantum wells in hetrostructures.	**12**
Module-4	**Tunneling transport and Quantum Hall effect** Potential step, T-Matrices, Resonant tunneling, Superlattices and minibands, Coherent transport in many channels, Tunneling in hetrostructures, Schrodinger equation with electric and magnetic fields, Quantum hall effect	**12**
Module-5	**Two-Dimensional electron gas (2DEG)** Revision of approximate methods, scattering rates: the golden rule, Absorption in a quantum well, Electronic structure of a 2DEG, Optical properties of quantum wells: Kane model, bands in a quantum well, Interband and intersubband transitions in a quantum well, Optical gain and lasers, Excitons	**12**

Text Book

[T1] John H. Davies, The Physics of Low-Dimensional Semiconductors an Introduction, Cambridge University Press.

[T2] Thomas Heinzel, Mesoscopic electronics in solid state nanostructures, Wiley-VCH

[T3] Jan G. Korvink, Andreas Greiner, Semiconductors for micro and Nanotechnology – An Introduction for Engineers. Wiley-VCH

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	Y
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Quiz1	√	√	√		
Quiz II				√	√
Assignment	√	√	√	√	√
End Sem Examination	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	H	H	H	H
B	H	H	H	L	L
C	H	H	L	H	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	M	H	H
2	H	H	H	M	H	H
3	H	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1 L2		Ch1	**Introduction to Semiconductor Nanostructures** Introduction, Semiconductor quantum dot and quantum wire,	T1, T2, T3				
	L3 L4			Density of states for 0-D, 1D and 2D nanostructures.	T1, T2, T3				
	L5			Two-dimensional semiconductors.	T1, T2, T3				

	L6								
	L7		Ch2	**Hetrostructures** General properties and growth of hetrostructures	T1, T2, T3				
	L8			Band engineering	T1, T2, T3				
	L9			Layered structures	T1, T2, T3				
	L10			Quantum wells and barriers	T1, T2, T3				
	L11			Doped hetrostructures, Wires and dots	T1, T2, T3				
	L12			Optical confinement,	T1, T2, T3				
	L13 L14			Effective mass approximation and Effective mass theory in hetrostructures.	T1, T2, T3				
	L15 L16		Ch3	**Quantum wells and Low-Dimensional Systems** Infinite deep square well,	T1, T2, T3				
	L17			square well of finite depth,	T1, T2, T3				
	L18 L19			parabolic well,	T1, T2, T3				
	L20 L21			triangular well,	T1, T2, T3				
	L22 L23 L24			Low-dimensional systems, Occupation of subbands,	T1, T2, T3				
	L25 L26			Quantum wells in hetrostructures.	T1, T2, T3				
	L27		Ch4	**Tunneling transport and Quantum Hall effect** Potential step	T1, T2, T3				
	L28			T-Matrices	T1, T2, T3				
	L29			Resonant tunneling	T1, T2, T3				
	L30			Superlattices and minibands	T1, T2, T3				

	L31 L32			Coherent transport in many channels	T1, T2, T3				
	L33 L34			Tunneling in hetrostructures	T1, T2, T3				
	L35 L36			Schrodinger equation with electric and magnetic fields	T1, T2, T3				
	L37 L38			Quantum hall effect	T1, T2, T3				
	L39		Ch5	**Two-Dimensional electron gas (2DEG)** Revision of approximate methods					
	L40 L41			scattering rates: the golden rule	T1, T2, T3				
	L42 L43			Absorption in a quantum well	T1, T2, T3				
	L44 L45			Electronic structure of a 2DEG, Optical properties of quantum wells: Kane model	T1, T2, T3				
	L46			bands in a quantum well	T1, T2, T3				
	L47 L48			Interband and intersubband transitions in a quantum well	T1, T2, T3				
	L49 0			Optical gain and lasers, Excitons	T1, T2, T3				

Group E- Plasma Sciences:

1. Introduction to Plasma Physics
2. Plasma Processing of Materials

COURSE INFORMATION SHEET

Course code: PH 511
Course title: Introduction to Plasma Physics
Pre-requisite(s):
Co- requisite(s):
Credits: **4** L:4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level:PE V
Branch: PHYSICS
Name of Teacher:

Group : E **Option 1**

Code: PH 511	**Title: Introduction to Plasma Physics**	**L-T-P-C [4-0-0-4]**

Module	**Course Objective:**
1.	To impart the knowledge about the fundamental and basics of Plasma Physics.
2.	To learn about the charged particle motion in electric and magnetic field.
3.	To provide the knowledge about the ionization process and diffusion.
4.	To learn about the basic Plasma Diagnostic Methods.
5.	To learn how to use plasma for various application.

Module	**Course Outcome**
1.	Will have an idea about the basis of Plasma (Fourth State of Matter).
2.	Will be able to visualize the motion of charged particles in electric and magnetic field.
3.	Will have knowledge about the ionization and diffusion of Plasma.
4.	Will be able to measure the different plasma parameters.
5.	Will be familiar with different applications of Plasma.

Module-1	The fourth state of matter, collective behavior, charge neutrality, space and time scale, concept of plasma temperature, Classification of Plasma, Debye shielding, Debye length, plasma frequency, plasma parameters and criteria for plasma state.	**[8]**
Module-2	Single particle dynamics, charged particle motion in electric field, magnetic field and in combined electric and magnetic field, Basics of $E \times B$ drift, Drift of guiding centre, gradient drift, curvature drift and magnetic mirror.	**[8]**
Module-3	Ionization by collision, Townsends theory of collision ionization, The breakdown potential, Thermal ionization and excitation, concepts of diffusion, mobility and electrical conductivity, Ambipolar diffusion.	**[8]**
Module-4	Basic plasma diagnostics, Single probe method, Double probe method, Optical emission spectroscopy (basic idea), Abel inversion.	**[8]**
Module-5	Controlled Thermonuclear fusion, Tokamak, Laser Fusion, MHD Generator, Industrial applications of plasma.	**[8]**

References:

1. Introduction to Plasma Physics and Controlled Fusion, Francis, F. Chen, Plenum Press, 1984
2. Fundamental of Plasma Physics, J, A. Bittencourt, Springer-Verlag New York Inc., 2004
3. The Fourth State of Matter- Introduction to Plasma Science, S. Eliezer and Y. Eliezer, IoP Publishing Ltd.,, 2001.
4. Elementary Plasma Physics, L. A. Arzimovich, Blaisdell Publishing Company, 1965
5. Plasmas- The Fourth State of Matter, D. A. Frank- Kamenetskii, Macmillan Press, 1972

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	L	M	L
B	M	H	L	L	L
C	M	L	H	L	L
D	M	L	L	H	L
E	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes											
	a	B	C	d	e	f	g	h	I	j	k	l
1	M	H	M	M	M	H						
2	M	H	M	M	M	H						
3	M	H	M	M	M	H						
4	M	H	M	M	M	H						
5	M	H	L	M	M	H						

Mapping Between COs and Course Delivery (CD) methods				
CD	Course Delivery methods		Course Outcome	Course Delivery Method

CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 CD2
CD2	Tutorials/Assignments		CO2	CD1 CD2
CD3	Seminars		CO3	CD1 CD2
CD4	Mini projects/Projects		CO4	CD1 CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L2			The fourth state of matter, collective behavior, charge neutrality,	T1 R1				
	L3-L4			space and time scale, concept of plasma temperature,	T1 R1				
	L5-L6			Classification of Plasma, Debye shielding, Debye length,	T1 R1				
	L7-L8			plasma frequency, plasma parameters and criteria for plasma state.	T1 R1				
	L9-L10			Single particle dynamics, charged particle motion in electric field,	T1T2 R1				
	L11-L12			magnetic field and in combined electric and magnetic field,	T1T2 R1				
	L13-L14			Basics of $E \times B$ drift, Drift of guiding centre,	T1T2 R1				
	L15-L16			Basics of $E \times B$ drift, Drift of guiding centre,	T1T2 R1				
	L17-L20			Ionization by collision, Townsends theory of collision ionization, The breakdown potential,	T2 R1				
	L21-L24			Thermal ionization and excitation, concepts of diffusion, mobility and electrical conductivity, Ambipolar diffusion	T2 R1				
	L25-L28			Basic plasma diagnostics, Single probe method, Double probe method,	T2 R1				
	L29-L32			Optical emission spectroscopy (basic idea), Abel inversion	T2 R1				
	L33-L36			Controlled Thermonuclear fusion, Tokamak,	T1 R1				

	L37-L40			Laser Fusion, MHD Generator, Industrial applications of plasma.	T1 R1				

COURSE INFORMATION SHEET

Course code: PH 512
Course title: Plasma Processing of Materials
Course code: SAP
Course title: Plasma Processing of Materials
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 4 T: 0 P: 0
Class schedule per week: 0x
Class: I.M.Sc. / M.Sc.
Semester / Level:
Branch: Physics
Name of Teacher: Dr. Sanat Kr. Mukherjee

Group : E **<u>Option 2</u>**

Code: PH 512	Title: Plasma Processing of Materials	L-T-P-C [4-0-0-4]

Course Objectives
This course enables the students to:

A.	Defineplasma and its parameters
B.	Outline the design principles of high and low-pressure plasma torches.
C.	Identify the processes of measurement of plasma parameters.
D.	Outline the industrial applications of low temperature plasma
E.	Explain arc plasma-based systems and illustrate their industrial applications

Course Outcomes
After the completion of this course, students will be able to:

1.	Define plasma, classify it into various types in terms of the plasma parameters and explain the various types of reactions involved in a plasma.
2.	Demonstrate the construction and working of high and low-pressure plasma torches.
3.	Illustrate the various processes of measurement of plasma parameters.
4	Outlinevarious plasma processes, such as, plasma etching, plasma ashing, plasma polymerization, etc., and their associated techniques such as, sputtering, nitriding, etc.
5.	Illustrate arc plasma based applications like, plasma spraying, plasma waste processing, plasma cutting, etc.

Module-1	Plasma-the fourth state of matter, Plasma Parameters, Debye length, Plasma oscillations & frequency, Plasma Sheath, Interaction of electromagnetic wave with plasma, Concept about plasma equilibrium, Industrial Plasmas, Cold and thermal plasma, Plasma Chemistry, Homogeneous and Heterogeneous reaction, Reaction rate coefficients, Plasma Surface interaction.	**[8]**
Module-2	Design principles and construction of plasma torches and thermal plasma reactors, Efficiency of plasma torches in converting electrical energy in to thermal energy, Designing aspects of low pressure plasma reactors.	**[8]**
Module-3	Measurements of Plasma parameters, Electrical probes, Single and double Langmuir probe, Magnetic probe, Calorimetric measurements, Enthalpy Probes, Spectroscopic techniques.	**[8]**
Module-4	Plasma Etching Anisotropic etching, plasma cleaning, surfactants removal, plasma ashing, plasma polymerization, Plasma sputtering and PECVD Thin film coatings, magnetron sputtering, RF PECVD, MW PECVD, plasma nitriding.	**[15]**
Module-5	Module 5:Plasma Spraying Non-transferred plasma torches, powder feeder, optimization of spraying processes, spherodization, Arc plasmas, Plasma torches, plasma waste processing, Synthesis of materials and metallurgy in arc plasmas, Plasma cutting and Welding.	**[6]**

Text books:

1. Introduction to Plasma Physics and Controlled Fusion, Francis, F. Chen, Plenum Press, 1984
2. Fundamental of Plasma Physics, J, A. Bittencourt, Springer-Verlag New York Inc., 2004
3. The Fourth State of Matter- Introduction to Plasma Science, S. Eliezer and Y. Eliezer, IoP Publishing Ltd.,, 2001.

Reference books:

1. Elementary Plasma Physics, L. A. Arzimovich, Blaisdell Publishing Company, 1965
2. Plasmas- The Fourth State of Matter, D. A. Frank- Kamenetskii, Macmillan Press, 1972

_Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	No
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

AssessmentCompoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	Yes	Yes	Yes	No	No
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment	Yes	Yes	Yes	Yes	Yes

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	L	M	L
2	H	H	M	L	L	L
3	H	M	M	L	L	L
4	H	M	M	L	L	L
5	H	H	H	L	H	L

Course Outcome #	Course Objectives				
	a	b	c	d	e

1	H	M	M	M	L
2	M	H	M	M	L
3	M	M	H	L	L
4	M	M	H	L	L
5	M	M	L	L	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD8
CD2	Tutorials/Assignments		CO2	CD1, CD2 and CD8
CD3	Seminars		CO3	CD1, CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	ModuleNo.	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks byfaculty if any
1-2	L1-2		I	Plasma-the fourth state of matter, Plasma Parameters, Debye length	T2	CO-1		PPT Digi Class/Chalk-Board	
	L3-4			Plasma oscillations & frequency, Plasma Sheath, Interaction of electromagnetic wave with plasma, Concept about plasma equilibrium	T2	CO-1		PPT Digi Class/Chalk-Board	
2	L5			Industrial Plasmas, Cold and thermal plasma,	T1	CO-1		PPT Digi Class/Chalk-Board	
2-3	L6			Plasma Chemistry, Homogeneous and Heterogeneous reaction	T1	CO-1		PPT Digi Class/Chalk-Board	
3	L7-8			Reaction rate coefficients, Plasma Surface interaction		CO-1		PPT Digi Class/Chalk-Board	
4	L9-12		II	Design principles and construction of plasma torches and thermal plasma reactors	T3	CO-2		PPT Digi Class/Chalk-Board	
5	L13-			Efficiency of plasma	T1	CO-2		PPT Digi	

	14			torches in converting electrical energy in to thermal energy				Class/Chal k-Board	
5-6	L15-16		III	Measurements of Plasma parameters	T1	CO-3		PPT Digi Class/Chal k-Board	
7	L17-18			Electrical probes, Single and double Langmuir probe		CO-3		PPT Digi Class/Chal k-Board	
8	L19-20			Magnetic probe, Calorimetric measurements Enthalpy Probes,	T2	CO-3		PPT Digi Class/Chal k-Board	
8-9	L21-22			Spectroscopic techniques.	T1, T2,	CO-3		PPT Digi Class/Chal k-Board	
9-10	L23-25		IV	Plasma Etching Anisotropic etching	T1, T2,	CO-4		PPT Digi Class/Chal k-Board	
10-11	L26-28			plasma cleaning, surfactants removal	T1, T2,	CO-4		PPT Digi Class/Chal k-Board	
11-12	L29-31			plasma ashing, plasma polymerization	T1, T2,	CO-4		PPT Digi Class/Chal k -Board	
12	L32-33			Plasma sputtering and PECVD Thin film coatings	T1, T2,	CO-4		PPT Digi Class/Chal k-Board	
13	L34-35			magnetron sputtering	T1, T2,	CO-4		PPT Digi Class/Chal k-Board	
13	L36			, RF PECVD, MW PECVD	T1, T2,	CO-4		PPT Digi Class/Chal k-Board	
14	L37			plasma nitriding	T1, T2,	CO-4		PPT Digi Class/Chal k-Board	
14	L40		V	Plasma Spraying Non-transferred plasma torches	T1, T2,	CO-5		PPT Digi Class/Chal k-Board	
14	L41			powder feeder, optimization of spraying processes	T2	CO-5		PPT Digi Class/Chal k-Board	
15	L42			spherodization, Arc plasmas, Plasma torches	T1, T2,	CO-5		PPT Digi Class/Chal k-Board	
15	L43-44			plasma waste processing, Synthesis of materials and metallurgy in arc plasmas	T2	CO-5		PPT Digi Class/Chal k-Board	
16	L45			Plasma cutting and	T2	CO-5		PPT Digi	

				Welding				Class/Chalk-Board	

PE-VI to VII

Group A- Theoretical and Computational Physics:
1. Theoretical and Computational Fluid Dynamics **2.** Theoretical and Computational Condensed Matter Physics 3. Nonlinear Dynamics and Chaos

COURSE INFORMATION SHEET

Course code: PH 514
Course title: Theoretical and Computational Fluid Dynamics
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 2 T: 0 P: 4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE VI//VII
Branch: PHYSICS
Name of Teacher:
Group : A **Option 1**

Code: **PH 514**	**Title: Theoretical and Computational Fluid Dynamics** Theory &Programming using C for solving problems on following topics**:**	**L-T-P-C** **[2- 0-4- 4]**

Course Objectives

This course enables the students:

A.	To learn the techniques of model atomic and molecular systems.
B.	To receive explanation of methods to deal with the different ensembles used in Statistical Mechanics.
C.	To obtain training on numerical methods used for integrations in Fluid Dynamics.
D.	To discuss ways to analyze the accuracy of correlation functions and equilibrium averages.

Course Outcomes

After the completion of this course, students will be:

1.	Learning about common models used to describe atoms and molecules
2.	Able to prepare codes for transforming between different ensembles.
3.	Develop a good handle on relevant numerical integrations.
4.	Achieve competence in the estimation of errors involved in computing correlation functions and equilibrium averages.

Module-1	Model systems and interaction potentials: Atomic systems, Molecular systems, Lattice systems, Calculating the potential, Constructing an intermolecular potential, Studying small systems: periodic and spherical boundary conditions.	**[11]**
Module-2	Statistical Mechanics: Statistical ensembles, Transformation between ensembles, Fluctuations, Time correlations, Transport coefficients.	**[9]**
Module-3	Molecular dynamics: Finite difference methods, Verlet algorithm, Linear and nonlinear molecules, Checks on accuracy.	**[7]**
Module-4	Monte Carlo methods: Monte Carlo integration, Importance sampling, Metropolis method, Molecular liquids.	**[9]**
Module-5	Analyzing results: Time correlation functions, Fast Fourier transform, Estimation of errors in equilibrium averages and fluctuations, Errors in time correlation functions**.**	**[9]**

References:

1. “Computer Simulation of Liquids” by Allen and Tildesley, Oxford Science Publications .
2. “The Art of Molecular Dynamics Simulation” by D. C. Rappaport, Cambridge University Press.

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks					
End Sem Examination Marks					
Quiz I					
Quiz II					

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4
A	H	M	M	M
B	M	H	M	M
C	M	L	H	M
D	L	M	H	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	M	M	H	M
2	L	H	M	M	H	M
3	L	H	H	M	H	M
4	L	H	H	M	H	M

Lecture wise Lesson planning Details.

Week No	Lect. No.	Tentative Date	Ch. No	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L3			Model systems and interaction potentials: Atomic systems, Molecular systems	T1,T2	1			
2	L4-L6			Lattice systems, Calculating the potential, Constructing an intermolecular potential,	T1,T2	1			
3	L7-L9			Studying small systems: periodic and spherical boundary conditions	T1,T2	1			
4	L10-L12			Statistical Mechanics: Statistical ensembles	T1,T2	2			
5	L13-			Transformation between ensembles,	T1,T2	2			

	L15			Fluctuations					
6	L16-L18			Time correlations, Transport coefficients.	T1,T2	2			
7	L19-L21			Molecular dynamics: Finite difference methods, Verlet algorithm	T1,T2	3			
8	L22-L24			Linear and nonlinear molecules, Checks on accuracy.	T1,T2	3			
9	L25-L27			Monte Carlo methods: Monte Carlo integration	T1,T2	4			
10	L28-L30			Importance sampling, Metropolis method	T1,T2	4			
11	L31-L33			Molecular liquids.	T1,T2	4			
12	L34-L36			Analyzing results: Time correlation functions, Fast Fourier transform	T1,T2	5			
13	L37-L39			Estimation of errors in equilibrium averages and fluctuations	T1,T2	5			
14	L40L42			Errors in time correlation functions.	T1,T2	5			

COURSE INFORMATION SHEET

Course code: PH 515
Course title: Theoretical and Computational Condensed Matter Physics
Pre-requisite(s):
Co- requisite(s):
Credits: **4**L: 2 T: 0 P:4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE VI / VII
Branch: PHYSICS
Name of Teacher:

Group : A **Option 2**

Code: **PH 515**	**Title: Theoretical and Computational Condensed Matter Physics** Theory &Programming using C for solving problems on following topics:	**L-T-P-C** **[2- 0-4- 4]**

Course Objectives:
The course aims to give students the basic concepts of condensed matter physics and to prepare them to formulate the problems in condensed matter physics so that these can be solved on a computer. The main objectives of the course are

1. To teach how Monte-Carlo techniques can be used to solve various physical systems.
2. To give concepts of first order phase transitions, second order phase transitions and mean field theory using Ising model.
3. To teach the equilibrium properties and time evolution of simple fluids.
4. To provide the concept on computation of free energies of solids and how to obtain them numerically.
5. To introduce the method of dissipative particle dynamics.

Program Outcomes:
After taking the course the student should be able to

1. Use Monte-Carlo simulation to obtain the equilibrium configuration of a physical system.
2. Differentiate between first order and second order phase transitions and appreciate the efficiency of mean field theory.
3. Calculate transport coefficients and space-time correlation function of simple fluids.
4. Compute the free energy of perfect or imperfect solids numerically.
5. Understand the fundamentals of dissipative particle dynamics technique.

Module-1	**Random Systems** Generation of Random Numbers, Introduction to Monte Carlo Methods: Integration, Random Walks, Self-Avoiding Walks, Random Walks and Diffusion, Diffusion, Entropy, and the Arrow of Time, Cluster Growth Models, Fractal Dimensionalities of Curves, Percolation	**[10]**
Module-2	**Statistical Mechanics, Phase Transitions, and the Ising Model** The Ising Model and Statistical Mechanics, Mean-Field Theory, The Monte Carlo Method, The Ising Model and Second-Order Phase Transitions, First-Order Phase Transitions	**[10]**
Module-3	**Equilibrium and Dynamical properties of simple fluids** Thermodynamic measurements, Structure, Packing studies, Cluster analysis, Transport coefficients Measuring transport coefficients, Space-time correlation functions	**[10]**
Module-4	**Free Energies of Solids** Thermodynamic Integration, Free Energies of Solids, Free Energies of Molecular Solids, Vacancies and Interstitials, Numerical Calculations	**[10]**
Module-5	**Dissipative Particle Dynamics** Justification of the Method, Implementation of the Method, DPD and Energy Conservation	**[10]**

Text books:
T1: "Computation Physics" by Nicholas J. Giordano, Pearson Addison-Wesley
T2: "The Art of Molecular Dynamics Simulation" by D. C. Rappaport, Cambridge University Press.

Reference books:
R1: "Understanding Molecular Simulation" by Daan Frenkel, Academic Press.

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	Y

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	C05
End Sem Examination Marks	√	√	√	√	√
Quiz 1	√	√			
Quiz 2			√		
Quiz 3				√	

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Objectives onto Course Outcomes

Course Outcome #	Program Outcomes				
	a	b	c	d	e
1	H	L	L	L	L
2	L	H	L	L	L
3	L	L	H	L	L
4	L	L	L	H	L
5	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	M	H	H
2	H	H	H	M	H	H
3	H	H	H	M	H	H
4	H	H	H	M	H	H
5	H	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD9
CD2	Tutorials/Assignments		CO2	CD1 , CD2and CD9
CD3	Seminars		CO3	CD1, CD2 and CD9
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD9
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD9
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1-3	L1-L10			Generation of Random Numbers, Introduction to Monte Carlo Methods: Integration, Random Walks, Self-Avoiding Walks, Random Walks and Diffusion, Diffusion, Entropy, and the Arrow of Time, Cluster Growth Models, Fractal Dimensionalities of Curves, Percolation	T1, T2	1		PPT Digi Class/Chock -Board	
3-5	L11-L20			The Ising Model and Statistical Mechanics, Mean-Field Theory, The Monte Carlo Method, The Ising Model and Second-Order Phase Transitions, First-Order Phase Transitions	T1, R1	2			
6-8	L21-L30			Thermodynamic measurements, Structure, Packing studies, Cluster analysis, Transport coefficients Measuring transport	T1, T2, R1	3			

				coefficients, Space-time correlation functions					
8-10	L31-L40			Thermodynamic Integration, Free Energies of Solids, Free Energies of Molecular Solids, Vacancies and Interstitials, Numerical Calculations	T1, T2	4			
11-14	L41-L50			Justification of the Method, Implementation of the Method, DPD and Energy Conservation	T1, T2, R1	5			

COURSE INFORMATION SHEET

Course code: PH 516
Course title: Nonlinear Dynamics and Chaos
Pre-requisite(s): Classical Dynamics
Co- requisite(s):
Credits: **4**L: 2 T: 0 P: 4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE V
Branch: PHYSICS
Name of Teacher:

Code: PH 516	**Title: Nonlinear Dynamics and Chaos**	**L-T-P-C 2- 0-4- 4]**
Course Objectives: The objective of the course is to 1. Train students to calculate fixed points and do stability analysis of various systems motivated from physics/biology. 2. Give a clear concept of bifurcation and some examples of the phenomenon. 3. Teach them to plot limit cycles of various differential equations on computer using C language. 4. Teach properties of limit cycles taking examples from physics. 5. Train students to solve problems on coevolution and the impact of environment on population growth using concepts from physics. **Course Outcomes**:The student should be able to 1. Model physical or biological systems computationally and obtain their fixed points, saddle points, attractors, etc. 2. Compute the evolution of phase space as various parameters are changed. 3. Visualize limit cycles of various nonlinear systems graphically. 4. Solve problems related to oscillators, viz., relaxation oscillators, weakly nonlinear oscillators, etc. 5. Solve simple models of population growth of multiple-species on computer.		
Module-1	**Flows on the Line & Circle** Fixed Points and Stability, Population Growth, Linear Stability Analysis, Existence and Uniqueness, Impossibility of Oscillations, Potentials, Solving Equations on the Computer, Uniform Oscillator, Nonuniform Oscillator, Overdamped Pendulum, Fireflies, Superconducting Josephson Junctions	**[12]**
Module-2	**Bifurcations** Saddle-Node Bifurcation, Transcritical Bifurcation, Laser Threshold, Pitchfork Bifurcation, Overdamped Bead on a Rotating Hoop, Imperfect Bifurcations and Catastrophes, Insect Outbreak, Chaos	**[10]**
Module-3	**Phase Plane** Phase Portraits, Existence, Uniqueness, and Topological Consequences, Fixed Points and Linearization, Rabbits versus Sheep, Conservative Systems, Reversible Systems, Pendulum, Index Theory	**[10]**
Module-4	**Limit Cycles** Ruling Out Closed Orbits, Poincare-Bendixson Theorem, Lienard Systems, Relaxation Oscillators, Weakly Nonlinear Oscillators	**[8]**
Module-5	**Population Dynamics** Multispecies model: limit cycles and time delays, Randomly Fluctuating Environment, Niche Overlap and Limiting Similarity	**[10]**
Text books: T1: Nonlinear dynamics and Chaos: with applications to physics, biology, chemistry, and engineering by Steven H. Strogatz, CRC Press. T2: “Stability and Complexity in Model Ecosystems” by Robert M May, Princeton University Press.		

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	Y

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	C05
End Sem Examination Marks	√	√	√	√	√
Quiz 1	√	√			
Quiz 2			√		
Quiz 3				√	

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Objectives onto Course Outcomes

Course Outcome #	Program Outcomes				
	a	b	c	d	e
1	H	L	L	L	L
2	L	H	L	L	L
3	L	L	H	L	L
4	L	L	L	H	L
5	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	M	H	H
2	H	H	H	M	H	H
3	H	H	H	M	H	H
4	H	H	H	M	H	H
5	H	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD9
CD2	Tutorials/Assignments		CO2	CD1 , CD2and CD9
CD3	Seminars		CO3	CD1, CD2 and CD9
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD9
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD9
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1-3	L1-L12			Fixed Points and Stability, Population Growth, Linear Stability Analysis, Existence and Uniqueness, Impossibility of Oscillations, Potentials, Solving Equations on the Computer, Uniform Oscillator, Nonuniform Oscillator, Overdamped Pendulum, Fireflies, Superconducting Josephson Junctions	T1, T2	1		PPT Digi Class/Chock -Board	
4-6	L13-L22			Saddle-Node Bifurcation, Transcritical Bifurcation, Laser Threshold, Pitchfork Bifurcation, Overdamped Bead on a Rotating Hoop, Imperfect Bifurcations and Catastrophes, Insect Outbreak, Chaos	T1, T2	2			
6-8	L23-			Phase Portraits, Existence, Uniqueness, and Topological	T1,T2	3			

	LL32			Consequences, Fixed Points and Linearization, Rabbits versus Sheep, Conservative Systems, Reversible Systems, Pendulum, Index Theory					
9-10	L33-L40			Ruling Out Closed Orbits, Poincare-Bendixson Theorem, Lienard Systems, Relaxation Oscillators, Weakly Nonlinear Oscillators	T1,T2	4			
11-14	L41-L50			Multispecies model: limit cycles and time delays, Randomly Fluctuating Environment, Niche Overlap and Limiting Similarity	T1, T2	5			

COURSE INFORMATION SHEET

Course code: PH 517
Course title: Nonconventional Energy Materials
Pre-requisite(s): Student should qualify 'Solid State Physics' or similar paper
Co- requisite(s): Knowledge of Mathematical Physics, Quantum Mechanics, and Statistical Mechanics
Credits: **4** L: 4 T: 0 P: 0
Class schedule per week: 4
Class: I.M.Sc./ M.Sc.
Semester / Level: X/IV
Branch: Physics
Name of Teacher:

Group : B **Option 1**

Code: PH 517	**Title: Nonconventional Energy Materials**	**L-T-P-C [4-0-0-4]**

Course Objectives

This course enables the students:

A.	Todefine the current scenario of the conventional sources of energy and importance of sustainable energy sources.
B.	To explain the basic of PN Junction solar cell.
C.	To define the solar cell characterization.
D.	To illustrate the various solar cell technologies.
E.	To explain the other nonconventional energy sources

Course Outcomes

After the completion of this course, students will be able to:

1.	Explain the current status of conventional sources of energy and list the various sustainable energy sources.
2.	Define various properties of the semiconducting materials, formation of PN junction and generation of photo-voltage and photo-current of PN Junction solar cell.
3.	Demonstrate the measurement of solar cell parameters and solar cell design for high Isc, design for high Voc, design for high FF.
4.	Explain the fabrication of wafer based solar cells, thin film solar cell, organic solar cells, dye-sensitized solar cell, GaAs solar cells, Thermo-photovoltaics and multijunction solar cells.
5.	Discuss the concepts of wind energy, bio energy, tidal power, fuel cells, and solar thermal.

Module-1	Energy sources and their availability, conventional sources of energy: Fossil fuel, Hydraulic energy, Nuclear energy: nuclear fission, nuclear fusion, Environmental impact of conventional sources of energy, Need for sustainable energy sources, Nonconventional energy sources, Current status of renewable energy sources.	**[5]**
Module-2	Structure of solar cell materials, direct and indirect band gap semiconductor, carrier concentration and distribution, drift and diffusion current densities, P-N Junction: space charge region, energy band diagram, carrier movements and current densities, carrier concentration profile; P-N junction in non-equilibrium condition, I-V Relation, P-N Junction under Illumination, Generation of photovoltage, Light generated current, I-V equation of solar cells.	**[10]**
Module-3	Solar Cell Characteristics and Cell parameters: Short circuit current, open circuit voltage, fill factor, efficiency; losses in solar cells, Solar Cell Design: design for high Isc, design for high Voc, design for high FF; Solar spectrum at the Earth's surface, solar simulator: I-V measurement, quantum efficiency measurement, minority carrier lifetime and diffusion length measurement.	**[10]**
Module-4	Wafer-based Si solar cell fabrication: saw damage removal and surface texturing, P-N Junction formation, ARC and surface passivation, metal contacts—pattern defining and deposition. High efficiency solar cells, Thin Film Solar Cell Technologies: advantages of thin film technologies, thin films solar cell structures, thin film crystalline, microcrystalline, polycrystalline, and amorphous Si solar cells. Emerging solar cell technologies: working principle of organic solar	**[15]**

	cells, material properties and structure of organic solar cells; Dye-sensitized Solar Cell: working principle, materials and their Properties; GaAs solar cells, Thermo-photovoltaics, multijunction solar cells.	
Module-5	Other nonconventional Energy Sources: Wind Energy: Classification of wind mills, advantages and disadvantage of wind energy; Bio Energy: Bio gas and its compositions, process of bio gas, generation – wet process, dry process, utilization and benefits of biogas technology. Tidal Power: Introduction, classification of tidal power plants, factors affecting the suitability of the site for tidal power plant, advantages and disadvantages of tidal power plants. Fuel Cells: Introduction, working of fuel cell, types of fuel cells, advantages of fuel cell technology. Solar Thermal: Solar collectors, solar cookers, solar water heater.	**[10]**

Text/Reference Books:

1. Solar cells: Operating principles, technology and system applications by Martin A Green, Prentice Hall Inc, Englewood Cliffs, NJ, USA, 1981.
2. Semiconductor for solar cells, H J Moller, Artech House Inc, MA, USA, 1993.
3. Solis state electronic device, Ben G Streetman, Prentice Hall of India Pvt Ltd., New Delhi 1995.
4. Direct energy conversion, M.A. Kettani, Addision Wesley Reading, 1970.
5. Hand book of Batteries and fuel cells, Linden, Mc Graw Hill, 1984.

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I	√	√	√		
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome
3. Teacher's assessment

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Outcomes					
Course	**1**	**2**	**3**	**4**	**5**

Objectives					
A	H	L	L	L	L
B	M	H	M	M	L
C	M	M	H	L	L
D	M	L	L	H	L
E	M	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	L	L	M	H	L	H
2	M	H	M	H	H	H
3	M	H	M	H	H	H
4	M	H	M	H	H	H
5	M	H	M	H	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
	L1			World energy status, current energy scenario in India, environmental aspects of energy utilization, Classification of energy, Energy Resources, need of renewable energy, non-conventional energy sources.	R1				
	L2, L3			An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean energy,	R1				

	L4, L5			Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity. Energy conservation and storage.	R1				
	L6-L10			Solar energy, its importance, storage of solar energy, solar pond, non-convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell	R1, R2 T1				
	L11-L15			absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems	R1, R2 T1				
	L16-L19			Wind Energy: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies.	R1, R2				
	L20-L22			Ocean Energy, Potential against Wind and Solar, Wave Characteristics, Wave Energy Devices.	R1, R2				
	L23-L25			Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass.	R1, R2				
	L26-L30			Biomass energy, resources, conversion, gasification, liquefaction, production, energy farming,	R1, R2				
	L31-L33			Geothermal Energy: Geothermal Resources, Geothermal Technologies.	R1, R2				
	L34, L35			small hydro resources. Layout, water turbines, classifications, generators, status.	R1, R2				
	L36-L38			Direct Energy conversion: Thermoelectric effects, generators, Thermionic generators, magneto hydro	R1, R2				

				dynamics generators, Fuel cells					
	L39, L40			photovoltaic generators, electrostatic mechanical generators, Thin film solar cells, nuclear batteries.	R1, R2				

COURSE INFORMATION SHEET

Course code: PH 518
Course title: Cryogenic Physics
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 4 T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level:PE VI / VII
Branch: PHYSICS
Name of Teacher:
Group : B **Option 2**

Code: PH 518	Title: Cryogenic Physics	L-T-P-C [4-0-0-4]

Course Objectives : This course enables the students

A.	To become familiar with low temperature and the principles and methods to produce low temperature.
B.	To acquire basic understanding of the macroscopic manifestations of quantum phenomenon at low temperatures like superfluidity of He^4, He^3 and superconductivity.
C.	To acquire basic knowledge of the behaviour of various physical properties at low temperature.
D.	To become aware of various special phenomena observed at low temperature and their manifestation in the physical properties.
E	Become conversant with the principles and methods to produce low temperature.

Course Outcomes : After the completion of this course, students will be

1.	Able to explain the physics and production of low temperature.
2.	Able to describe and analyze the macroscopic manifestations of quantum phenomenon at low temperatures.
3.	Able to summarize and apply the knowledge of the behaviour of various physical properties at low temperature.
4.	Able to discuss and compare various special phenomena observed at low temperatures.
5.	Compare different methods of producing low temperature.

Module-1	**Quantum Fluids:** Introduction to low temperature physics; cryo-liquids; helium-general properties; superfluid ^4He, experimental observation, two-fluid model and Bose-Einstein condensation; normal-fluid and superfluid ^3He; mixtures of ^3He and ^4He.	**[8]**
Module-2	**Solids at Low Temperature (Phonons and Electrons):** Specific heat of phonons-Debye model, significance of the Debye temperature; specific heat of conduction electrons in simple metals; electrical conductivity, relaxation-time approximation, Matthiessen's rule, electron-phonon scattering, electron-magnon scattering; thermal conductivity of metals; Kondo effect; Heavy Fermion Systems.	**[8]**
Module-3	**Solids at Low Temperature (Magnetic Moments, Spins):** Paramagnetic systems-isolated spins, magnetic contribution to specific heat, Schottky anomaly; spin waves-magnons, ferromagnets, anti-ferromagnets.	**[8]**
Module-4	**Solids at Low Temperature (Introduction to Superconductivity, Shubnikov-de Haas Oscillations , Colossal Magnetoresistance):** Transition temperature, Meissner effect, type-I and type-II superconductors; phenomenological description, London equations; microscopic theory of superconductors; flux quantization; Shubnikov-de Haas (SdH) oscillations, quantization of Bloch electrons in a uniform magnetic field; colossal magnetoresistance (CMR).	**[8]**
Module-5	**Refrigeration:** Liquefaction of gases, expansion engines, Joule-Thomson expansion; closed cycle refrigerators, Gifford Mc-Mahon coolers; simple-helium bath cryostats; ^3He-^4He dilution refrigerator; Pomeranchuk cooling; refrigeration by adiabatic demagnetization of a paramagnetic salt and adiabatic nuclear demagnetization.	**[8]**

Textbooks:

1. Low-Temperature Physics, Christian Enss and Siegfried Hunklinger, Springer 2005.
2. Matter and Methods at Low Temperatures, Frank Pobell, Springer 2007.

References:
1. Introduction to Solid State Physics, Charles Kittel, 8th edition, John Wiley and Sons, 2005. (For SdH oscillations)
2. Solid State Physics, Neil W. Ashcroft and N. David Mermin, Harcourt College Publishers, 1976. (For SdH oscillations)

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	No
Mini projects/Projects	Yes
Laboratory experiments/teaching aids	Yes
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

AssessmentCompoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	Yes	Yes	Yes	No	No
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment	Yes	Yes	Yes	Yes	Yes

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	L	H	H	L	H	M
2	M	H	H	L	H	M
3	M	H	H	L	H	M
4	L	H	H	L	H	M
5	L	H	H	L	H	M

Course Outcome #	Course Objectives				
	a	b	c	d	e
1	H	H	H	L	L
2	M	H	M	M	L

3	M	M	H	M	L
4	M	M	H	H	L
5	M	L	L	L	H

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2, CD4,CD5 and CD8
CD2	Tutorials/Assignments		CO2	CD1, CD2, CD4,CD5 and CD8
CD3	Seminars		CO3	CD1, CD2, CD4,CD5 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2, CD4,CD5 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2, CD4,CD5 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Module No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodologyused	Remarks byfaculty if any
1-2	L1		I	Introduction to low temperature physics, course objectives, grading scheme	T1-T2	CO-1		PPT Digi Class/Chalk-Board	
	L2-L5			Cryoliquids, general properties of He, Superfluid ^{4}He, Experimental Observation, Two fluid model, Bose Einstein Condensation	T1-T2	CO-1		PPT Digi Class/Chalk-Board	
2	L6-7			Superfluid and Normal Fluid ^{3}He.	T1-T2	CO-1		PPT Digi Class/Chalk-Board	
2	L8			Mixtures of ^{3}He and ^{4}He.	T1-T2	CO-1		PPT Digi Class/Chalk-Board	
3	L9-L10		II	Solids at Low Temperature: Phonons and electrons, specific heat of Phonons, Debye model	T1-T2	CO-2		PPT Digi Class/Chalk-Board	
3	L11			Specific heat of conduction electrons in	T1-T2	CO-2		PPT Digi Class/Chal	

				simple metals				k-Board	
3-4	L11-L13			Electrical conductivity, relaxation-time approximation, Matthiessen's rule, electron-phonon scattering, electron-magnon scattering	T1-T2	CO-2		PPT Digi Class/Chalk-Board	
4	L13-16			Thermal conductivity of metals; Kondo effect; Heavy Fermion Systems	T1-T2	CO-2		PPT Digi Class/Chalk-Board	
5	L17-20		III	Solids at Low Temperature (Magnetic Moments, Spins) Paramagnetic systems-isolated spins, magnetic contribution to specific heat, Schottky anomaly	T1-T2	CO-3		PPT Digi Class/Chalk-Board	
6	L21-24			Spin waves-magnons, ferromagnets, anti-ferromagnets	T1-T2	CO-3		PPT Digi Class/Chalk-Board	
7	L25-28		IV	Solids at Low Temperature (Introduction to Superconductivity, Shubnikov-de Haas Oscillations , Colossal Magnetoresistance) Transition temperature, Meissner effect, type-I and type-II superconductors; phenomenological description, London equations; microscopic theory of superconductors; flux quantization;	T1-T2	CO-4		PPT Digi Class/Chalk-Board	
8	L29-32			Shubnikov-de Haas (SdH) oscillations, quantization of Bloch electrons in a uniform magnetic field; colossal magnetoresistance (CMR).	T1-T2, R1-R2	CO-4		PPT Digi Class/Chalk-Board	
9	L33-34		V	Refrigeration: Liquefaction of gases, expansion engines, Joule-Thomson expansion	T1-T2	CO-5		PPT Digi Class/Chalk-Board	

9	L35-36			Closed cycle refrigerators, Gifford Mc-Mahon coolers; simple-helium bath cryostats	T1-T2	CO-5		PPT Digi Class/Chalk-Board	
10	L37-40			^{3}He-^{4}He dilution refrigerator; Pomeranchuk cooling; refrigeration by adiabatic demagnetization of a paramagnetic salt and adiabatic nuclear demagnetization.	T1-T2	CO-5		PPT Digi Class/Chalk-Board	

COURSE INFORMATION SHEET

Course code: PH 519
Course title: Physics of Thin Films
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 4 T: 0 P: 00
Class schedule per week: 0x
Class: I.M.Sc. / M.Sc.
Semester / Level:X / IV
Branch: Physics
Name of Teacher:

Group : B **Option 3**

Code PH 519	Title: Physics of Thin Films	L-T-P-C [4 0 0 4]

Course Objectives
This course enables the students to:

A.	Definevacuum and compare various vacuum pumps and gauges.
B.	Outline the thermodynamics of thin films.
C.	Illustrate the mechanism of thin film formation.
D.	Explain various techniques of thin film formation.
E.	Summarize various properties of thin films.

Course Outcomes
After the completion of this course, students will be able to:

1.	Demonstrate various types of pumps and gauges, inspect leak in vacuum and can design a vacuum system.
2.	Define the thermodynamical parameters of thin films and can outline interdiffusion in thin films.
3.	Demonstrate the stages of thin film formation and can outline the conditions for the formation of amorphous, crystalline and epitaxial films.
4	Illustrate and compare physical vapour deposition (PVD) and chemical vapour deposition (CVD) techniques.
5.	Define various thin film properties and outline the techniques of their determination.

Module-1	**Vacuum Science & Technology:** Classification of vacuum ranges, Kinetic theory of gases, gas transport and pumping, Conductance and Throughput, Classification of vacuum pumps, single stage and double stage rotary pump, diffusion pump, turbomolecular pump, cryopump and Classification of gauges, Mechanical gauges: McLeod gauge, Thermal conductivity gauges: Pirani gauge and thermocouple gauge, Ionization gauges: Bayard-Alpert gauge, Penning gauge, leak detection.	**[8]**
Module-2	**Basic Thermodynamics of Thin Films** Solid surface, interphase surface, Surface energies: Binding energy and Interatomic Potential energy, latent heat, surface tension, Liquid surface energy measurement by capillary effect, by zero creep, magnitude of surface energy, General concept, jump frequency and diffusion flux, Fick's First law, Nonlinear diffusion, Fick's second law, calculation of diffusion coefficient, interdiffusion and diffusion in thin films	**[8]**
Module-3	**Mechanisms of Film Formation** Stages of thin film formation: Nucleation, Adsorption, Surface diffusion, capillarity theory of nucleation, statistical theory of nucleation, growth and coalescence of islands, grain structure and microstructure of thin films, diffusion during film growth, polycrystalline and amorphous films, Theories of epitaxy, role of interfacial layer, epitaxial film growth, super lattice structures	**[8]**
Module-4	**Methods of Preparation of Thin Films:**	**[15]**

	Physical vapour deposition: Vacuum evaporation-Hertz- Knudsen equation, evaporation from a source and film thickness uniformity, Glow discharge and plasmas-Plasma structure, DC, RF and microwave excitation; Sputtering processes-Mechanism and sputtering yield, Sputtering of alloys; magnetron sputtering, Reactive sputtering; vacuum arc: cathodic and anodic vacuum arc deposition. Chemical vapour deposition: Thermodynamics of CVD, gas transport, growth kinetics, Plasma chemistry, plasma etching mechanisms; etch rate and selectivity, orientation dependent etching; PECVD.	
Module-5	**Characterization of thin films**: Deposition rate, Film thickness and uniformity, Structural properties: Crystallographic properties, defects, residual stresses, adhesion, hardness, ductility, electrical properties, magnetic properties; optical properties.	**[6]**

Text books:

1. The Material Science of Thin Films by Milton Ohring, Academic Press, Inc., 1992.
2. Handbook of Thin Films by Maissel and Glang
3. Thin Film Phenomena by K. L. Chopra (McGraw Hill, 1969)

Reference books:

1. Thin Film Deposition: Principles & Practice by Donald L. Smith (McGraw Hill, 1995)
2. Coating Technology Handbook by D. Satas, A. A. Tracton, Marcel Dekkar Inc. USA.
3. Arc Plasma Technology in Material Science, P. A. Gerdeman and N. L. Hecht, Springer Verlag, 1972.

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	No
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

AssessmentCompoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	Yes	Yes	Yes	No	No
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment	Yes	Yes	Yes	Yes	Yes

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	L	M	L
2	H	H	M	L	L	L
3	H	M	M	L	L	L
4	H	M	M	L	L	L
5	H	H	H	L	H	L

Course Outcome #	Course Objectives				
	a	b	c	d	e
1	H	M	M	M	L
2	M	H	M	M	L
3	M	M	H	L	L
4	M	M	H	L	L
5	M	M	L	L	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD8
CD2	Tutorials/Assignments		CO2	CD1, CD2 and CD8
CD3	Seminars		CO3	CD1, CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Module No.	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1-2	L1-2		I	Classification of vacuum ranges, Kinetic theory of gases	T2	CO-1		PPT Digi Class/Chalk-Board	
	L3-4			gas transport and pumping, Conductance and Throughput	T2	CO-1		PPT Digi Class/Chalk -Board	
2	L5			Classification of vacuum pumps, single stage and	T1	CO-1		PPT Digi Class/Chalk-Board	

				double stage rotary pump, diffusion pump, turbomolecular pump,					
2-3	L6			cryopump and Classification of gauges, Mechanical gauges: McLeod gauge	T1	CO-1		PPT Digi Class/Chalk-Board	
3	L7			Thermal conductivity gauges: Pirani gauge and thermocouple gauge,		CO-1		PPT Digi Class/Chalk-Board	
3	L8			Ionization gauges: Bayard-Alpert gauge, Penning gauge, leak detection.	T3	CO-2		PPT Digi Class/Chalk-Board	
4	L9		II	Solid surface, interphase surface	T3	CO-2		PPT Digi Class/Chalk-Board	
4	L10			Surface energies: Binding energy and Interatomic Potential energy	T1	CO-2		PPT Digi Class/Chalk-Board	
5	L11-12			latent heat, surface tension, Liquid surface energy measurement by capillary effect, by zero creep	T1	CO-2		PPT Digi Class/Chalk-Board	
5	L13			magnitude of surface energy, General concept, jump frequency and diffusion flux		CO-2		PPT Digi Class/Chalk-Board	
6	L14-16			Fick's First law, Nonlinear diffusion, Fick's second law,	T1, T2, T3	CO-2		PPT Digi Class/Chalk-Board	

				calculation of diffusion coefficient, interdiffusion and diffusion in thin films					
7	L17-18		III	Stages of thin film formation: Nucleation, Adsorption, Surface diffusion	T1	CO-3		PPT Digi Class/Chalk-Board	
7-8	L19-20			capillarity theory of nucleation, statistical theory of nucleation, growth and coalescence of islands		CO-3		PPT Digi Class/Chalk-Board	
8	L21-22			grain structure and microstructure of thin films, diffusion during film growth	T2	CO-3		PPT Digi Class/Chalk-Board	
9	L23			polycrystalline and amorphous films, Theories of epitaxy	T1, T2,	CO-3		PPT Digi Class/Chalk-Board	
9	L24			role of interfacial layer, epitaxial film growth, super lattice structures	T2, T3	CO-3		PPT Digi Class/Chalk-Board	
9-10	L25-26		IV	Vacuum evaporation-Hertz-Knudsen equation, evaporation from a source and film thickness uniformity	T1	CO-4		PPT Digi Class/Chalk-Board	
10	L27-28			Glow discharge and plasmas-Plasma structure, DC, RF and microwave excitation	T1	CO-4		PPT Digi Class/Chalk-Board	
11	L29-30			Sputtering processes-Mechanism and	T2	CO-4		PPT Digi Class/Chalk-Board	

				sputtering yield, Sputtering of alloys					
11-12	L31-32			magnetron sputtering, Reactive sputtering	T2	CO-4		PPT Digi Class/Chalk-Board	
12	L33-34			vacuum arc: cathodic and anodic vacuum arc deposition. Chemical vapour deposition	T2	CO-4		PPT Digi Class/Chalk-Board	
13	L35-36			Thermodynamics of CVD, gas transport, growth kinetics, Plasma chemistry	T2	CO-4		PPT Digi Class/Chalk-Board	
14	L37-39			plasma etching mechanisms; etch rate and selectivity, orientation dependent etching; PECVD	T2	CO-4		PPT Digi Class/Chalk-Board	
14	L40		V	Deposition rate, Film thickness and uniformity	T2	CO-5		PPT Digi Class/Chalk-Board	
15	L41			Structural properties: Crystallographic properties, defects	T2	CO-5		PPT Digi Class/Chalk-Board	
15	L42			residual stresses, adhesion, hardness, ductility	T2	CO-5		PPT Digi Class/Chalk-Board	
15	L43			electrical properties	T2	CO-5		PPT Digi Class/Chalk-Board	
16	L44			magnetic properties;	T2	CO-5		PPT Digi Class/Chalk-Board	
16	L45			optical properties	T2	CO-5		PPT Digi Class/Chalk-Board	

COURSE INFORMATION SHEET

Course code: PH 520
Course title: Theory of Dielectrics and Ferroics
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level:PE VI / VII
Branch: PHYSICS
Name of Teacher:
Group : B **Option 4**

		L T C P
Code: PH 520	**Title: Theory of dielectrics and ferroics**	3-1-0-4

Course Objectives

This course enables the students:

A.	To become familiar with the concept of polarisation in ideal and non-ideal dielectrics.
B.	To be familiarized with electrochemical impedance spectroscopy.
C.	To become familiar with the theory of ferroelectricity using domain theory and understand different type of phase transition in ferroelectric materials.
D.	To acquire an understanding of the theory of ferromagnetism and know about the different types of magnetic ordering.
E.	To become familiar with the concept of multiferroics and different types of mechanisms by which multiferroics can be formed.

Course Outcomes

After the completion of this course, students will be:

1.	Able to differentiate between different type of dielectrics, ferroelectrics and able to interpret the experimental results with different theoretical models.
2.	Able to apply the concept of relaxation, resonance and dispersion in dielectrics using frequency and time domain method.
3.	Able to differentiate between different types of ferroelectric materials and able to calculate the recoverable energy, efficiency from the hysteresis loop.
4.	Able to identify and compare different kinds of magnetic ordering.
5.	Able to categorize different types of multiferroics based on the different mechanisms of their origin.

Module-1	Macroscopic theory of dielectrics: Polarisation in dielectrics, Clausius Mosotti relation for ideal dielectrics, Lorentz field, Debye correction to Clausius Mosotti equation, frequency and temperature dependency of dielectrics, Temperature coefficient of dielectrics, dielectric losses. The double well potential model for polarization and determination of depth of potential wells.	**[10]**
Module-2	Dielectric spectroscopy: introduction to impedance spectroscopy, physical models for equivalent circuit elements, dielectric relaxation in materials with single time constant, distribution of relaxation time, interface and boundary conditions, grain boundary effects. Elementary idea of measurement technique in frequency and time domain methods.	**[10]**
Module-3	Ferroelectricity: Ferroelectricity, Microscopic theory of Ferroelectricity, Landau primer of ferroelectricity, Phase transition of ferroelectrics (1^{st}, 2^{nd} and relaxor kind), soft optical phonons, hysteresis loop, Recoverable energy, Piezoelectricity and energy harvesting, transducer.,	**[10]**
Module-4	Ferromagnetism: Weiss model of a ferromagnet, magnetic susceptibility, effect of a magnetic field, origin of the molecular field, Weiss model of antiferromagnet, magnetic susceptibility, effect of a strong magnetic field, types of antiferromagnetic order, ferrimagnetism, helical order, spin glasses, frustration.	**[10]**

Module-5	Multiferroics: Ferroic, magnetoelectric, multiferroic, magnetodielectric, magnetoelectric coupling, Type I and Type II Multiferroics, charge-order driven multiferroicity, examples of charge-ordered driven multiferroicity, lone-pair electron multiferroic systems, geometric ferroelectricity, frustrated magnetism triggered ferroelectricity, applications of multiferroics: magnetoelectric switching, multiferroics for spintronics.	**[10]**

Textbooks:

1. Applied Electromagnetism and Materials by Andre Moliton, Springer, 2007
2. Magnetism in Condensed Matter, Oxford Master Series in Condensed Matter Physics 4, Stephen Blundell, Oxford University Press, 2001.
3. Multiferroic Materials: Properties, Techniques and Applications, Junling Wang, CRC Press, Taylor and Francis group, 2017.

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Yes
Tutorials/Assignments	Yes
Seminars	Yes
Mini projects/Projects	No
Laboratory experiments/teaching aids	No
Industrial/guest lectures	No
Industrial visits/in-plant training	No
Self- learning such as use of NPTEL materials and internets	Yes
Simulation	No

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

AssessmentCompoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	Yes	Yes	Yes	No	No
End Sem Examination Marks	Yes	Yes	Yes	Yes	Yes
Assignment	Yes	Yes	Yes	Yes	Yes

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	M	H	H	L	L	M
2	L	H	H	L	L	M
3	M	H	H	L	L	L
4	H	M	M	L	L	L
5	M	H	H	H	L	L

Course Outcome #	Course Objective				
	a	b	c	d	e
1	H	M	M	L	M
2	M	H	M	L	M
3	M	M	H	L	M
4	L	L	L	H	H
5	M	M	M	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2 and CD8
CD2	Tutorials/Assignments		CO2	CD1, CD2 and CD8
CD3	Seminars		CO3	CD1, CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Module No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-2		I	Macroscopic theory of dielectrics: Polarisation in dielectrics, ClausiusMosotti relation for ideal dielectrics,	T1	1, 2		PPT Digi Class/Chalk -Board	
1	L3			Lorentz field, Debye correction to ClausiusMosotti equation,	T1			PPT Digi Class/Chalk -Board	
1	L4-L5			frequency and temperature dependency of dielectrics,	T1			PPT Digi Class/Chalk -Board	

2	L6			Temperature coefficient of dielectrics, dielectric losses.	T1			PPT Digi Class/Chalk -Board	
2	L7-8			The double well potential model for polarization and determination of depth of potential wells.	T1			PPT Digi Class/Chalk -Board	
4	L9-10		II	Dielectric spectroscopy: introduction to impedance spectroscopy,	T1			PPT Digi Class/Chalk -Board	
4	L11			physical models for equivalent circuit elements	T1			PPT Digi Class/Chalk -Board	
5	L12-13			dielectric relaxation in materials with single time constant, distribution of relaxation time,	T1			PPT Digi Class/Chalk -Board	
5	L14-15			interface and boundary conditions, grain boundary effects.	T1			PPT Digi Class/Chalk -Board	
6	L16			Elementary idea of measurement technique in frequency and time domain methods.	T1			PPT Digi Class/Chalk -Board	
	L17		III	Ferroelectricity: Ferroelectricity, Microscopic theory of Ferroelectricity,	T1			PPT Digi Class/Chalk -Board	
	L18			Landau primer of ferroelectricity,	T1			PPT Digi Class/Chalk -Board	
	L19			Phase transition of ferroelectrics (1^{st}, 2^{nd} and relaxor kind),	T1			PPT Digi Class/Chalk -Board	
	L20			soft optical phonons, hysteresis loop,	T1			PPT Digi Class/Chalk -Board	
	L21-24			Recoverable energy, Piezoelectricity and energy harvesting, transducer	T1			PPT Digi Class/Chalk -Board	
	L25		IV	Ferromagnetism: Weiss model of a ferromagnet,	T2			PPT Digi Class/Chalk -Board	
	L26			magnetic susceptibility,effect of a magnetic field,	T2			PPT Digi Class/Chalk -Board	
	L27			origin of the molecular field, Weiss model of antiferromagnet, magnetic susceptibility	T2			PPT Digi Class/Chalk -Board	

	28			effect of a strong magnetic field,	T2			PPT Digi Class/Chalk -Board	
	29-30			types of antiferromagnetic order	T2			PPT Digi Class/Chalk -Board	
	L31-32			ferrimagnetism, helical order, spin glasses, frustration.	T2			PPT Digi Class/Chalk -Board	
	L33		V	Multiferroic, magnetoelectric, multiferroic,	T3			PPT Digi Class/Chalk -Board	
	L34			magnetodielectric, magnetoelectric coupling, Type I and Type II Multiferroics,	T3			PPT Digi Class/Chalk -Board	
	L35			charge-order driven multiferroicity, examples of charge-ordered driven multiferroicity,	T3			PPT Digi Class/Chalk -Board	
	L36			lone-pair electron multiferroic systems,	T3			PPT Digi Class/Chalk -Board	
	L37-38			geometric ferroelectricity, frustrated magnetism triggered ferroelectricity,	T3			PPT Digi Class/Chalk -Board	
	L39-40			applications of multiferroics: magnetoelectric switching, multiferroics for spintronics	T3			PPT Digi Class/Chalk -Board	

<u>COURSE INFORMATION SHEET</u>

Course code: PH 515
Course title: Theoretical and Computational Condensed Matter Physics
Pre-requisite(s):
Co- requisite(s):
Credits: **4**L: 2 T: 0 P:4
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE VI / VII
Branch: PHYSICS
Name of Teacher:
Group : B **<u>Option 5</u>**

Same Given As above(in Group A)

Group C- Photonics:	
1. Photonic and Optoelectronic Devices 2. Holography and Applications 3. Quantum photonics and applications	4. Introduction to Nanophotonics

COURSE INFORMATION SHEET

Course code: PH 521
Course title: Photonics and Optoelectronic Devices
Pre-requisite(s):
Co- requisite(s):
Credits: **4**L: 3 T:1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: VI / VII
Branch: PHYSICS
Name of Teacher:
Group : C **Option 1**

Code: PH 521	Title: Photonics and Optoelectronic Devices	L-T-P-C [3 1 0 4]

Course Objectives This course enables the students:

	To explain the properties of optoelectronic material and optical processes in semiconductor.
B.	To understand underlying principle & working of liquid crystal displays, optical modulator, and switches.
C.	To understand principle & working of light sources and photodetectors.
D	To know the working of optical nonlinear devices and understand its significance for optical computing.
E	To acquire the knowledge of the function and working of photonic switches and interconnects

Course Outcomes After the completion of this course, students will be:

1.	Able to identify suitable optoelectronic materials and explain optical phenomena occurring in semiconductor
2.	Able to recognize parameters for optimizing the performance of liquid crystal displays, optical modulator, and switches & solve related numerical problems.
3.	Able to identify the parameters for optimizing the performance of light sources and detectors.
4.	To define the role of different nonlinear optical devices in optical computing.
5.	To select appropriate photonic switch and interconnect for different operations under different working condition.

Module-1	**Optical processes in semiconductors:** Electron-hole pair formation and recombination, Direct and indirect bandgap semiconductors, structural property of crystalline, polycrystalline, amorphous materials, optoelectronic materials, Liquid crystals, compound semiconductors, absorption in semiconductors, Stark effects in quantum well structures, Absorption and emission spectra, excitonic effects.	**10**
Module-2	**Displays, optical modulators, and switches:** Liquid crystal cells (principle), Passive and Active matrix liquid crystal displays, Electro-optic modulator, Magneto-optic modulator, Acousto-optic modulator. Electro-absorption modulators, Mach-Zehnder Electrorefraction (Electro-optic) modulators, optical switches.	**8**
Module-3	**Optical sources and detectors:** Light emitting diodes, surface- and edge- emitting configuration. Injection laser diodes, gain and index guided lasers, PIN and avalanche photodiodes, Photoconductors, Phototransistors, noise in photodetector. Solar cells (spectral response, conversion efficiency), Charge-coupled devices, Characteristics and applications.	**12**
Module-4	**Optical computing:** Digital optical computing: Nonlinear devices, optical bistable devices, SEED devices, Optical phase conjugate devices, integrated devices, spatial light modulators (SLM), Optical Memory: Holographic data storage	**10**
Module-	**Photonic switching and interconnects:** Kerr gates, Nonlinear Directional couplers, Nonlinear optical	**10**

5	loop mirror (NOLM), Soliton logic gates, Free-space optical interconnects, wave-guide interconnects, holographic inteconnections.	

References

1. Essentials of optoelectronics, Alan Rogers, 1st Ed., Chapman & Hall.
2. Introduction to Fiber Optics, Ghatak & Thyagarajan, Cambridge University press.
3. Optoelectronics: An Introduction to Materials and Devices, Jasprit Singh, The McGraw-Hill Companies.
4. Semiconductor Optoelectronics Devices, P. Bhattacharya, PHI.
5. Optoelectronics and Photonics, principles and practices S. O. Kasap, Prentice Hall
6. Photonic switching and Interconnects; Abdellatif Marrakchi, Marcel Dekker, Inc.
7. Optical Computing, an Introduction, Mohammad A. Karim and Abdul A. S Awwal, John Wiley & Sons Inc

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

AssessmentCompoents	CO1	CO2	CO3	CO4	CO5
Quiz 1	√	√			
Quiz 2			√	√	
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Assignment	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objective	Course Outcomes				
	1	2	3	4	5
A	H	H	H	H	H
B	L	H	M	M	L
C	M	H	H	M	H
D	M	M	H	H	H
E	M	H	H	H	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	-	H	M
2	H	H	H	-	H	H
3	M	H	H	-	H	H
4	M	H	M	-	H	H
5	L	H	M	-	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1, CD2
CD2	Tutorials/Assignments		CO2	CD1
CD3	Seminars		CO3	CD1, CD2
CD4	Mini projects/Projects		CO4	CD1, CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD8
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1		1	Electron-hole pair formation and recombination	R3, R4, R5	1, 2		CD1, CD2	
	L2			Direct and indirect bandgap semiconductors	R3, R4, R5	1		CD1, CD2	
	L3			structural property of crystalline, polycrystalline, amorphous materials,	R3, R4	1		CD1, CD2	
	L4			optoelectronic materials	R3, R4, R5	1		CD1, CD2	
2	L5			Liquid crystals,	R3	1		CD1, CD2	
	L6			compound semiconductors	R4	1		CD1, CD2	
	L7			absorption in semiconductors	R3, R4, R5	1		CD1, CD2	
	L8			Stark effects in quantum well structures	R3, R4, R5	1		CD1, CD2	
3	L9			Absorption and	R3, R4,	1		CD1,	

				emission spectra	R5			CD2	
	L10			excitonic effects	R4	1		CD1, CD2	
	L11		2	Liquid crystal cells (principle)	R3	2		CD1, CD2	
	L12			Passive and Active matrix liquid crystal displays	R3	2		CD1, CD2	
4	L13			Electro-optic modulator	R3, R4, R5	1,2		CD1, CD2	
	L4			Magneto-optic modulator	R3, R4, R5	1,2		CD1, CD2	
	L15			Acousto-optic modulator	R3, R4, R5	1,2		CD1, CD2	
	L16			Electro-absorption modulators	R3, R4, R5	1,2		CD1, CD2	
5	L17			Mach-Zehnder Electrorefraction (Electro-optic) modulators	R3, R4, R5	1,2		CD1, CD2	
	L18			optical switches	R4	1,2		CD1, CD2	
	L19		3	Light emitting diodes	R3, R4, R5	1,3		CD1, CD2	
	L20			Surface- emitting configuration	R3, R4, R5	1,3		CD1, CD2	
6	L21			edge- emitting configuration	R3, R4, R5	1,3		CD1, CD2	
	L22			Injection laser diodes	R3, R4, R5	1,3		CD1, CD2	
	L23			gain and index guided lasers	R3, R4, R5	1,3		CD1, CD2	
	L24			PIN photodiodes	R3, R4, R5	1,3		CD1, CD2	
7	L25			Avalanche photodiodes	R3, R4, R5	1,3		CD1, CD2	
	L26			Photoconductors	R3, R4, R5	1,3		CD1, CD2	
	L27			Phototransistors	R3, R4, R5	1,3		CD1, CD2	
	L28			Noise in photodetector	R3, R4, R5	1,3		CD1, CD2	
8	L29			Solar cells (spectral response, conversion efficiency)	R3, R4, R5	1,3		CD1, CD2	
	L30			Charge-coupled devices, Characteristics and applications	R3, R4, R5	1,3		CD1, CD2	
	L31		4	Digital optical computing	R6, R7	3,4		CD1, CD8	
9	L32			Nonlinear devices	R4, R6	3,4		CD1, CD8	

	L33			optical bistable devices	R4	3,4		CD1, CD8	
	L34			SEED devices	R4	3,4		CD1, CD8	
	L35			Optical phase conjugate devices	R6, R7	3,4		CD1, CD8	
10	L36 - L37			integrated devices	R6, R7	3,4		CD1, CD8	
	L38 - L39			spatial light modulators (SLM)	R6, R7	3,4		CD1, CD8	
	L40			Optical Memory: Holographic data storage	R6, R7	4,5		CD1, CD8	
11	L41		5	Kerr gates	R4, R6, R7	4,5		CD1, CD8	
	L42 - L43			Nonlinear Directional couplers	R6, R7	4,5		CD1, CD8	
	L44			Nonlinear optical loop mirror (NOLM)	R6, R7	4,5		CD1, CD8	
12	L45			Soliton logic gates	R6, R7	4,5		CD1, CD8	
	L46 - L47			Free-space optical interconnects	R6, R7	4,5		CD1, CD8	
13	L48 - L49			wave-guide interconnects	R6, R7	4,5		CD1, CD8	
	L50			holographic inteconnections	R6, R7	4,5		CD1, CD8	

<u>**COURSE INFORMATION SHEET**</u>

Course code: PH 522
Course title: Holography and Applications
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 3 T:1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: VI / VII
Branch: PHYSICS
Name of Teacher:
Group : C <u>**Option 2**</u>

Code: PH 522	Title: Holography and Applications	L-T-P-C [3 1 0 4]

Course Objectives This course enables the students:

A.	To understand the basics of holograms and able to differentiate between holography and photography
B.	To acquire the knowledge of different types of holograms.
C.	To understand different materials used for hologram recordings and its merits and demerits.
D.	To have an idea of using holographic technique in varieties of diverse applications
E	To acquire knowledge in holographic optical elements and to estimate how these optical elements can be utilized.

Course Outcomes After the completion of this course, students will be:

1.	Able to identify the parameters which differentiate holograms from photographs
2.	Able to distinguish between various types of holograms.
3.	Able to analyze the different parameters of holographic recording materials.
4.	Able to utilize holographic interferometric technique in various new applications
5.	Able to experiment with holographic elements for various applications.

Module-1	**Basics of Holography:** Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves. Point source holograms, In line Hologram, off axis hologram, Fourier Hologram, Lenses Fourier Hologram, Image Hologram, Fraunhofer Hologram. Holographic interferometer, double exposure hologram, real-time holography, digital holography, holographic camera.	**[10]**
Module-2	**Theory of Hologram:** Coupled wave theory, Thin Hologram, Volume Hologram, Transmission Hologram, Reflection Hologram, Anomalous Effect.	**[8]**
Module-3	**Recording Medium:** Microscopic Characteristics, Modulation transfer function, Diffraction efficiencies, Image Resolution, Nonlinearities, S/N ratio, Silver halide emulsion, Dichromated gelatin, Photoresist, Photochrometics, Photothermoplastics, photorefractive crystals.	**[13]**
Module-4	**Applications**: Microscopy, interferometry, NDT of engineering objects, particle sizing, holographic particle image velocimetry; imaging through aberrated media, phase amplification by holography; Optical testing; Information storage.	**[13]**
Module-5	Holographic Optical Elements (HOE): multifunction, holographic lenses, holographic mirror, holographic beam splitters, polarizing, diffuser, interconnects, couplers, scanners; Optical data processing, holographic solar connectors; antireflection coating, holophotoelasticity;	**[8]**

Text books:

T1: Optical Holography, Principle Techniques and applications: P. Hariharan, Cambridge University Press
T2: Holographic Recording materials; H.M.Smith, Springer Verlag

Reference books: R1: Lasers and Holography P C Mehta and V V Rampal, World Scientific

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I	√	√			
Quiz II			√	√	

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	L	H	
B	H	H	M	M	L
C	H	H	H	M	M
D		M	M	H	H
E	L	M	M	H	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	M	H	H		L	H

2	M	H	M		M	H
3	M	H	H	L	L	M
4	M	M	H	L	H	M
5	M	M	M	L	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	**Course Delivery methods**		**Course Outcome**	**Course Deliver Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No	Topics to be covered	Text Book / References	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L2			Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves	T1, R1	CO1		PPT Digi Class/Chock-Board	
	L3-L6			Point source holograms, In line Hologram, off axis hologram, Fourier Hologram, Lenses Fourier Hologram, Image Hologram	T1, R1	CO1		PPT Digi Class/Chock-Board	
	L7-L10			Fraunhofer Hologram. Holographic interferometer, double exposure hologram, real-time holography, digital holography	T1, R1	CO1		PPT Digi Class/Chock-oard	
	L11-L14			Theory of Hologram: Coupled wave theory, Thin Hologram, Volume Hologram	T1, R1	CO2		PPT Digi Class/Chock-Board	
	L15-			Transmission Hologram,	T1, R1	CO2		PPT Digi Class/Ch	

	L18			Reflection Hologram, Anomalous Effect.				ock-Board	
	L19-L22			Recording Medium: Microscopic Characteristics, Modulation transfer function, Diffraction efficiencies,	T2, R1	CO3		PPT Digi Class/Ch ock-Board	
	L23-L26			Image Resolution, Nonlinearities, S/N ratio, Silver halide emulsion	T2, R1	CO3		PPT Digi Class/Ch ock-Board	
	L27-L31			Dichromated gelatin, Photoresist, Photochrometics, Photothermoplastics, photorefractive crystals.	T2, R1	CO3		PPT Digi Class/Ch ock-Board	
	L32-L35			Applications: Microscopy, interferometry, NDT of engineering objects, particle sizing,	T1, R1	CO4		PPT Digi Class/Ch ock-oard	
	L36-L39			holographic particle image velocimetry; imaging through aberrated media	T1, R1	CO4		PPT Digi Class/Ch ock-Board	
	L40-L44			phase amplification by holography; Optical testing; Information storage	T1, R1	CO4		PPT Digi Class/Ch ock-oard	
	L45-L46			Holographic Optical Elements (HOE): multifunction, holographic lenses, holographic mirror	T1, R1	CO5		PPT Digi Class/Ch ock-Board	
	L47-L50			holographic beam splitters, polarizing, diffuser, interconnects, couplers, scanners	T1, R1	CO5		PPT Digi Class/Ch ock-Board	
	L51-L52			Optical data processing, holographic solar connectors; antireflection coating, holophotoelasticity	T1, R1	CO5		PPT Digi Class/Ch ock-Board	

COURSE INFORMATION SHEET

Course code: PH 523
Course title: Quantum photonics and applications
Pre-requisite(s):

Co- requisite(s):
Credits: **4** L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: VI / VII
Branch: PHYSICS
Name of Teacher:
Group : C **Option 3**

Code: PH 523	**Title: Quantum photonics and applications**	**L-T-P-C** [3 1 0 4]

Course Objectives : This course enables the students:

A.	To assess light-matter interaction at the nanoscale (1-100 nm) in terms of photon statistics for identification of single photon sources.
B.	To Identify various plasmonic nanoantenna (nanoparticles, nanorods) for enhanced electromagnetic interaction
C.	To identify a source of single photons and discuss a method to detect the single photons efficiently.
D.	To design chip scale devices for propagation of single photons for quantum communications
E	To assess the present status and future applications of single photons in quantum technology

Course Outcomes : After the completion of this course, students will be

1.	Able to identify semiconducting quantum dot as a single photon source.
2.	To develop skills of designing a suitable metal nanoantenna for enhanced light-matter interaction, thus making single photon source faster and brighter.
3.	To characterize (theoretically) whether a given source of the photon, is a single photon source.
4.	To design (theoretically) photonic circuits for the propagation of single photons on semiconductor and metallic platform.
5.	To understand the modern and future scope of quantum communication.

Module-1	Classical optical communications and their limitations, quantum optical communications, Semiconducting quantum dots, quantum dot single photon sources, classification of light states and photon statistics. Photon detection and correlation function.Single-Photon Pulses and Indistinguishability of Photons.	**12**
Module-2	Plasmonic nanoantennas, fabrications, characterizations and applications in quantum communications devices	**8**
Module-3	Single photon sources for quantum information: Fabrication and characterizations, Han burry Brown and Twiss measurements (single photons characterization), The Hong–Ou–Mandel effect (indistinguishability test).	**12**
Module-4	Resonant excitation of single photon sources, Integrated quantum photonic circuits and devices, semiconductor, metallic platform, single photon filtering and multiplexing. .	**8**
Module-5	Principles of quantum key distribution (QKD), Implementing QKD, Fiber-based QKD, Free-space QKD, Diamond-based single-photon sources and their application in quantum key distribution, Quantum repeaters	**10**

Reference:

1. Michler, P. (Ed.). (2009). Single semiconductor quantum dots (Vol. 28). Berlin: Springer.
2. Novotny, L. & Hecht, B., Principles of nano-optics, Cambridge university press, 2006
3. Lounis, B., &Orrit, M. (2005). Single-photon sources. Reports on Progress in Physics, 68(5), 1129.
4. Prawer, Steven, and Igor Aharonovich, eds. Quantum information processing with diamond: Principles and applications. Elsevier, 2014.
5. Briegel , H.-J. , Dürr , W. , Cirac , J. I. and Zoller , P. (1998) ‘ Quantum repeaters: The role of imperfect local operations in quantum communication ’, Phys Rev Lett , 81 , 5932 – 5935 ,

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y

Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	M	L	M
B	M	H	M	L	L
C	L	L	H	L	L
D	-	L	L	H	L
E	L	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	H	L	H
2	H	H	H	H	M	H
3	H	H	H	M	L	M
4	H	M	H	H	L	M
5	M	H	H	H	H	H

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L2		1	Classical optical communications and their limitations, quantum optical communications	T1, T2,	1,2		PPT Digi Class/ Chock -Board	
	L3-L7			Semiconducting quantum dots, quantum dot single photon sources,		1,		Digi Class/ Chock -Board	
	L8-L10			classification of light states and photon statistics		1,2		Digi Class/Chock -Board	
	L11-L12			Photon detection and correlation function.Single-Photon Pulses and Indistinguishability of Photons..		1,2,3		Digi Class/Chock-Board	
	L13-L20			Plasmonic nanoantennas, fabrications, characterizations and applications in quantum communications devices.		1,2		DigiClass /Chock -Board	
	L21-L32			Single photon sources for quantum information: Fabrication and characterizations, Han burry Brown and Twiss measurements (single photons characterization), The Hong–Ou–Mandel effect (indistinguishability		1		Digi Class/Chock -Board	

				test).					
	L33-L40			Resonant excitation of single photon sources, Integrated quantum photonic circuits and devices, semiconductor, metallic platform, single photon filtering and multiplexing.		2		Digi Class/Chock -Board	
	L41-L50			Principles of quantum key distribution (QKD), Implementing QKD, Fiber-based QKD, Free-space QKD, Diamond-based single-photon sources and their application in quantum key distribution, Quantum repeaters		3		Digi Class/Chock -Board	

COURSE INFORMATION SHEET

Course code: PH 524
Course title: Introduction to Nanophotonics
Pre-requisite(s):
Co- requisite(s):
Credits: **4** L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: VI / VII
Branch: PHYSICS
Name of Teacher:
Group C **Option 4**

Code: PH 524	**Title: Introduction to Nanophotonics**	**L-T-P-C [3 1 0 4]**

Course Objective: Course enables the students:

A	To identify optical phenomenon and tools to understand physics at nanoscales.
B.	To evaluate different quantum systems in zero, one, two and three-dimensional system at the nanoscale.
C.	To discuss photonic crystals and manifestation of nonlinear optical interactions with it.
D	To discuss different types of microstructure fibres and photonic crystal fibre devices.
E	To identify the manifestation of optical interaction with metallic nanostructures and nanophotonic devices like microcavity and waveguides.

Course Outcomes : After the completion of this course, students will be:

1.	To solve problems of optical confinement at nanoscales.
2.	To evaluate light-matter interaction in Nano-systems (quantum dots, well etc).
3.	To design theoretical models for photonic crystals.
4.	To design (theoretically) different types of microstructure fibres and photonic crystal fibre devices
5.	To assess the field enhancement in metal nanoparticles and its application in surface plasmon waveguides. Further he/she will be able to apply knowledge of light confinement in microcavity for microcavity lasers.

Module-1	Foundations for Nanophotonics: similarities and differences of photons and electrons and their confinement. Propagation through a classically forbidden zone: tunnelling. Localization under a periodic potential: Band gap. Cooperative effects for photons and electrons. Nanoscale optical interactions, axial and lateral nanoscopic localization, scanning near-field optical microscopy. Nanoscale confinement of electronic interactions: Quantum confinement effects, nanoscale interaction dynamics, nanoscale electronic energy transfer. Cooperative emissions	**10**
Module-2	Quantum wells, quantum wired, quantum dots, quantum rings and superlattices. Quantum confinement, density of states, optical properties. Quantum confined stark effect. Dielectric confinement effect, Core-shell quantum dots and quantum-dot-quantum wells. Quantum confined structures as lasing media. Organic quantum-confined structures	10
Module-3	Photonic Crystals: basics concepts, features of photonic crystals, wave propagation, photonic band-gaps, light guiding. Theoretical modeling of photonic crystals. Methods of fabrication. Photonic crystal optical circuitry. Nonlinear photonic crystals. Applications of photonic crystals. Microstructure fibers: photonic crystal fiber (PCF), photonic band gap fibers (PBG), band gap guiding, single mode and multi-mode, dispersion engineering, nonlinearity engineering, PCF devices. .	12
Module-4	Plasmonics: Metallic nanoparticles, nanorods and nanoshells, local field enhancement. Collective modes in nanoparticle arrays, particle chains and arrays. surface plasmons, plasmon waveguides. Applications of metallic Nanostructures	8
Module-5	Nanophotonic Devices: Quantum well lasers: resonant cavity quantum well lasers and light emitting diodes, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavity LED. Microcavity-based single photon sources.	10

References:

T1. Nanophotonics, Paras N Prasad, John Wiley & Sons (2004)
T2 . Fundamentals of Photonic Crystal Fibers; Fredric Zolla- Imperial College Press.
T3. Photonic Crystals; John D Joannopoulos, Princeton University Press.
T4 Photonic Crystals: Modelling Flow of Light; John D Joannopoulos, R.D. Meade and J.N.Winn, Princeton University Press (1995)

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II				√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	M	L	M
B	M	H	M	L	L
C	L	L	H	L	L
D	-	L	L	H	L
E	L	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	H	L	H

2	H	H	H	H	M	H
3	H	H	H	M	L	M
4	H	M	H	H	L	M
5	M	H	H	H	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 and CD2
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L4		1	Foundations for Nanophotonics: similarities and differences of photons and electrons and their confinement. Propagation through a classically forbidden zone: tunneling. Localization under a periodic potential: Band gap.	T1, T2,	1,2		PPT Digi Class/Chock -Board	
	L3-L7			Cooperative effects for photons and electrons. Nanoscale optical interactions, axial and lateral nanoscopic localization, scanning near-field optical microscopy.		1,		Digi Class/Chock -Board	
	L8-L10			Nanoscale confinement of electronic interactions: Quantum confinement effects, nanoscale interaction dynamics, nanoscale		1,2		Digi Class/Chock -Board	

				electronic energy transfer. Cooperative emissions					
	L11-L12			Quantum wells, quantum wired, quantum dots, quantum rings and superlattices. Quantum confinement, density of states, optical properties...		1,2,3		Digi Class/Ch ock -Board	
	L13-L15			Quantum confined stark effect. Dielectric confinement effect, Core-shell quantum dots and quantum-dot-quantum wells.		1,2		Digi Class/Ch ock -Board	
	L16-L20			Quantum confined structures as lasing media. Organic quantum-confined structures		3		Digi Class/Ch ock -Board	
	L21-L25			Photonic Crystals: basics concepts, features of photonic crystals, wave propagation, photonic band-gaps, light guiding. Theoretical modeling of photonic crystals. Methods of fabrication		3		Digi Class/Ch ock -Board	
	L26-L30			Photonic crystal optical circuitry. Nonlinear photonic crystals. Applications of photonic crystals. Microstructure fibers: photonic crystal fiber (PCF), photonic band gap fibers (PBG), band gap guiding, single mode and multi-mode, dispersion engineering, nonlinearity engineering, PCF devices. .		3			
	L31-L35			Plasmonics: Metallic nanoparticles, nanorods and nanoshells, local field enhancement. Collective modes in nanoparticle arrays, particle chains and arrays. surface plasmons, plasmon		4			

				waveguides. Applications of metallic Nanostructures					
	L36-L50			Nanophotonic Devices: Quantum well lasers: resonant cavity quantum well lasers and light emitting diodes, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavity LED. Microcavity-based single photon sources.		5			

Group D- Electronics:	
1. Microprocessor and Microcontroller Applications **2.** Integrated Electronics	**3.** Microwave Electronics

COURSE INFORMATION SHEET

Course code: PH 525
Course title: Microprocessor and Microcontroller Applications
Pre-requisite(s):
Co- requisite(s):
Credits: **4** L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level:PE VI / VII
Branch: PHYSICS
Name of Teacher:
Group : D **Option 1**

Code: PH 525	**Title: Microprocessor and Microcontroller Applications**	**L-T-P-C** **3-1-0-4**

Course Objectives

This course enables the students:

A.	The first module introduces architecture of 8085 and 8086 Microprocessor.
B.	The module-2 is compilation of information about I/O communication Interface.
C.	Microcontrollers (8051), its architecture and working is subject of module-3
D.	The 4th module contains Real time control sequences and programming of 8051-microcontroller.
E.	The AVR RISC microcontroller architecture is covered in module-5.

Course Outcomes

After the completion of this course, students will be:

1.	The course intends to impart knowledge of Microprocessors and microcontrollers to enable learners gain the knowledge of basics of Modern computation.
2.	Knowledge of 8085/8086 architecture would make learners rich about working and design of microprocessors and microcontrollers.
3.	The course also includes information about microcontrollers, real time control of 8051 and AVR RISC microcontroller architecture. This would enable learners to understand fundamentals of microcontrollers and implement it to design / use microcontroller for new environments.

Module-1	**8086 Architecture** Introduction to 8085 Microprocessor, 8086 Architecture-Functional diagram. Register Organization, Memory Segmentation. Programming Mode!. Memory addresses. Physical memory organization. Architecture of 8086, signal descriptions	[15]

	of 8086-common function signals. Minimum and Maximum mode signals. Timing diagrams. Interrupts of 8086. Instruction Set and Assembly Language Programming of 8086: Instruction formats, addressing modes, instruction set, assembler directives, macros, simple programs involving logical, branch and call instructions, sorting, evaluating arithmetic expressions, string manipulations.	
Module-2	**I/O and Communication Interface:** 8255 PPI various modes of operation and interfacing to 8086. Interfacing keyboard, display, stepper motor interfacing, D/A and A/D converter. Memory interfacing to 8086, Interrupt structure of 8086, Vector interrupt table, Interrupt service routine, Introduction to DOS and BIOS interrupts, Interfacing Interrupt Controller 8259 DMA Controller 8257 to 8086. Communication interface: Serial communication standards, Serial data transfer schemes. 8251 USART architecture and interfacing, RS-232, IEEE-4-88, Prototyping and trouble shooting	[14]
Module-3	**Introduction to Microcontrollers:** Overview of 8051 microcontroller. Architecture. I/O Ports. Memory organization, addressing modes and instruction set of 8051, simple program	[6]
Module-4	**8051 Real Time Control:** Interrupts, timer/ Counter and serial communication, programming Timer Interrupts, programming external hardware interrupts, programming the serial communication interrupts, programming 8051 timers and counters.	[7]
Module-5	**The AVR RISC microcontroller architecture:** Introduction, AVR Family architecture, Register File, The ALU. Memory access and Instruction execution. I/O memory. EEPROM. I/O ports. Timers. UART. Interrupt Structure	[7]

TEXT BOOKS:

1 D. V. Hall. Micro processors and Interfacing, TMGH. 2'1 edition 2006.
2 Kenneth. J. Ayala. The 8051 microcontroller , 3rd edition, Cengage learning, 2010

REFERENCE BOOKS:

1 Advanced Microprocessors and Peripherals -A. K. Ray and K.M. Bhurchandani, TMH, 2nd edition 2006.
2 The 8051 Microcontrollers, Architecture and programming and Applications -K.Uma Rao, Andhe Pallavi,,Pearson, 2009.
3 Micro Computer System 8086/8088 Family Architecture. Programming and Design -By Liu and GA Gibson, PHI, 2nd Ed.,
4 Microcontrollers and application, Ajay. V. Deshmukh, TMGH. 2005

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I	√	√			
Quiz II			√	√	

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	Course Outcomes				
	1	**2**	**3**	**4**	**5**
A	H	M	M	L	H
B	M	H	M	M	H
C	L	L	H	M	L
D	M	L	L	H	H
E	H	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes						
	a	b	c	d	e	f	
1	H	M	H	M	M	M	
2	L	H	H	M	H	H	
3	H	L	M	M	L	M	
4	L	M	H	M	M	M	
5	L	H	H	M	H	H	

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / Refere	Cos mapped	Actual Content covered	Methodology used	Remarks by faculty if

					nces				any
1	L1-L2		1	Introduction to 8085 Microprocessor, 8086 Architecture-Functional diagram.	T1, R3	CO1		CD1, CD2	
	L3-L5			Register Organization, Memory Segmentation. Programming Model	T1,R3	CO1		CD1, CD2	
2	L6			Memory addresses. Physical memory organization.	T1,R3	CO1		CD1, CD2	
	L7-8			Architecture of 8086, signal descriptions of 8086-common function signals. Minimum and Maximum mode signals.	T1, R3	CO1		CD1, CD2	
3	L9			Timing diagrams. Interrupts of 8086.	T1, R3	CO1		CD1, CD2	
	L10-11			Instruction Set and Assembly Language Programming of 8086: Instruction formats, addressing modes, instruction set, assembler directives,	T1, R3	CO1		CD1, CD2	
4	L12-13			macros, simple programs involving logical, branch and call instructions, sorting,	T1, R3	CO1		CD1, CD2	
	L14-15			evaluating arithmetic expressions, string manipulations.	T1, R3	CO1		CD1, CD2	
5	L16		2	8255 PPI various modes of operation and interfacing to 8086	T2	CO2		CD1, CD2	
	L17-18			Interfacing keyboard, display, stepper motor interfacing, D/A and A/D converter.	T2	CO2		CD1, CD2	
6	L19-20			Memory interfacing to 8086, Interrupt structure of 8086, Vector interrupt table, Interrupt service routine,	T2	CO2		CD1, CD2	
	L21-22			Introduction to DOS and BIOS interrupts, Interfacing Interrupt Controller 8259 DMA Controller 8257 to 8086.	T2	CO2		CD1, CD2	
7	L23-25			Communication interface: Serial	T2	CO2		CD1, CD2	

				communication standards, Serial data transfer schemes.					
	L26-27			8251 USART architecture and interfacing, RS-232, IEEE-4-88,	T2	CO2		CD1, CD2	
8	L28-29			Prototyping and trouble shooting	T2	CO2		CD1, CD2	
	L30-31		3	Overview of 8051 microcontroller. Architecture.	T2	CO3		CD1, CD2	
9	L32-33			I/O Ports. Memory organization,	T2	CO3		CD1, CD2	
	L33-L34			addressing modes and instruction set of 8051,	T2	CO3		CD1, CD2	
	L35			simple program	T2	CO3		CD1, CD2	
10	L36-37		4	Interrupts, timer/ Counter and serial communication,	T2, R2	CO4		CD1, CD2	
	L38-39			programming Timer Interrupts, programming external hardware interrupts	T2, R2	CO4		CD1, CD2	
11	L40-41			programming the serial communication interrupts	T2, R2	CO4		CD1, CD2	
	L42			programming 8051 timers and counters	T2, R2	CO4		CD1, CD2, and CD8	
	L43		5	Introduction	R4	CO5		CD1, CD2, and CD8	
	L44-45			AVR Family architecture, Register File, The ALU.	R4	CO5		CD1, CD2, and CD8	
12	L46-47			Memory access and Instruction execution.	R4	CO5		CD1, CD2, and CD8	
	L48-49			Timers. UART. Interrupt Structure	R4	CO5		CD1, CD2, and CD8	

COURSE INFORMATION SHEET

Course code: PH 526
Course title: Integrated Electronics
Pre-requisite(s):
Co- requisite(s):

Credits: **4** L: 3 T:1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE VI / VII
Branch: PHYSICS
Name of Teacher:
Group : D **Option 2**

Code: **PH 526**	Title: **Integrated Electronics**		**L-T-P-C** **3-1-0-4**
Course Objectives This course enables the students: A. First module of the course contains information about various type of circuitry to achieve logic processing for digital devices. B. The second module of the course would introduce the learners to the processes currently being followed in foundry for fabrication of Integrated devices. C. The learners should explain different nanoscale devices. D. The working and construction of nanoscale electronic devices is planned to be covered in Module-4. E. The final module, module-5 contains an account of functional thin films, nanostructures and their applications. Information contained in this module bridges ongoing research with the course taught.			
Course Outcomes After the completion of this course, students will be: 1. This course would introduce students about designing and making process of integrated devices. 2. The various fabrication process taught in module-II would enrich their knowledge to various foundry fabrication processes enabling them with skills of nanofabrication. 3. Knowledge of functioning and construction of nanoscale electronic devices would cater the need to keep them update with recent technologies in the field. 4. Knowledge of functioning and construction of nanoscale optoelectronic devices would cater the need to keep them update with recent technologies in the field. 5 Knowledge of various types of functional thin films, nanostructures and their applications would enable learners understand working of presently used various type of sensors and devices.			
Module-1	**Logic Families** Diode Transistor Logic, High Threshold Logic, Transistor-transistor Logic, Resistor-transistor Logic, Direct Coupled Transistor Logic, Comparison of Logic families		5
Module-2	**Integrated Chip Technology** Overview of semiconductor industry, Stages of Manufacturing, Process and product trends, Crystal growth, Basic wafer fabrication operations, process yields, semiconductor material preparation, yield measurement, contamination sources, clean room construction, substrates, diffusion, oxidation and photolithography, doping and depositions, implantation, rapid thermal processing, metallization. patterning process, Photoresists, physical properties of photoresists, Storage and control of photoresists, photo masking process, Hard bake, develop inspect, Dry etching Wet etching, resist stripping, Doping and depositions: Diffusion process steps, deposition, Drive-in oxidation, Ion implantation, CVD basics, CVD process steps, Low pressure CVD systems, Plasma enhanced CVD systems, Vapour phase epitoxy, molecular beam epitaxy. Design rules and Scaling, BICMOS ICs: Choice of transistor types, pnp transistors, Resistors, capacitors, Packaging: Chip characteristics, package functions, package		20

	operations	
Module-3	**Nanoelectronic devices** Effect of shrinking the p-n junction and bipolar transistor; field-effect transistors, MOSFETs, Introduction, CMOS scaling, the nanoscale MOSFET, vertical MOSFETs, electrical characteristics of sub-100 nm MOS transistors, limits to scaling, system integration limits (interconnect issues etc.), heterostructure and heterojunction devices, ballistic transport and high-electron-mobility devices, HEMT, Carbon Nanotube Transistor, single electron effects, Coulomb blockade. Single Electron Transistor, Resonant Tunneling Diode, Resonant Tunneling Transistor, applications in high frequency and digital electronic circuits and comparison with competitive devices.	15
Module-4	**Nano-Optoelectronic devices** Direct and indirect band gap semiconductors, QWLED, QWLaser, Quantum Cascade Laser Integrated Micromachining Technologies for Transducer Fabrication	5
Module-5	**Applications of Functional Thin Films and Nanostructures** Functional Thin Films and Nanostructures for Gas Sensing, Chemical Sensors, Applications of Functional Thin Films for Mechanical sensing, Sensing Infrared signals by Functional Films.	5

References

Textbooks and Reference Books:

1 Herbert Taub, Donald L. Schilling, Digital Integrated Electronics, McGraw-Hill, 1977
2 S.M. Sze, Ed, Modern Semiconductor Device Physics, Wiley, New York
3 S.M. Sze and K.K. Ng, Physics of Semiconductor Devices, 3rd Ed, Wiley, Hoboken.
4 S. Wolf and R.N. Tauber, Silicon Processing, vol. 1, (Lattice Press)
5 S.Wolf and R. N. Tauber, Silicon Processing for the VLSI Era. (Lattice Press, 2000)
6 Streetman, B.G. Solid State Electronic Devices, Prentice Hall, Fifth Edition, 2000
7 R. D. Doering and Y. Nishi, Handbook of Semiconductor Manufacturing Technology, CRC Press, Boca Raton.
8 W. R. Fahrner (Editor), Nanotechnology and Nanoelectronics, Materials, Devices, Measurement Techniques
9 Anis Zribi, Jeffrey Fortin (Editors), Functional Thin Films and Nanostructures for Sensors Synthesis, Physics, and Applications

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Quiz I	√	√			
Quiz II			√	√	
Assessment	√	√	√	√	√
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	Course Outcome				
	1	2	3	4	5
A	H	L	M	M	M
B	M	H	H	H	H
C	L	M	H	H	M
D	L	M	M	H	H
E	L	M	H	H	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes					
	a	b	c	d	e	f
1	H	H	H	M	M	M
2	M	H	H	M	H	H
3	M	H	M	M	H	M
4	M	H	M	M	H	M
5	M	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD, CD2 and CD8
CD4	Mini projects/Projects		CO4	CD1, CD2 and CD8
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any

1	L1-L2		1	Diode Transistor Logic, High Threshold Logic, Transistor-transistor Logic	R2, R3, and R6			CD1, CD2	
	L3-L4			Resistor-transistor Logic, Direct Coupled Transistor Logic,	R2, R3, and R6			CD1, CD2	
	L5			Comparison of Logic families	R2, R3, and R6			CD1, CD2	
	L6-7		2	Overview of semiconductor industry, Stages of Manufacturing, Process and product trends	R1,R4, R5			CD1, CD2	
	L8-9			Crystal growth, Basic wafer fabrication operations, process yields, semiconductor material preparation,	R1, R4, R5			CD1, CD2	
	L9			yield measurement, contamination sources, clean room construction,	R1, R4, R5			CD1, CD2	
	L10-12			substrates, diffusion, oxidation and photolithography, doping and depositions, implantation, rapid thermal processing, metallization.	R1, R4, R5			CD1, CD2	
	L13-14			patterning process, Photoresists, physical properties of photoresists,	R1, R4, R5			CD1, CD2	
	L15-16			Storage and control of photoresists, photo masking process, Hard bake, develop inspect,	R1, R4, R5			CD1, CD2	
	L17-18			Dry etching Wet etching, resist stripping,	R1, R4, R5			CD1, CD2	
	L19-20			Doping and depositions: Diffusion process steps, deposition, Drive-in oxidation, Ion implantation,	R1, R4, R5			CD1, CD2	
	L21-22			CVD basics, CVD process steps, Low pressure CVD systems, Plasma enhanced CVD systems, Vapour phase epitoxy, molecular beam epitaxy.	R1, R4, R5			CD1, CD2	
	L23-24			Design rules and Scaling, BICMOS ICs: Choice of transistor types, pnp	R1, R4, R5			CD1, CD2	

				transistors, Resistors, capacitors					
	L25			Packaging: Chip characteristics, package functions, package operations	R1, R4, R5			CD1, CD2	
	L26-27		3	Effect of shrinking the p-n junction and bipolar transistor; field-effect transistors, MOSFETs,	R8, R9			CD1, CD2, and CD8	
	L28-29			Introduction, CMOS scaling, the nanoscale MOSFET, vertical MOSFETs	R8, R9			CD1, CD2, and CD8	
	L30-31			electrical characteristics of sub-100 nm MOS transistors, limits to scaling, system integration limits (interconnect issues etc.)	R8, R9			CD1, CD2, and CD8	
	L32-33			heterostructure and heterojunction devices, ballistic transport and high-electron-mobility devices,	R8, R9			CD1, CD2, and CD8	
	L34-L35			HEMT, Carbon Nanotube Transistor, single electron effects, Coulomb blockade.	R8, R9			CD1, CD2, and CD8	
	L36-38			Single Electron Transistor, Resonant Tunneling Diode, Resonant Tunneling Transistor	R8, R9			CD1, CD2, and CD8	
	L39-40			applications in high frequency and digital electronic circuits and comparison with competitive devices	R8, R9			CD1, CD2, and CD8	
	L41		4	Direct and indirect band gap semiconductors	R8, R9			CD1, CD2, and CD8	
	L42-43			QWLED, QWLaser, Quantum Cascade Laser	R8, R9			CD1, CD2, and CD8	
	L44-45			Integrated Micromachining Technologies for Transducer Fabrication	R8, R9			CD1, CD2, and CD8	
	L46-48		5	Functional Thin Films and Nanostructures for Gas Sensing, Chemical Sensors	R9			CD1, CD2, and CD8	
	L49-50			Applications of Functional Thin Films for Mechanical sensing, Sensing Infrared signals by Functional Films	R9			CD1, CD2, and CD8	

COURSE INFORMATION SHEET

Course code: PH 527
Course title: Microwave Electronics
Pre-requisite(s):
Co- requisite(s):
Credits: **4**L: 3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE VI / VII
Branch: PHYSICS
Name of Teacher:
Group : D **Option 4**

Code: PH 527	**Title: Microwave Electronics**	**L-T-P-C [3-1-0-4]**

Course Objectives

This course enables the students:

A.	Module-1 contains information about Transmission lines and wave-guides.
B.	The design and working of various types of micro-wave sources is covered in module-II.
C.	Module-III contains information about various types of stripline, microstrip lines and Network analysis.
D.	Knowledge about Micro-wave passive components and methods to measure various microwave parameters are planned to be covered in Module-IV.
E.	Module-V contains information about design, fabrication and working of microwave integrated circuit technology.

Course Outcomes

After the completion of this course, students will be:

1.	Leaner would gain knowledge about working, design and application of microwave frequency electronics.
2.	The course is intended to enrich the learner about Microwave transmission lines and waveguides. Through it students would be able to understand the propagation of microwave through transmission lines and Waveguides.
3.	Learner would gather understanding of devices used for microwave generation, detection and microwave network analysis
4.	Learner would also enrich their knowledge in terms of various microwave passive components, microwave parameters and microwave integrated circuit technology

Module-1	**Transmission lines and Waveguides** Introduction of Microwaves and their applications. Types of Transmission lines, Characterization in terms of primary and secondary constants, Characteristic impedance, General wave equation, Loss less propagation, Propagation constant, Wave reflection at discontinuities, Voltage standing wave ratio, Transmission line of finite length, The Smith Chart, Smith Chart calculations for lossy lines, Impedance matching by Quarter wave transformer, Single and double stub matching. Rectangular Waveguides: TE and TM wave solutions, Field patterns, Wave impedance and Power flow.	12
Module-2	**Microwave Sources** Microwave Linear-Beam (O type) and Crossed-Field tubes (M type), Limitations of conventional tubes at microwave frequencies, Klystron, Multicavity Klystron Amplifiers, Reflex Klystrons, Helix Travelling-wave tubes, magnetron Oscillators. Tunnel diode, TED ¬Gunn diode, Avalanche transit time devices IMPATT (also TRAPAT) and parametric devices.	7

Module-3	**Stripline and microstrip lines and Network analysis** Dominant mode of propagation, Field patterns, Characteristic impedance, Basic design formulas and characteristics. Parallel coupled striplines and microstrip lines-Even-and odd-mode excitations. Slot lines and Coplanar lines. Advantages over waveguides. Microwave Network Analysis: Impedance and Admittance matrices, Scattering matrix, Parameters of reciprocal and Loss less networks, ABCD Matrix, Scattering matrices of typical two-port, three-port and four-port networks, Conversion between two-port network matrices.	11
Module-4	**Microwave Passive Components and measurements** Waveguide Components: E-plane and H-plane Tees, Magic Tee, Shorting plunger, Directional couplers, and Attenuator. Stripline and Microstrip line Components: Open and shorted ends. Half wave resonator, Lumped elements (inductors, capacitors and resistors) in microstrip. Ring resonator, 3-dB branchline coupler, backward wave coupler, Wilkinson power dividers and rat-race hybrid ring. Low pass and band pass filters. Microwave Measurements: Detection of microwaves, Microwave power measurement, Impedance measurement, Measurement of reflection loss (VSWR), and transmission loss in components. Passive and active circuit measurement & characterization using network analyser, spectrum analyser and noise figuremeter	14
Module -5	**Microwave Integrated Circuit Technology** Substrates for Microwave Integrated Circuits (MICs) and their properties. Hybrid technology – Photolithographic process, deposited and discrete lumped components. Microwave Monolithic Integrated Circuit (MMIC) technology-Substrates, MMIC process, comparison with hybrid integrated circuit technology (MIC technology).	6

RECOMMENDED BOOKS:

1 Electromagnetic Waves and Radiating Systems – E.C. Jordan & K.G. Balmain, Prentice Hall, Inc.
2 Microwave Devices and Circuits -S. Y. LIAO, PHI
3 Introduction to Microwave Theory and Measurements – L. A. Lance, TMH
4 Transmission lines and Networks – Walter C. Johnson, McGraw Hill, New Delhi
5 Networks Lines and Fields – John D. Ryder
6 Microwave Engineering: Passive Circuits -Peter A. Razi, Prentice Hall of India Pvt. Ltd, New Delhi.
7 Waveguides – H.R.L. Lamont, Methuen and Company Limited, London
8 Foundations for Microwave Engineering – Robert E. Collin, McGraw Hill Book Company, New Delhi
9 Microwave Engineering – Annapurna Das, TMH, New Delhi

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Quiz I	√	√			
Quiz II			√	√	
Assesment	√	√	√	√	√
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	Course Outcomes				
	1	**2**	**3**	**4**	**5**
A	H	M	M	L	H
B	H	H	M	L	H
C	M	L	H	L	L
D	H	L	L	H	H
E	L	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes					
	a	b	c	d	e	f
1	H	M	H	M	H	H
2	H	H	H	M	H	H
3	H	L	M	M	L	M
4	H		H	M	M	M
5	M	H	H	M	H	H

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 and CD2
CD2	Tutorials/Assignments		CO2	CD1 and CD2
CD3	Seminars		CO3	CD1 and CD2
CD4	Mini projects/Projects		CO4	CD1 and CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1, CD2 and CD8
CD6	Industrial/guest lectures		-	-
CD7	Industrial visits/in-plant training		-	-
CD8	Self- learning such as use of NPTEL materials and internets		-	-
CD9	Simulation		-	-

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L2		1	Introduction of Microwaves and their applications.	R1, R4, and R7	CO1		CD1, CD2	
	L3-L5			Types of Transmission lines, Characterization in terms of primary and secondary constants, Characteristic impedance	R1, R4, and R7	CO1		CD1, CD2	
2	L6			General wave equation, Loss less propagation, Propagation constant, Wave reflection at discontinuities,	R1, R4, and R7	CO1		CD1, CD2	
	L7			Voltage standing wave ratio, Transmission line of finite length,	R1, R4, and R7	CO1		CD1, CD2	
	L8			The Smith Chart, Smith Chart calculations for lossy lines,	R1, R4, and R7	CO1		CD1, CD2	
3	L9			Impedance matching by Quarter wave transformer, Single and double stub matching.	R1, R4, and R7	CO1		CD1, CD2	
	L10-12			Rectangular Waveguides: TE and TM wave solutions, Field patterns, Wave impedance and Power flow.	R1, R4, and R7	CO1		CD1, CD2	
4	L13-14		2	Microwave Linear-Beam (O type) and Crossed-Field tubes (M type), Limitations of conventional tubes at microwave frequencies,	R2	CO2		CD1, CD2	
	L15			Klystron, Multicavity Klystron Amplifiers, Reflex Klystrons	R2	CO2		CD1, CD2	
5	L16-17			Helix Travelling-wave tubes, magnetron Oscillators.	R2	CO2		CD1, CD2	
	L18			Tunnel diode, TED ¬Gunn diode,	R2	CO2		CD1, CD2	
	L19			Avalanche transit time devices IMPATT (also TRAPAT) and parametric devices.	R2	CO2		CD1, CD2	
6	L20-21		3	Dominant mode of propagation, Field patterns, Characteristic impedance,	R4, R5	CO1, CO3		CD1, CD2	
	L22			Basic design formulas and characteristics.	R4, R5	CO1, CO3		CD1, CD2	
	L23			Parallel coupled striplines	R4, R5	CO1,		CD1, CD2	

				and microstrip lines-Even-and odd-mode excitations.		CO3			
	L24			Slot lines and Coplanar lines. Advantages over waveguides	R4, R5	CO1, CO3		CD1, CD2	
7	L25-27			Microwave Network Analysis: Impedance and Admittance matrices, Scattering matrix,	R4, R5	CO1, CO3		CD1, CD2	
	L28			Parameters of reciprocal and Loss less networks, ABCD Matrix,	R4, R5	CO1, CO3		CD1, CD2	
8	L29			Scattering matrices of typical two-port, three-port and four-port networks,	R4, R5	CO1, CO3		CD1, CD2	
	L30			Conversion between two-port network matrices.	R4, R5	CO1, CO3		CD1, CD2	
	L31-32		4	Waveguide Components: E-plane and H-plane Tees, Magic Tee, Shorting plunger, Directional couplers, and Attenuator.	R6, R8	CO4		CD1, CD2	
9	L33-34			Stripline and Microstrip line Components: Open and shorted ends.	R6, R8	CO4		CD1, CD2	
	L35-36			Half wave resonator, Lumped elements (inductors, capacitors and resistors) in microstrip.	R6, R8	CO4		CD1, CD2	
10	L37-38			Ring resonator, 3-dB branchline coupler, backward wave coupler, Wilkinson power dividers and rat-race hybrid ring.	R6, R8	CO4		CD1, CD2	
	L39			Low pass and band pass filters.	R6, R8	CO4		CD1, CD2	
11	L40-42			Microwave Measurements: Detection of microwaves, Microwave power measurement, Impedance measurement, Measurement of reflection loss (VSWR), and transmission loss in components.	R6, R8	CO4		CD1, CD2	
	L43-44			Passive and active circuit measurement & characterization using network analyser, spectrum analyser and noise figuremeter	R6, R8	CO4		CD1, CD2	
12	L45		5	Substrates for Microwave Integrated Circuits (MICs) and their properties.	R9	CO5		CD1, CD2	
	L46-47			Hybrid technology –	R9	CO5		CD1, CD2,	

				Photolithographic process, deposited and discrete lumped components.				and CD8	
	L48			Microwave Monolithic Integrated Circuit (MMIC) technology-Substrates	R9	CO5		CD1, CD2, and CD8	
	L49-50			MMIC process, comparison with hybrid integrated circuit technology (MIC technology).	R9	CO5		CD1, CD2, and CD8	

Group E- Plasma Sciences:	
1. Theory of Plasmas 2. Plasma Confinement **3.** Waves and Instabilities in Plasma	**4.** Physics of Thin Films

COURSE INFORMATION SHEET

Course code: PH 528
Course title: Theory of Plasmas
Pre-requisite(s):
Co- requisite(s):
Credits: **4**L:3 T: 1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE VI/ VII
Branch: PHYSICS
Name of Teacher:
Group : E **Option 1**

Code: PH 528	**Title: Theory of Plasmas**	**L-T-P-C [3-1-0-4]**
Plasma Theory **Course Objective** 1. To learn about the similarity of plasma with fluid. 2. To learn about the diffusion and mobility of plasma. 3. To learn about the resistivity and single fluid MHD equation of plasma. 4. To learn about the Boltzmann and the Vlasov equation. 5. To learn about the different type of discharges. **Course Outcome** 1. Be familiar about the method by which plasma can be treated as a fluid. 2. Be familiar with the diffusion and mobility process. 3. Be able to derive the set of single fluid MHD equation. 4. Be able to describe plasma with Boltzmann and Vlasov equation. 5. Be familiar with the different type of electrical discharges.		
Module-1	Relation of plasma physics to ordinary electromagnetic field, Fluid equation of motion, Fluid drifts perpendicular to B, Fluids drifts parallel to B, Plasma approximation.	**[8]**
Module-2	Diffusion and mobility in weakly ionized gases, Decay of a plasma by diffusion, steady state solution, Recombination, diffusion across a magnetic field, collision in fully ionized plasma.	**[8]**
Module-3	Mechanics of coulomb collisions, Physical meaning of resistivity, Numerical value of resistivity, Single fluid MHD equations, Diffusion in fully ionized plasma, Bohm diffusion and Neoclassical diffusion.	**[8]**
Module-4	Concepts of elementary kinetic theory of plasmas, The meaning of distribution function, Boltzmann and Vlasov equation	**[8]**
Module-5	Electrical discharges, Electrical breakdown in gases, glow discharge, Self sustained discharges, Paschen curve, High frequency electrical discharge in gases, electrode less discharge, capacitively and Inductively coupled plasmas, ECR Plasmas, Electrical arcs .	**[8]**
References 1. Gas Discharge Physics, Y P Raizer, Springer, 1997 2. Introduction to Plasma Physics and Controlled Fusion, Francis, F. Chen, Plenum Press, 1984 3. Fundamental of Plasma Physics, J, A. Bittencourt, Springer-Verlag New York Inc., 2004 4. Plasma Physics (Plasma State of Matter) S. N. Sen , Pragati Prakashan, 1999		

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	L	L	L	L
B	M	H	L	L	L
C	M	M	H	L	L
D	M	L	L	H	L
E	L	L	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes											
	a	B	C	d	E	f	g	H	i	j	K	l
1	M	H	M	M	M	H						
2	M	H	L	M	M	H						
3	M	H	H	M	M	H						
4	M	H	H	M	M	H						
5	M	H	L	M	M	H						

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 CD2

CD2	Tutorials/Assignments		CO2	CD1 CD2
CD3	Seminars		CO3	CD1 CD2
CD4	Mini projects/Projects		CO4	CD1 CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect No.	Tentative Date	Ch No.	Topics to be covered	Text Book / Refere Nces	COs mapped	Actual Content covered	Methodology used	Remarks by Faculty if any
1	L1-L5			Relation of plasma physics to ordinary electromagnetic field, Fluid equation of motion,	T2 T3 R1				
	L6-L10			Fluid drifts perpendicular to B, Fluids drifts parallel to B, Plasma approximation	T2 T3 R1				
	L11-L15			Diffusion and mobility in weakly ionized gases, Decay of a plasma by diffusion,	T2 T3 R1				
	L16-L20			steady state solution, Recombination, diffusion across a magnetic field, collision in fully ionized plasma.	T2 T3 R1				
	L21-L25			Mechanics of coulomb collisions, Physical meaning of resistivity, Numerical value of resistivity,	T2 T3 R1				
	L26-L30			Single fluid MHD equations, Diffusion in fully ionized plasma, Bohm diffusion and Neoclassical diffusion.	T2 T3 R1				
	L31-L35			Concepts of elementary kinetic theory of plasmas,	T2 T3 R1				
	L36-L40			The meaning of distribution function, Boltzmann and Vlasov equation	T2 T3 R1				
	L41-L45			Electrical discharges, Electrical breakdown in gases, glow discharge, Self sustained discharges, Paschen curve,	T1 R1				
	L46-L50			High frequency electrical discharge in gases, electrode less discharge,	T1 R1				

				capacitively and Inductively coupled plasmas, ECR Plasmas, Electrical arcs .					

COURSE INFORMATION SHEET

Course code: PH 529
Course title: Plasma Confinement
Pre-requisite(s):
Co- requisite(s):
Credits: 4L: 4T: 0 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level:PE VI / VII
Branch: PHYSICS
Name of Teacher:

Group : E **Option 2**

Code: PH 529	**Title: Plasma Confinement**	**L-T-P-C [4-0-0-4]**

Course Objective

1. To learn about the fundamental and basics of plasma confinement.
2. To learn about the Magnetic confinement scheme and related heating machanicsm.
3. To learn about the transport of plasma.
4. To learn about plasma-surface interaction.
5. To learn about the Magnetohydrodynamics generator.

Course Outcome

1. Will be familiar with the plasma confinement for thermonuclear fusion.
2. Will have an idea how plasma can be confined magnetically.
3. Be familiar with the transport of plasma and its role in thermonuclear fusion.
4. Be familiar with plasma surface interaction and its role in fusion.
5. Be familiar with the energy generation by MHD generator.

Module-1	Nuclear Fusion and plasma physics: Fusion as energy source, Fusion reactions, Controlled thermonuclear fusion and fusion reactor, Lawson criterion, Ignition, Fuel resources, Reactor economics, Plasma confinement schemes, Magnetic confinement, Inertial confinement, Laser-Fusion .	**[8]**
Module-2	Magnetic confinement: Larmor orbits, particle drifts, Magnetic mirror, Z-pinch, Theta-pinch, spheromak, Tokamak, safety factor, plasma beta, Aspect-ratio, Flux surfaces, plasma current, Grad-Shafranov equation, collisions, kinetic equation, Fokker-Planck equation, collision times, resistivity, plasma heating, Ohmic heating, RF heating, Neutral beam heating.	**[8]**
Module-3	Collisional Transport: Classical transport – minimal dissipation, diffusion, random walk estimate, heat conductivity, Fluid evolution in a torus – transport closure, radial fluxes, neoclassical transport, Surface flows, Axis symmetric fluxes.	**[8]**
Module-4	Plasma-surface interaction: Plasma surface interactions, Boundary layer, Recycling, Atomic and molecular processes, Desorption and wall cleaning, Sputtering, Arcing, Limiters, Divertors, Heat flux, Evaporation and heat transfer, Tritium inventory. Radiation from Plasma	**[8]**
Module-5	MHD Generator: Magnetohydrodynamic Generator, Basic theory, Principle of working, The fuel in MHD, Magnet in MHD Generator.	**[8]**

References

1. Plasma Physics (Plasma State of Matter) S. N. Sen , Pragati Prakashan, 1999
2. Magnetic Fusion Technology, T J Dolan, 2014
3. Plasma Physics and Fusion energy, J P Freidberg Cambridge University Press, 2008
4. Tokamaks, J wessen, Oxford Science Publication, 1987

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	L	L	L
B	M	H	L	L	L
C	L	L	H	L	L
D	L	M	M	H	L
E	L	M	L	L	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes											
	a	b	c	d	E	f	g	H	I	j	k	l
1	M	H	M	M	H	H						
2	M	H	M	M	H	H						
3	M	H	M	M	H	H						
4	M	H	M	M	H	H						
5	M	H	M	M	H	H						

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods		Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 CD2
CD2	Tutorials/Assignments		CO2	CD1 CD2
CD3	Seminars		CO3	CD1 CD2
CD4	Mini projects/Projects		CO4	CD1 CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / Refere Nces	COs mapped	Actual Conten t covere d	Methodology Used	Remarks by faculty if any
1	L1-L5			Nuclear Fusion and plasma physics: Fusion as energy source, Fusion reactions, Controlled thermonuclear fusion and fusion reactor, Lawson criterion, Ignition,					
	L6-L10			Fuel resources, Reactor economics, Plasma confinement schemes, Magnetic confinement, Inertial confinement, Laser-Fusion .					
	L11-L15			Magnetic confinement: Larmor orbits, particle drifts, Magnetic mirror, Z-pinch, Theta-pinch, spheromak, Tokamak, safety factor, plasma					

				beta, Aspect-ratio,					
	L16-L20			Flux surfaces, plasma current, Grad-Shafranov equation, collisions, kinetic equation, Fokker-Planck equation, collision times, resistivity, plasma heating, Ohmic heating, RF heating, Neutral beam heating.					
	L21-L25			Collisional Transport: Classical transport – minimal dissipation, diffusion, random walk estimate, heat conductivity,					
	L26-L30			Fluid evolution in a torus – transport closure, radial fluxes, neoclassical transport, Surface flows, Axis symmetric fluxes					
	L31-L35			Plasma-surface interaction: Plasma surface interactions, Boundary layer, Recycling, Atomic and molecular processes,					
	L36-L40			Desorption and wall cleaning, Sputtering, Arcing, Limiters, Divertors, Heat flux, Evaporation and heat transfer, Tritium inventory. Radiation from Plasma					
	L41-L45			MHD Generator: Magnetohydrodynamic Generator, Basic theory,					
	L46-L50			Principle of working, The fuel in MHD, Magnet in MHD Generator.					

COURSE INFORMATION SHEET

Course code: PH 530
Course title: Waves and Instabilities in Plasma
Pre-requisite(s):
Co- requisite(s):
Credits: **4** L: 3 T:1 P: 0
Class schedule per week:
Class: I.M.Sc.
Semester / Level: PE VI / VII
Branch: PHYSICS
Name of Teacher:

Group : E **Option 3**

Code: PH 530	**Title: Waves and Instabilities in Plasma**	**L-T-P-C [3-1-0-4]**

Course Objective

1. To learn the fundamental and basics of Plasma waves.
2. To learn about the electromagnetic waves.
3. To learn about the Landau Damping.
4. To learn about the different type of instabilities.
5. To learn about the MHD stability.

Course outcome:

1. Will be familiar with the plasma waves.
2. Be able to handle electromagnetic waves mathematically.
3. Be able to derive mathematically Landau damping related concept.
4. Will be familiar with the different type of instabilities.
5. Be able to handle MHD stability mathematically.

Module-1	Representations of waves, group velocity, Plasma Oscillations, Electron plasma waves, sound waves, ion waves, validity of plasma approximations, comparison of ion and electron waves, electrostatic electron oscillations perpendicular to B.	**[8]**
Module-2	Electrostatic ion waves perpendicular to B, The lower hybrid frequency, electromagnetic waves with B=0, Experimental applications, electromagnetic waves perpendicular to B, Cutoffs and resonances, electromagnetic waves parallel to B, Whistler mode, Faraday rotation.	**[8]**
Module-3	Hydromagnetic waves, Magnetosonic waves, Alfven waves, Plasma oscillations and Landau damping, A physical derivation of Landau damping.	**[8]**
Module-4	Equilibrium and stability, Hydromagnetic equilibrium, Diffusion of magnetic field into a plasma, Classification of instabilities, two stream instability, The gravitational instability, Resistive drift waves.	**[8]**
Module-5	MHD stability, Energy principle, Kink instability, Internal kink, tearing modes, Resistive layer, Tearing stability, Mercier criterion, Ballooning modes, Beta limit.	**[8]**

References

1. Tokamaks, J Wessons, 1987, Oxford Science Publication.
2. Introduction to Plasma Physics f F Chen.
3. The theory of plasma waves, T H Stix, 1962, McGraw-Hill New York.
4. Fundamental of Plasma Physics, J, A. Bittencourt, Springer-Verlag New York Inc., 2004

Course Delivery methods	
Lecture by use of boards/LCD projectors/OHP projectors	Y
Tutorials/Assignments	Y
Seminars	N
Mini projects/Projects	N
Laboratory experiments/teaching aids	N
Industrial/guest lectures	N
Industrial visits/in-plant training	N
Self- learning such as use of NPTEL materials and internets	Y
Simulation	N

Course Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizes	30 (10+10+10)
End Sem Examination Marks	50

Assessment Compoents	CO1	CO2	CO3	CO4	CO5
Mid Sem Examination Marks	√	√	√		
End Sem Examination Marks	√	√	√	√	√
Quiz I			√	√	
Quiz II					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Mapping between Course Objectives and Course Outcomes

Course Objectives	1	2	3	4	5
A	H	M	L	L	L
B	M	H	L	L	L
C	M	M	H	L	L
D	L	L	L	H	M
E	L	L	L	M	H

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes											
	a	b	C	D	E	f	g	H	i	j	k	l
1	M	H	M	M	H	H						
2	M	H	M	M	H	H						
3	M	H	H	M	H	H						
4	M	H	M	M	H	H						
5	L	H	L	M	H	H						

Mapping Between COs and Course Delivery (CD) methods				
CD	**Course Delivery methods**		**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors		CO1	CD1 CD2
CD2	Tutorials/Assignments		CO2	CD1 CD2
CD3	Seminars		CO3	CD1 CD2
CD4	Mini projects/Projects		CO4	CD1 CD2
CD5	Laboratory experiments/teaching aids		CO5	CD1 CD2
CD6	Industrial/guest lectures			
CD7	Industrial visits/in-plant training			
CD8	Self- learning such as use of NPTEL materials and internets			
CD9	Simulation			

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Tentative Date	Ch. No.	Topics to be covered	Text Book / References	COs Mapped	Actual Content covered	Methodology used	Remarks by faculty if any
1	L1-L5			Representations of waves, group velocity, Plasma Oscillations, Electron plasma waves, sound waves, ion waves,	T2 T3 R1				
	L6-L10			validity of plasma approximations, comparison of ion and electron waves, electrostatic electron oscillations perpendicular to B.	T2 T3 R1				
	L11-L15			Electrostatic ion waves perpendicular to B, The lower hybrid frequency, electromagnetic waves with B=0, Experimental applications,	T2 T3 R1				
	L16-L20			electromagnetic waves perpendicular to B, Cutoffs and resonances, electromagnetic waves parallel to B, Whistler mode, Faraday rotation	T2 T3 R1				
	L21-L25			Hydromagnetic waves, Magnetosonic waves, Alfven waves,	T2 T3 R1				
	L26-L30			Plasma oscillations and Landau damping, A physical derivation of Landau damping					
	L31-L35			Equilibrium and stability, Hydromagnetic equilibrium, Diffusion of magnetic field into a plasma,	T1 T2 R1				
	L36-L40			Classification of instabilities, two stream instability, The gravitational instability, Resistive drift waves.	T1 T2 R1				
	L41-L45			MHD stability, Energy principle, Kink instability, Internal kink,	T1 T2 R1				
	L46-L50			tearing modes, Resistive layer, Tearing stability, Mercier criterion, Ballooning modes, Beta limit.	T1 T2 R1				

COURSE INFORMATION SHEET

Course code: PH 519
Course title: Physics of Thin Films
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L: 4 T: 0 P: 0
Class schedule per week:
Class: M.Sc.
Semester / Level: IV/ PE VI- VII
Branch: PHYSICS
Name of Teacher: Dr. Sanat Mukherjee

Group : E **Option 4**

Same given as above (in Group B)