The University of Burdwan

Syllabus for 3-year Degree/4-year Honours
In
Physics
Under Curriculum and Credit Framework for Undergraduate Programs (CCFUP) as per NEP, 2020
With effect from 2023-24

FORWARDED
Abhijit Chakraborty
Professor & Head
Department of Physics
The University of Burdwan
Burdwan-713104

08.06.2026

SEMESTER WISE & COURSE WISE CREDIT DISTRIBUTION STRUCTURE UNDER CCFUP AS PER NEP, 2020

Semester	Course Type	Paper Code	Name of the Course	Credit	Lect.	Tut.	Pract./ Viva	Full Marks	Distribution of Marks		
									Theory	Pract. /Tut. /Viva	Internal Assessment
I	Major/DS Course (Core)Code: PHYS1011	100-199	MATHEMATICAL PHYSICS-I	4	3	0	1	75	40	20	15
	Minor Course Code: PHYS1021	100-199	MATHEMATICAL PHYSICS-I	4	3	0	1	75	40	20	15
	Multi/Interdisciplinary Code: PHYS1031		CONCEPTS OF PHYSICS 1	3	2	1	0	50	40	00	10
	Ability Enhancement Course (AEC) [L_1-1 MIL] Code: …..1041		Arabic /Bengali /Hindi /Sanskrit /Santali /Urdu Or Equivalent Course from SWAYAM /Any other UGC Recognized Platform	2	2	0	0	50	40	00	10
	Skill Enhancement Course (SEC)Code: PHYS1051		RENEWABLE ENERGY AND ENERGY HARVESTING	3	2	1	0	50	40	00	10
	Common Value Added (CVA) CourseCode: CVA1061		EnvironmentalScience/Education	4	3	0	1	100	60	20	20
	Total			**20**				**400**			

Semester	Course Type	Paper Code	Name of the Course	Credit	Lect.	Tut.	Pract./ Viva	Full Marks	Distribution of Marks		
									Theory	Pract. /Tut. /Viva	Internal Assessment
II	Major/DS Course (Core) Code: PHYS2011	100-199	MECHANICS	4	3	0	1	75	40	20	15
	Minor CourseCode: PHYS2021	100-199	MECHANICS	4	3	0	1	75	40	20	15
	Multi/Interdisciplin aryCode: PHYS2031		CONCEPTS OF PHYSICS 2	3	2	1	0	50	40	00	10
	Ability Enhancement Course (AEC)[L_2-1] Code:ENGL2041		Functional English Or Equivalent Course from SWAYAM /Any other UGCRecognized Platform	2	2	0	0	50	40	00	10
	Skill Enhancement Course (SEC) Code: PHYS2051		ELECTRICAL CIRCUITS AND NETWORK SKILLS	3	2	1	0	50	40	00	10
	Common Value Added (CVA) Course Code: CVA2061		Understanding India /Digital & Technological Solutions /Health &Wellness, YogaEducation, Sports& Fitness	4	3/3	1/0	0/1	100	80/60	0/20	20
Skill based vocational course (addl. 4 Cr) during summer term for 8 weeks, who will exit the program after securing 40 Cr.											
For UG Certificate 40 Cr + Additional 4 Cr (work based vocational course) = 44 Cr. Students are allowed to re-enter within 3 years and complete the program within the stipulated maximum period of 7 years											
	Total			**20**				**400**			

Semester	Course	Paper Code	Name of the	Credi	Lect.	Tut.	Pract./	Full	Distribution of Marks

	Type		Course	t			Viva	Marks	Theory	Pract. /Tut. /Viva	Internal Assessment
III	Major /DS Course (Core)	PHYS3011	Electricity and Magnetism	5	4		1	75	40	20	15
		PHYS3012	Waves and Optics	5	4		1	75	40	20	15
	Minor Course (Voc. Education & Training)	MSR3021 or HRM 3021 or RSA 3021	Medical Sales Representative or Human Resource Management or Retail Sales Associate	4	3	1	0	75	60	0	15
	Multi /Inter-disciplinary	PHYS3031	Electricity, Magnetism and Electronics	3	2	1		50	40	0	10
	AEC (MIL) [L_1-2]	……..3041	Arabic/ Bengali/ Hindi/ Sanskrit/ Santali/ Urdu or Equivalent Course from SWAYAM /Any other UGC recognized platform	2	2			50	40	0	10
	Skill Enhance-ment Course (SEC)	PHYS3051	Basic Instruments and Their Usage	3	2	1		50	40	0	10
Total				**22**				**375**			

Semester	Course	Paper Code	Name of the	Credit	Lect.	Tut.	Pract./	Full	Distribution of Marks

	Type		Course				Viva	Marks	Theory	Pract. /Tut./Viva	Internal Assessment
IV	Major/ DS Course (Core)	PHYS4011	Heat and Thermodynamics	5	4		1	75	40	20	15
		PHYS4012	Mathematical Physics-II	5	4		1	75	40	20	15
		PHYS4013	Classical Mechanics and Special Theory of Relativity	5	5		0	75	60	0	15
	Minor Course	PHYS4021	Thermal Physics	4	3	0	1	75	40	20	15
	Minor Course (Other than Physics)	PHYS 4021		4				75			
	Ability Enhance-ment Course (AEC) [L_2-2]	ENGL4041	Language and Creativity or Equivalent Course from SWAYAM/Any other UGC recognized platform	2	2	0	0	50	40	0	10
Total				**25**				**425**			

Semester	Course Type	Course Code	Name of the Course	Credit	Lect.	Tut.	Pract. /Viva	Full Marks	Distribution of Marks		
									Theory	Pract. /Tut./Viva	Internal Assessment

V	Major Core Course	PHYS5011	Mathematical Physics-III	5	4		1	75	40	20	15
		PHYS5012	Elements of Modern Physics	5	4		1	75	40	20	15
		PHYS5013	Analog Systems and Applications	5	4		1	75	40	20	15
	Minor Course (Vocational Education & Training)	MSR 5021 Or HRM 5021 Or RSA 5021	Medical sales Representative OR Human Resource Management OR Retail Sales Associate	4	3	1	0	75	60	0	15
	Internship	INT 5081		2	0	0	2	50	00	50 (Project/ Field Diary:30 +Viva-voce 20)	00
Total				**21**				**350**			

Semester	**Course Type**	**Course Code**	**Name of the Course**	**Credit**	**Lect.**	**Tut.**	**Pract. /Viva**	**Full Marks**	**Distribution of Marks**		
									Theory	**Pract. /Tut./Viva**	**Internal Assessment**
VI	Major	PHYS6011	Quantum Mechanics	4	3		1	75	40	20	15
		PHYS6012	Electromagnetic Theory	4	3		1	75	40	20	15
		PHYS6013	Digital Systems and Applications	4	3		1	75	40	20	15

		PHYS6014	Atomic & Molecular Spectroscopy	4	3		1	75	40	20	15
	Minor Course (Vocational Education & Training)	MSR 6021 Or HRM 6021 Or RSA 6021	Medical Sales Representative OR Human Resource Management OR Retail Sales Associate	4	3	1	0	75	60	0	15
Total				20				375			
Grand Total (Sem.- I to VI)				128				2325			

SEMESTER	**Course Type**	**Code**	**Name of the Course**	**Credit**	**L – T - P**	**Marks**	**Marks Dist. Th. – Pr. - IA**
VII	Major/Core Course	**7011**	**Advanced Quantum Mechanics**	6	4 – 0 -2	75	40 – 20 – 15
	Major/Core Course	**7012**	**Nuclear and Particle Physics**	6	6 – 0 -0	75	60 – 00 – 15
	Major/Core Course	**7013**	**Solid State Physics**	6	4- 0- 2	75	40 – 20 – 15
	Major/Core Course	**7014**	**Communication Systems**	6	4- 0- 2	75	40 – 20 – 15
	Minor Course	**7021**	**Electricity, Magnetism and Optics**	4	3 - 0 - 1	75	40 – 20– 15
	Total			**28**		**375**	

SEMESTER	**Course Type**	**Code**	**Name of the Course**	**Credit**	**L – T - P**	**Marks**	**Marks Dist. Th. – Pr. - IA**
VIII	Major/Core Course	**8011**	Statistical Mechanics	6	4- 0- 2	75	40 – 20 – 15

Hons. With Research Project/ Dissertation	Minor Course	**8021**	Modern Physics	4	3- 0- 1	75	40 – 20– 15
	Research Project/ Dissertation	**8091**		12	0- 0- 12	225	Seminar Presentation, Preparation & Submission of Research Project/Dissertation-135 + Viva-90
	Total			**22**		**375**	

OR

VIII Hons.	Major/Core Course	**8011**	Statistical Mechanics	6	4- 0- 2	75	40 – 20 – 15
	Major/Core Course	**8012**	Astronomy & Astrophysics	4	4- 0- 0	75	60 – 00 – 15
	Major/Core Course	**8013**	Laser and Fiber Optics	4	3- 0- 1	75	40 – 20 – 15
	Major/Core Course	**8014**	Materials Science	4	4- 0- 0	75	60 – 00 – 15
	Minor Course	**8021**	Modern Physics	4	3- 0- 1	75	40 – 20– 15
	Total			**22**		**375**	
	Grand total (Sem. I -VIII)			**178**		**3075**	

MAJOR-PHYSICS COURSE
Semester I

MAJOR-I: PHYS1011: MATHEMATICAL PHYSICS-I (Credits: Theory-03, Practical - 01)
F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: ***The aim of this course is to equip the students with mathematical methods that are important prerequisites for physics courses***.

Theory: **60 Hours**

Calculus

Recapitulation: Limits, Continuity, Average and instantaneous quantities, Differentiation, Plotting functions, Intuitive ideas of continuous, differentiable *etc*. functions and plotting of curves. Approximation: Taylor and binomial series (statements only).

3 Hours

First Order and Second Order Differential equations: First order differential equations and Integrating factor, Homogeneous equations with constant coefficients, Wronskian and general solution, Statement of the existence and the Uniqueness theorem for Initial Value problems, Particular Integral.

9 Hours

Calculus of functions of more than one variable: Partial derivatives, Exact and inexact differentials.

6 Hours

Vector Calculus

Recapitulation of Vectors: Properties of vectors under rotations, Scalar product and its invariance under rotations, Vector product, Scalar triple product and their interpretation in terms of area and volume respectively, Scalar and Vector fields.

5 Hours

Vector Differentiation: Directional derivatives and normal derivative, Gradient of a scalar field and its geometrical interpretation, Divergence and Curl of a vector field, Del and Laplacian operators, Vector identities.

6 Hours

Vector Integration: Ordinary integrals of vectors, Multiple integrals, Jacobian, Notion of an infinitesimal line, surface and volume elements, Line, surface and volume integrals of vector fields, Flux of a vector field, Gauss' divergence theorem, Green's and Stokes theorems and their applications (no rigorous proofs).

10 Hours

Orthogonal Curvilinear Coordinates:

Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

6 Hours

Reference Books:

1. Mathematical Methods for Physicists: G.B. Arfken, H.J. Weber, F.E. Harris, 7th Edition,

Elsevier.

2. An introduction to ordinary differential equations: E.A. Coddington, PHI learning
3. Vector Analysis: M R Spiegel, Schaums Outline Series.
4. Mathematical Tools for Physics: James Nearing, Dover Publications.
5. Higher Engineering Mathematics: B S Grewal, Khanna Publisher.
6. Advanced Engineering Mathematics: D.G. Zill and W.S. Wright, 5^{th} Edition, Jones and Bartlett Learning.
7. Mathematical Physics: H K Dass and R Verma, S. Chand & Company Pvt. Ltd.
8. Engineering Mathematics: S.Pal and S.C. Bhunia, Oxford University Press.
9. Advanced Engineering Mathematics, Erwin Kreyszig, Wiley India.
10. Essential Mathematical Methods, K.F. Riley&M.P.Hobson, Cambridge Univ. Press.

MAJOR-I: PHYS1011: MATHEMATICALPHYSICS-I

Practical: **30 Hours**

COURSE OBJECTIVE: The aim of this course is to learn computer programming and numerical analysis and to emphasize its role in solving problems in Physics.

Topics	**Description with Applications**
Introduction and Overview	Computer architecture and organization, Memory, Input/Output devices.
Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, Algorithms, Sequence, Selection and Repetition, Single and double precision arithmetic, Underflow and overflow, Emphasize the importance of making equations in terms of dimensionless variables, Iterative methods.
Errors and Error-Analysis	Truncation and round off errors, Absolute and relative errors, Floating point computations.
Review of C & C++ Programming Fundamentals	Introduction to Programming, Constants, Variables, Data types, Operators and expressions, I/O statements, *scanf* and *printf*, *cin* and *cout*, Manipulators for data formatting, Control statements (Decision making statements: if statement, if else Statement, Nested if structure, else if ladder statement, Ternary Operator, *goto* statement, switch case statement. Unconditional

	and conditional looping: while loop, do-while loop, for loop, break and continue statements, Nested loops). Arrays (1D & 2D), Strings, User defined functions, Structure and Union, Idea of classes and objects.
Programs: 1. Write and execute a program in C/C++ to compute the factorial of a positive integer including Zero. 2. Write and execute a program in C/C++ to calculate the sum of the squares of n natural numbers. 3. Write and execute a program in C/C++ to find the area and the volume of a Sphere by varying the radius. 4. Write and execute a program in C/C++ to display Fibonacci series. 5. Write and execute a program in C/C++ to find the value of Sine function using power series (the argument will be given during execution). 6. Write and execute a program in C/C++ to find the value of Cosine function using power series (the argument will be given during execution) 7. Write and execute a program in C/C++ to find the value of e^x (x will be given during the execution of the program). 8. Write and execute a program in C/C++ to sort the elements of an array of elements in ascending/ descending order. 9. Write and execute a program in C/C++ to separate odd and even integers in arrays. 10. Write and execute a program in C/C++ to find the largest and smallest in a given set of numbers. 11. Write and execute a program in C/C++ to calculate value of π.	

COURSE OUTCOME: On completion of this course, the student must be able to perform different mathematical operations like calculus and vector operations which are extremely essential to study theoretical and experimental physics.

Reference Books:

1. Introduction to Numerical Analysis, S .S.Sastry,5th Edn., 2012 ,PHI Learning Pvt. Ltd.
2. Schaum's Outline of Programming with C++ .J.Hubbard, 2000, McGraw-Hill Pub.
3. Numerical Recipes in C: The Art of Scientific Computing, W.H. Press et al, 3rd Edn., 2007, Cambridge University Press.
4. A first course in Numerical Methods, U.M. Ascher & C.Greif, 2012, PHI Learning.
5. Elementary Numerical Analysis,K.E.Atkinson, 3rd Edn., 2007, Wiley India Edition.

6. An Introduction to Computational Physics, T.Pang, 2nd Edn., 2006, Cambridge Univ. Press

7. Computational Physics, Darren Walker, 1stEdn., 2015, Scientific International Pvt. Ltd.

8. Programming in ANSI C, E Balagurusamy, McGraw Hill Education.

9. Object Oriented Programming with C++, E. Balagurusamy, McGraw Hill Education.

10. Let Us C, Y Kanetkar, BPB Publications.

MAJOR-PHYSICS COURSE

Semester II

MAJOR II: PHYS2011: MECHANICS (Credits: Theory - 03, Practical - 01)

F.M. = 75 (Theory- 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: The objective of this course is to provide an in-depth understanding of the principles of Newtonian mechanics and apply them to solve problems involving the dynamics of classical mechanical systems.

Theory: **60 Hours**

Fundamentals of Dynamics: Reference frames, Inertial frames, Review of Newton's Laws of Motion. Galilean transformation, Galilean invariance, Momentum of variable-mass system: Motion of a rocket, Motion of a projectile in Uniform gravitational field, Dynamics of a system of particles: Centre of Mass, Motion relative to the centre of mass, Principle of conservation of momentum, Impulse.

6 **Hours**

Work and Energy: Work-Energy theorem, Conservative and non-conservative forces, Potential energy, Energy diagram, Stable and unstable equilibrium, Force as gradient of potential energy, Work and potential energy, Work done by non-conservative forces, Law of conservation of Energy.

4 **Hours**

Collisions: Elastic and inelastic collisions between particles in Centre of mass and Laboratory frames.

3 **Hours**

Rotational Dynamics: Angular momentum of a particle and a system of particles, Torque and the principle of conservation of angular momentum, Rotation about a fixed axis, Moment of Inertia, Calculation of moments of inertia for regular shaped bodies, Kinetic energy of rotation. Motion involving both translation and rotation.

8 **Hours**

Elasticity: Elastic properties of matter, Hooke's Law, Relation between Elastic constants, Twisting torque on a cylinder or a wire, Bending of Beams: Cantilever, Beam supported near the ends on two knife edges held in the same horizontal plane and a concentrated load W is applied at the midpoint.

4**Hours**

Gravitation and Central Force Motion: Law of gravitation, Gravitational potential energy, Inertial and gravitational mass, Gravitational potential and the gravitational field due to a spherical shell and a solid sphere.

4 **Hours**

Motion of a particle under a central force field: Two-body problem, its reduction to one-body problem and its solution, the energy equation and energy diagram. Kepler's Laws, Satellite in circular orbit and applications. Geosynchronous orbits, Weightlessness, Basic idea of global positioning system (GPS).

6 **Hours**

Oscillations: Simple Harmonic Oscillations: Differential equation of SHM and its solution, Kinetic energy, potential energy, Total energy and their time-averaged values. Damped oscillation, Forced oscillations: Transient and steady states, Resonance, Sharpness of resonance, Power dissipation and Quality Factor, Compound pendulum.

6 **Hours**

Non-Inertial Systems: Non-inertial frames and fictitious forces: Uniformly rotating frame, Laws of Physics in rotating coordinate systems, Centrifugal force, Coriolis force and its applications. Components of velocity and acceleration in cylindrical and spherical coordinate

4 **Hours**

COURSE OUTCOME: This course in Mechanics serves as the foundation for further progress towards the study of physics at graduate or post-graduate level. Upon completion of the course, the student will be able to apply Newton's laws of motion to different force fields for a single particle and for a system of particles.

Reference Books:

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
2. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
3. Feynman Hours, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
4. Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
5. University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley
6. An Introduction to Classical Mechanics, R G Takwale & P S Puranik, TMG Hill.
7. Mechanics, P K Srivastava, New Age International Pvt. Ltd.
8. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.
9. Vibrations, Waves and Acoustics, D Chattopadhyay and P C Rakshit, Books and Allied Pvt. Ltd.
10. Advanced Acoustics, D P Roychaudhuri and P Banerjee, The New Book Stall, 2009

MAJOR-II: PHYS2011: MECHANICS

Practical: **30 Hours**

1. To study the Motion of Spring and calculate (a) Spring constant, (b) g and (c) Modulus of rigidity.
2. To determine the Moment of Inertia of a Flywheel/regular shaped body.
3. To determine g and velocity for a freely falling body using Digital Timing Technique.
4. To determine the Young's Modulus of a Wire by Optical Lever Method.
5. To determine the Modulus of Rigidity of a Wire by Maxwell's needle/dynamical method.
6. To determine the elastic Constants of a wire by Searle's method.
7. To determine the value of g using Bar pendulum/Kater's Pendulum.
8. To determine the value of Young's Modulus by Flexure method.

Reference Books

1. Advanced Practical Physics for students, B. L. Flint and H.T.Worsnop, 1971, Asia Publishing House.
2. A Text Book of Practical Physics, I.Prakash & Ramakrishna,11thEdn,2011,KitabMahal.
3. Engineering Practical Physics, S.Panigrahi &B.Mallick,2015,CengageLearningIndiaPvt.Ltd.
4. Practical Physics,G.L.Squires,2015, 4thEdition,CambridgeUniversityPress.
5. Practical Physics, D Chattopadhyay, P C Rakshit and B Saha, Books and Allied Pvt. Ltd.
6. Advanced Practical Physics, B Ghosh and K G Mazumdar, Sreedhar Publishers.
7. B. Sc. Practical Physics, Harnam Singh and P S Heme, S Chand and Company Limited.
8. B. Sc. Practical Physics, C L Arora, S Chand and Company Limited.

MINOR-PHYSICS COURSE

Semester I

MINOR-I: PHYS1021: MATHEMATICAL PHYSICS-I (Credits: Theory - 03, Practical - 01)

F.M. = 75 (Theory - 40, Practical - 20, Internal Assessment - 15)

COURSE OBJECTIVE: The aim of this course is to equip the students with mathematical methods that are important prerequisites for physics courses.

Theory: **45 Hours**

Calculus

Recapitulation: Limits, Continuity, Average and instantaneous quantities, Differentiation. Plotting functions.Intuitive ideas of continuous, differentiable etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only).

3 Hours

First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients.Wronskian and general solution.Statement of the existence and the Uniqueness theorem for Initial Value Problems.Particular Integral.

9 Hours

Calculus of functions of more than one variable: Partial derivatives, Exact and inexact differentials.

6 Hours

Vector Calculus

Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations.Vector product, Scalar triple product and their interpretation in terms of area and volume respectively.Scalar and Vector fields.

5 Hours

Vector Differentiation: Directional derivatives and normal derivative.Gradient of a scalar field and its geometrical interpretation.Divergence and curl of a vector field.Del and Laplacian operators.Vector identities.

6 Hours

Vector Integration: Ordinary integrals of vectors, Multiple integrals, Jacobian. Notion of an infinitesimal line, surface and volume elements.Line, surface and volume integrals of vector fields. Flux of a vector field, Gauss' divergence theorem. Green's and Stokes Theorems and their applications (no rigorous proofs).

10 Hours

Orthogonal Curvilinear Coordinates:

Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

6 Hours

Reference Books:

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
2. An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning
3. Vector Analysis, M R Spiegel, Schaums Outline Series.
4. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
5. Higher Engineering Mathematics, B S Grewal, Khanna Publisher.
6. Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
7. Mathematical Physics, H K Dass and R Verma, S. Chand & Company Pvt. Ltd.
8. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
9. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
10. Essential Mathematical Methods, K.F.Riley&M.P.Hobson, 2011, Cambridge Univ. Press

MINOR-I: PHYS1021: MATHEMATICALPHYSICS-I
Practical: **30 Hours**

COURSE OBJECTIVE: The aim of this course is to learn computer programming and numerical analysis and to emphasize its role in solving problems in Physics.

Topics	**Description with Applications**
Introduction and Overview	Computer architecture and organization, Memory, Input/Output devices.
Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, Algorithms, Sequence, Selection and Repetition, Single and double precision arithmetic, Underflow and overflow, Emphasize the importance of making equations in terms of dimensionless variables, Iterative methods.
Errors and Error-Analysis	Truncation and round off errors, Absolute and relative errors, Floating point computations.

Review of C & C++ Programming Fundamentals	Introduction to Programming, Constants, Variables, Data types, Operators and expressions, I/O statements, scanf and printf, cin and cout, Manipulators for data formatting, Control statements (Decision making statements: if statement, if else Statement, Nested if structure, else if ladder statement, Ternary Operator, goto statement, switch case statement. Unconditional and conditional looping: while loop, do-while loop, for loop, break and continue statements, Nested loops). Arrays (1D & 2D), Strings, User defined functions, Structure and Union, Idea of classes and objects.

Programs:

1. Write and execute a program in C/C++ to compute the factorial of a positive integer including Zero.
2. Write and execute a program in C/C++ to calculate sum of squares of n natural numbers.
3. Write and execute a program in C/C++ to find the area and the volume of a Sphere by varying the radius.
4. Write and execute a program in C/C++ to display Fibonacci series.
5. Write and execute a program in C/C++ to find the value of Sine function using power series (The argument will be given during execution).
6. Write and execute a program in C/C++ to find the value of Cosine function using power series (The argument will be given during execution)
7. Write and execute a program in C/C++ to find the value of ex (x will be given during execution of the program).
8. Write and execute a program in C/C++ to sort elements of an array of elements in ascending/ descending order.
9. Write and execute a program in C/C++ to separate odd and even integers in arrays.
10. Write and execute a program in C/C++ to find the largest and smallest in a given set of numbers.
11. Write and execute a program in C/C++ to calculate value of π.

COURSE OUTCOME: On completion of this course, the student must be able to perform different mathematical operations like calculus and vector operations which are extremely essential to study theoretical and experimental physics.

Reference Books

1. Introduction to Numerical Analysis, S .S.Sastry,5 thEdn., 2012 ,PHI Learning Pvt.Ltd.

2. Schaum's Outline of Programming with C++ .J.Hubbard,2000, McGraw-Hill Pub.

3. Numerical Recipes in C: The Art of Scientific Computing, W.H. Press et al, 3rdEdn., 2007, Cambridge University Press.

4. A first course in Numerical Methods, U.M. Ascher & C.Greif, 2012, PHI Learning.

5. Elementary Numerical Analysis,K.E.Atkinson, 3rd Edn., 2007, Wiley India Edition.

6. An Introduction to Computational Physics, T.Pang, 2ndEdn., 2006, Cambridge Univ. Press

7. Computational Physics, DarrenWalker, 1stEdn., 2015, Scientific International Pvt. Ltd.

8. Programming in ANSI C, E Balagurusamy, McGraw Hill Education.

9. Object Oriented Programming with C++, E. Balagurusamy, McGraw Hill Education.

10. Let Us C, Y Kanetkar, BPB Publications.

MINOR-PHYSICS COURSE

Semester II

MINOR II : PHYS2021: MECHANICS (Credits: Theory - 03, Practical - 01)

F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: The objectives of this course is to provide an in-depth understanding of the principles of Newtonian mechanics and apply them to solve problems involving the dynamics of classical mechanical systems.

Theory: **45 Hours**

Fundamentals of Dynamics: Reference frames, Inertial frames, Review of Newton's Laws of Motion. Galilean transformations, Galilean invariance. Momentum of variable-mass system: Motion of a rocket, Motion of a projectile in Uniform gravitational field, Dynamics of a system of particles: Centre of Mass, Motion relative to the centre of mass, Principle of conservation of momentum, Impulse.

6 Hours

Work and Energy: Work-Energy theorem, Conservative and non-conservative forces, Potential energy, Energy diagram, Stable and unstable equilibrium, Force as gradient of potential energy, Work and potential energy, Work done by non-conservative forces, Law of conservation of Energy.

4 Hours

Collisions: Elastic and inelastic collisions between particles in Centre of mass and Laboratory frames.

3 Hours

Rotational Dynamics: Angular momentum of a particle and a system of particles, Torque and the principle of conservation of angular momentum, Rotation about a fixed axis, Moment of Inertia, Calculation of moments of inertia for regular shaped bodies, Kinetic energy of rotation. Motion involving both translation and rotation.

8 Hours

Elasticity: Elastic properties of matter, Hooke's Law, Relation between Elastic constants, Twisting torque on a cylinder or a wire, Bending of Beams: Cantilever, Beam supported near the ends on two knife edges held in the same horizontal plane and a concentrated load W is applied at the midpoint.

4 Hours

Gravitation and Central Force Motion: Law of gravitation, Gravitational potential energy, Inertial and gravitational mass, Gravitational potential and the gravitational field due to a spherical shell and a solid sphere.

4 Hours

Motion of a particle under a central force field: Two-body problem, its reduction to one-body problem and its solution, the energy equation and energy diagram. Kepler's Laws, Satellite in circular orbit and applications. Geosynchronous orbits, Weightlessness, Basic idea of global positioning system (GPS).

6 Hours

Oscillations: Simple Harmonic Oscillations: Differential equation of SHM and its solution, Kinetic energy, potential energy, Total energy and their time-averaged values. Damped oscillation, Forced oscillations: Transient and steady states, Resonance, Sharpness of resonance, Power dissipation and Quality Factor, Compound pendulum.

6 Hours

Non-Inertial Systems: Non-inertial frames and fictitious forces: Uniformly rotating frame, Laws of Physics in rotating coordinate systems, Centrifugal force, Coriolis force and its applications. Components of velocity and acceleration in cylindrical and spherical coordinate systems.

4 Hours

COURSE OUTCOME: This course in Mechanics serves as the foundation for further progress towards the study of physics at graduate or post-graduate level. Upon completion of the course, the student will be able to apply Newton's laws of motion to different force fields for a single particle and for a system of particles.

Reference Books:

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
2. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
3. Feynman Hours, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
4. Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
5. University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley
6. An Introduction to Classical Mechanics, R G Takwale & P S Puranik, TMG Hill.
7. Mechanics, P K Srivastava, New Age International Pvt. Ltd.
8. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.
9. Vibrations, Waves and Acoustics, D Chattopadhyay and P C Rakshit, Books and Allied Pvt. Ltd.
10. Advanced Acoustics, D P Roychaudhuri and P Banerjee, The New Book Stall, 2009

MINOR II: PHYS2021: MECHANICS

Practical: **30 Hours**

1. To study the Motion of Spring and calculate (a) Spring constant, (b) g and (c) Modulus of rigidity.

2. To determine the Moment of Inertia of a Flywheel/regular shaped body.

3. To determine g and velocity for a freely falling body using Digital Timing Technique.

4. To determine the Young's Modulus of a Wire by Optical Lever Method.

5. To determine the Modulus of Rigidity of a Wire by Maxwell’s needle/dynamical method.

6. To determine the elastic Constants of a wire by Searle’s method.

7. To determine the value of g using Bar pendulum/Kater’s Pendulum.

8. To determine the value of Young’s Modulus by Flexure method.

Reference Books

1. Advanced Practical Physics for students, B. L. Flint and H.T.Worsnop, 1971, Asia Publishing House.
2. A Text Book of Practical Physics, I.Prakash & Ramakrishna,11thEdn,2011,KitabMahal.
3. Engineering Practical Physics, S.Panigrahi &B.Mallick,2015,CengageLearningIndiaPvt.Ltd.
4. Practical Physics,G.L.Squires,2015, 4thEdition,CambridgeUniversityPress.
5. Practical Physics, D Chattopadhyay, P C Rakshit and B Saha, Books and Allied Pvt. Ltd.
6. Advanced Practical Physics, B Ghosh and K G Mazumdar, Sreedhar Publishers.
7. B. Sc. Practical Physics, Harnam Singh and P S Heme, S Chand and Company Limited.
8. B. Sc. Practical Physics, C L Arora, S Chand and Company Limited.

MULTI-DISCIPLINARY COURSE (PHYSICS)
Semester I

MULTI-DISCIPLINARY-1: PHYS1031: CONCEPTS OF PHYSICS 1(Credits: 03)

F.M. = 50 (Theory- 40, Internal Assessment – 10)

COURSE OBJECTIVE: The aim of the course is to enable the students to be familiar with basic Physics.

Theory: **45 Hours**

Unit, Dimensions and Measurement of Physical Quantities

Need for a measurement, Units of measurement, Systems of units, SI units, Fundamental and derived units. Length, mass and time measurements, Accuracy and precision of measuring instruments, Errors in measurements, Significant figures. Dimensions of physical quantities, Dimensional analysis and its applications.

4 Hours

Kinematics

Motion in a Straight Line, Uniform and non-uniform rectilinear motion, Average speed and instantaneous velocity, Uniformly accelerated motion, Velocity-time and position-time graphs, Kinematic equations for uniformly accelerated motion (graphical treatment).

3 Hours

Scalar and vector quantities

Unit vector, Position and displacement vectors, Equality of vectors, Multiplication of vectors by a real number, Addition and subtraction of vectors, Relative velocity, Resolution of a vector in a plane, Rectangular components, Scalar and vector product of two vectors.

3 Hours

Motion in a plane

Uniform circular motion, projectile motion.

2 Hours

Laws of Motion

Intuitive concept of force, Inertia, Newton's first law of motion, Momentum and Newton's second law of motion, Impulse, Newton's third law of motion.Law of conservation of linear momentum and its applications.Static and kinetic friction, Laws of friction, Rolling friction, Lubrication. Dynamics of uniform circular motion, Centripetal force, Examples of circular motion (vehicle on a leveled circular road, vehicle on a banked road).

8 Hours

Work, Energy and Power

Work done by a constant force and a variable force, Kinetic energy, Work-energy theorem, power. Notion of potential energy, Potential energy of a spring, Conservative forces, Conservation of mechanical energy (Sum of kinetic and potential energies), Non-conservative forces, Motion in a vertical circle, Elastic and inelastic collisions in one and two dimensions.

8 Hours

System of Particles and Rotational Motion

Centre of mass of a two-particle system, Momentum conservation and Motion of centre of mass. Centre of mass of a rigid body, Centre of mass of a uniform rod. Moment of a force, Angular momentum, Law of conservation of angular momentum and its applications. Equilibrium of rigid bodies, Rigid body rotation and equations of rotational motion, Comparison of linear and rotational motion. Moment of inertia, Radius of gyration, Values of moments of inertia for simple geometrical objects (no derivation).

12 Hours

Gravitation

Universal law of gravitation, Acceleration due to gravity and its variation with altitude and depth.Gravitational potential energy and gravitational potential, Escape velocity, Orbital velocity of a satellite, Geo-stationary satellites.

5 Hours

COURSE OUTCOME: Students will develop the problem-solving capability and also learn the applications of Newtonian mechanics in daily life.

Reference Books:

1. Vector analysis, M.R. Spiegel, Tata McGraw Hill.
2. An introduction to Mechanics, D. Kleppner, R.J. Kolenkow, McGraw-Hill.
3. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. Tata McGraw-Hill.
4. Concepts of Physics, H C Verma, Vol 1 & 2, BharatiBhawan.
5. Mechanics, D.S. Mathur, S. Chand and Company Limited,
6. University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, Addison Wesley
7. Theoretical Mechanics, M.R. Spiegel, Tata McGraw Hill.
8. New Simplified Physics, S L Arora, Dhanpat RaI & Co. Pvt. Ltd, Vol.1, 2020

MULTI-DISCIPLINARY COURSE (PHYSICS)
Semester II

MULTI-DISCIPLINARY-2: PHYS2031 CONCEPTS OF PHYSICS 2(Credits: 03)

F.M.= 50 (Theory-40, Internal Assessment–10)

COURSE OBJECTIVE: ***The aim of the course is to enable the students to be familiar with basic Physics.***

Theory: **45 Hours**

General Properties of Matter

Mechanical properties of solids, Stress-strain relationship, Hooke's law, Elastic moduli. Mechanical properties of fluids, Pressure due to a fluid column, Pascal's law and its applications (hydraulic lift and hydraulic brakes).

Viscosity, Stokes' law, Terminal velocity, Streamline and turbulent flow, Critical velocity, Bernoulli's theorem and its applications.

Surface energy and surface tension, Angle of contact, Excess-pressure across a curved surface, Effects of surface tension to drops, bubbles and capillary rise.

13 Hours

Thermal Properties of Matter

Heat, Temperature, Thermal expansion, Thermal expansion of solids, liquids and gases, Anomalous expansion of water, Specific heat capacity, C_p, C_v – Calorimetry, Change of state, Latent heat capacity.

Processes of heat transfer: Conduction, Convection and Radiation, Thermal conductivity. Blackbody radiation, Planck's distribution law (qualitative discussion), Wien's displacement Law, Stefan's law.

8 Hours

Behavior of Perfect Gases and Kinetic Theory of Gases

Equation of state of a perfect gas, Work done in compressing a gas, Kinetic theory of gases: Postulates, Concept of pressure, Kinetic interpretation of temperature, RMS speed of gas molecules, Degrees of freedom, the law of equi-partition of energy (statement only) and its application to specific heat capacities of gases, Concept of mean free path, Avogadro's number.

8 Hours

Thermodynamics

Zeroth law of thermodynamics, Heat, work and internal energy, First law of thermodynamics, Isothermal and adiabatic processes, Second law of thermodynamics: Reversible and irreversible processes, Concept of entropy.

8 Hours

Oscillations and Waves

Oscillations: Periodic motion, Time period, Frequency, Displacement as a function of time, Simple harmonic motion (S.H.M): Differential equation, Phase, Oscillations of a loaded spring, Restoring force and force constant, Energy in S.H.M., Kinetic and potential energies, Derivation of the expression for the time period of a simple pendulum. Free, Forced and Damped oscillations (qualitative ideas only), Resonance.

8 Hours

COURSE OUTCOME: ***Students will develop the problem-solving capability and also learn the applications of Newtonian mechanics in daily life.***

Reference Books

1. Thermal Physics, S.Garg, R.Bansal and C.Ghosh,1993,Tata McGraw-Hill.

2. New Simplified Physics, S L Arora, Dhanpat RaI & Co. Pvt. Ltd, Vol.1, 2020
3. Concepts of Physics, H C Verma, Vol 1 & 2, Bharati Bhawan.
4. Waves: Berkeley Physics Course,vol.3,FrancisCrawford,2007,TataMcGraw-Hill.

5. Heat Thermodynamics and Statistical Physics, Brijlal, Subrahmanyam, Heme, S Chand.

6. Thermodynamics, Kinetic theory & Statistical thermodynamics, F.W.Sears & G.L.Salinger. 1988, Narosa.

7. A Treatise on Heat, Meghnad Saha and B.N.Srivastava, 1969, Indian Press.

SEC-PHYSICS

Semester-I

SEC-1:PHYS1051: RENEWABLE ENERGY AND ENERGY HARVESTING (Credits: 03)

F.M. = 50 (Theory - 40, Internal Assessment - 10)

COURSE OBJECTIVE:*To impart knowledge and hands on learning about various alternative energy sources like Wind, Solar, Mechanical, Ocean, Geothermal etc. To review the working of various energy harvesting systems which are installed worldwide.*

Theory: 45 Hours

Fossil Fuels and Alternate Sources of Energy: Fossil fuels and nuclear energy, Their limitation, Need of renewable energy, Non-conventional energy sources. An overview of the developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, Solar energy, Biomass, Biochemical conversion, Biogas generation, Geothermal energy, Tidal energy, Hydroelectricity.

8 Hours

Solar energy: Solar energy and 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, Absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits and sun tracking systems.

8 Hours

Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces and grid interconnection topologies.

5 Hours

Ocean Energy: Ocean Energy, Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices. Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass.

5 Hours

Geothermal Energy: Geothermal resources, Geothermal technologies.

4 Hours

Hydro Energy: Hydropower resources, Hydropower technologies, Environmental impact of hydro power sources.

5 Hours

Piezoelectric Energy harvesting: Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modelling piezoelectric generators, Piezoelectric energy harvesting applications, Human power.

5 Hours

Electromagnetic Energy Harvesting: Linear generators, Related Physics, Mathematical models, Recent applications, Carbon captured technologies, cell, Batteries, Power consumption, Environmental issues and Renewable sources of energy, Sustainability.

5 Hours

COURSE OUTCOME: The students are expected to learn not only the theories of the renewable sources of energy, but also to have hands-on experiences on them wherever possible.

Reference Books:

1. Non-conventional energy sources - G.D Rai - Khanna Publishers, New Delhi
2. Solar energy - M P Agarwal - S Chand and Co. Ltd.
3. Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.
4. Godfrey Boyle, “Renewable Energy, Power for a sustainable future”, 2004, Oxford University Press, in association with The Open University.
5. Dr. P Jayakumar, Solar Energy: Resource Assesment Handbook, 2009
6. J.Balfour, M.Shaw and S. Jarosek, Photovoltaics, Lawrence J Goodrich (USA).
7. http://en.wikipedia.org/wiki/Renewable_energy
8. Snatak Padartha Vigyan, Renewable Energy Sources, A M Rudra, A Bhattacharya and A Dan, The New Book Stall, 2018.

SEC-PHYSICS

Semester-II

SEC-2: PHYS2051: ELECTRICAL CIRCUITS AND NETWORK SKILLS (Credits: 03)

F.M.= 50 (Theory - 40, Internal Assessment - 10)

COURSE OBJECTIVE*: The aim of this course is to enable the students to understand the basics of electronic circuits. Practical design and trouble shoot of electronic instrument is also a major objective of this Couse.*

Theory: **45 Hours**

Basic Electricity Principles: Voltage, Current, Resistance, and Power. Ohm's law.Series, parallel, and series-parallel combinations.AC Electricity and DC Electricity.Familiarization with multimeter, voltmeter and ammeter.

5 Hours

Understanding Electrical Circuits: Main electric circuit elements and their combination. Rules to analyze DC sourced electrical circuits. Current and voltage drop across the DC circuit elements. Single-phase and three-phase alternating current sources. Rules to analyze AC sourced electrical circuits. Real, imaginary and complex power components of AC source.Power factor.Saving energy and money.

8 Hours

Electrical Drawing and Symbols: Drawing symbols. Blueprints.Reading Schematics. Ladder diagrams. Electrical Schematics.Power circuits. Control circuits. Reading of circuit schematics. Tracking the connections of elements and identify current flow and voltage drop. (5 Hours)

Generators and Transformers: DC Power sources. AC/DC generators.Inductance, capacitance, and impedance.Operation of transformers.

5 Hours

Electric Motors: Single-phase, three-phase & DC motors. Basic design.Interfacing DC or AC sources to control heaters & motors. Speed & power of ac motor.

5 Hours

Solid-State Devices: Resistors, inductors and capacitors. Diode and rectifiers.Components in Series or in shunt. Response of inductors and capacitors with DC or AC sources

5 Hours

Electrical Protection: Relays. Fuses and disconnect switches. Circuit breakers. Overload devices. Ground-fault protection.Grounding and isolating. Phase reversal. Surge protection.

Interfacing DC or AC sources to control elements (relay protection device)

5 Hours

Electrical Wiring: Different types of conductors and cables. Basics of wiring-Star and delta connection.Voltage drop and losses across cables and conductors.Instruments to measure current, voltage, power in DC and AC circuits.Insulation.Solid and stranded cable.Conduit Cable trays. Splices: wire nuts, crimps, terminal blocks, split bolts, and solder. Preparation of extension board.

7 Hours

COURSE OUTCOME: After the completion of the course the student will acquire necessary skills/ hands on experience /working knowledge on Multimeter, voltmeters, ammeters, electric circuit elements, dc power sources. With the knowledge of basic electronics a student can able to detect troubleshoot and repair some of the electronic instruments used in our daily life.

Reference Books:

1. A Text book in Electrical Technology - B L Theraja - S Chand & Co.
2. A Text book of Electrical Technology - A K Theraja
3. Performance and design of AC machines - M G Say ELBS Edn.

MAJOR-PHYSICS COURSE
Semester III

MAJOR-III:PHYS3011: Electricity and Magnetism (Credits: Theory-04, Practical - 01) F.M.=75(Theory-40, Practical–20, Internal Assessment–15)

Course Objective:*The objective of this paper is to give the basic concept as well asan in-depth understanding of the principles of electricity and magnetism and apply them to solve the problems related.*

Theory: **60 Hours**

Electrostatics

Unit I Quantization of electric charge, Coulomb's law, Principle of superposition, Electric field (Physical concept, quantitative definition and its source), Electric field of a point charge, Electric field lines and their properties, Charge density, Volume charge density, Surface charge density, Line charge density, Electric fields due to continuous charge distributions, Electric field due to a uniformly charged non-conducting rod at an axial point and at a point on the perpendicular bisector of that rod,Electric field due to a circular disc on the axial point.

5 Hours

Unit 2 Electric flux, Gauss' law, Differential form of Gauss' law, Equivalence of Coulomb's law and Gauss' law, Gaussian surface, Application of Gauss' law to evaluate the electric field at a point for charge distributions with spherical (A thin spherical shell of radius R with a charge +Q evenly distributed over its surface, thick shell, and a solid sphere of radius R with uniform volume charge density), planar (Infinitely large non-conducting plane with uniform surface charge density) and cylindricalsymmetry (Infinitely long non-conducting rod of uniform line charge density).

6 Hours

Unit 3 Conservative nature of electrostatic field, Electric scalar potential, Relation betweenthe electric field and the electric potential, Electric potential of a point charge and a group of point charges, Electric potential due to a continuous charge distribution, Electric potential and field due to an electric dipole, Force and torque acting on an electric dipole in a uniform electric field, Laplace's and Poisson's equations, The Uniqueness theorem (Proof required).

5 Hours

Unit 4 Electrostatic potential energy, Electrostatic potential energy of a collection of point charges,Electrostaticpotential energy of a continuous charge distribution (general expression and a charged sphere as an example), Self energy, Classical electron radius, Electrostatic potential energy of an electric dipole in a non-uniform electric field.

4 Hours

Unit 5 Equipotential surfaces, Electrostatic equilibrium properties (regarding electric charge, electric field and electric potential) of a conductor in a uniform electric field, Surface charge and force on a conductor, Boundary conditions on the electric field at the interface between a vacuum and a conductor, Capacitor as a charge storing device, Capacitance and the energy stored in a capacitor, Capacitance of a system of charged conductors, Parallel-plate capacitor, Capacitance of an isolated conductor, Method of Images and its application to: (1) Plane infinite sheet and (2) Sphere.

6 Hours

Unit 6 Dielectric properties of matter**:** Electric field inside a matter, Polarization, Polarization charges, Electrical susceptibility and dielectric Constant, Capacitor (parallel-plate, spherical, cylindrical) filled with dielectric, Displacement vector $\vec{D}$, Relations between $\vec{E}$, $\vec{P}$ and $\vec{D}$, Gauss' Law in dielectrics,Boundary conditions between two dielectric interfaces.

4 Hours

Steady Electric Current

Electric current, Current density, Continuity equation, Conductivity, Ohm's law, Electromotive force, Kirchhoff's first and second law- statement and applications, Thevenin′s, Norton′s and maximum power transfer theorems and their applications.

2 Hours

Magneto-statics

Unit 1 Electric current as a source of magnetic field, Definition and units (SI) of:Magnetic flux density $\vec{B}$, Magnetic field strength $\vec{H}$ and Magnetization vector ($\vec{M}$), Relation between $\vec{B}$, $\vec{H}$ and $\vec{M}$, Magnetic susceptibility and magnetic permeability,Boundary conditions between two magnetic media, Force (Lorentz force) on a moving charge in the simultaneous presence of both electric and magnetic fields, Trajectory of a charged particle in a crossed uniform electric and magnetic fields.

3 Hours

Unit 2 BiotSavart's Law and its applications: $\vec{B}$ due to current in (i) a long straight conductor, (ii) a circular loop, (iii) a solenoid, Current loop as a magnetic dipole and its dipole moment.

3 Hours

Unit 3 -Ampere's circuital law and its applications: $\vec{B}$ due to current in (i) a long straight conductor, (ii) a solenoid and (iii) a toroid.

2 Hours

Unit 4 Magnetic force on (i) a current element, (ii) a line current, Force between two current elements, Divergence and Curl of B (Gauss and Ampere's laws), Physical significance of the nature of the divergence and curl of B, Magnetic vector potential.

3 Hours

Transient current

Growth and decay of currents in LR, CR and LCR circuits, Time constant.

2 Hours

Alternating Current

Source of alternating current, Mean value, Peak value and RMS value of alternating voltage and current, Inductive and capacitive reactance, Real power, Reactive power and apparent power, Power triangle, Power factor, Series LCR circuit analysis, Phasor diagrams (AC voltage from a source (V), Current through the resistor R (i_R) and the voltage across R (V_R), Current through the capacitor C (i_c) and the voltage across C (V_c), Current through the inductor L(i_L) and the voltage across L (V_L), Calculation of total impedance of a series LCR circuit using the phasor diagram of V, V_R, V_L and V_c, Parallel LCR circuit analysis, Resonance in LCR circuits (series and parallel), LC oscillations.

7 Hours

Electromagnetic Induction

Faraday's law, Lenz's law and conservation of energy, Motional EMF, Eddy current, Principle of power generation, Self-inductance and mutual inductance,Induction oven, Induction brake, Reciprocity theorem, Energy stored in a magnetic Field,Introduction to Maxwell's equations,Continuity equation.

4 Hours

Electrical equipment

Moving coil ballistic and dead beat galvanometers:Workingprinciple, Derivation of the equation relating between the charge flowing through the coil and the ballistic throw of the galvanometer, Damping correction, Current, charge and voltage sensitivities of a moving coil galvanometer, Equation of motion of the coil, Non-oscillatory, aperiodic or dead beat motion, Critical damping, Light damping: Ballistic motion, Uses.

4 Hours

Course Outcome: ***At the end of this course, students will be able to comprehend the concept of electric field, electric flux, magnetic field and their origin. They will learn to apply the Gauss's theorem to find the electric fields for different types of charge distribution. The students will develop a sound perception about Electrostatics, Magneto-statics, Electric current and electromagnetic induction.***

Reference Books

1. Electricity and Magnetism, Purcell, M. Edward, DavidJ. Morin, 2013, Cambridge University Press, 3rd edition.
2. Electricity and Magnetism, R. Murugeshan, 2019, S. Chand Publishing,10th Edition.
3. Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw-Hill.
4. Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education.
5. Introduction to Electrodynamics, D.J. Griffiths,1998, Benjamin Cummings,3rd Edn.

6. Feynman Hours Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, PearsonEducation.
7. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.
8. Electricity and Magnetism Volume I, J.H.Fewkes& J. Yarwood, 1991, Oxford Univ. Press.

MAJOR-III: PHYS3011:Electricity and Magnetism
Practical: **30 Hours**
List of Experiments

1. ***To verify the Thevenin's, Norton's and Maximum Power transfer theorems***
2. ***To determine the Self-inductance of a coil using Anderson's bridge***
3. ***To study the response curve of a series LCR circuit and determine its (a) Resonant frequency,(b) Impedance at resonance, (c) Quality factor and (d) Band width***
4. ***To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonantfrequency and (b) Quality factor***
5. ***Measurement of Charge Sensitivity and CDR of a Ballistic Galvanometer***
6. ***Determination of a Ballistic Galvanometer Constant by Capacitor Charging-Dischargingmethod***
7. ***Construction of a One Ohm coil***
8. ***Determination of a Ballistic Galvanometer Constant by the Solenoid method***
9. ***Determination of Mutual Inductance of two coils by Carey-Foster's method***

Reference Books

1. Advanced Practical Physics for students, B.L. Flint and H.T.Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
4. Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning.
5. A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani.
6. B.Sc. Practical Physics, Harnam Singh, Dr. P.S. Hemne, 2018, S. Chand.
7. Advanced Practical Physics, B. Ghosh and K. G. Majumdar, Shreedhar Publishers.
8. Advanced Course in Practical Physics, D Chattopadhyay, P C Rakshit, New Central Book Agency.

MAJOR-PHYSICS COURSE
Semester III

MAJOR-III: PHYS3012:Waves and Optics (Credits: Theory-04, Practical -01)
F.M.=75 (Theory-40, Practical–20, Internal Assessment–15)

Course Objective: ***The objective of this course is to provide an in-depth understanding of the nature of waves in general, sound wave as an example of mechanical wave and light as an electromagnetic wave. It is also intended to provide a comprehensive idea of some phenomena like interference, diffraction and polarisation and their physical explanation in terms of the wave theory of light.***

Theory: **60 Hours**

Superposition of Collinear Harmonic Oscillations

Simple harmonic motion as a projection of a uniformly rotating vector on a reference axis, Linearity and superposition principle, Superposition of two collinear simple harmonic vibrations with different amplitudes, different initial phases and with: (1) same frequencies using both the analytical method and the vector method,(2)slightly different frequencies, Beats (graphical representation of beats), Superposition of a large number (N) of simple harmonic vibrations of equal amplitude and frequency but with (a) equal successive initial phase differences and (b) random phases by the vector method, Superposition of a large number (N) of simple harmonic vibrations of equal amplitude and same initial phase but with equal successive frequency differences by the analytical method.

7 Hours

Superposition of two Perpendicular Harmonic Oscillations

Superposition of two perpendicular simple harmonic oscillations having (1) equal frequencies, different amplitudes and an initial phase difference δ (graphical representation for δ varying between 0 and 2π), and(2) two different frequencies, different amplitudes and an initial phase difference δ (Lissajous Figures)using the analytical method as well as the graphical method.

3 Hours

Coupled Oscillations

Stiffness coupled oscillators: two identical pendulums (each a light rigid rod of length l supporting a mass m) coupled by a weightless spring of stiffness ***s***, Normal coordinates, Degrees of freedom, Normal modes of vibration, A large number (N) of coupled oscillators *e.g.*, a light string fixed at both ends, supporting N equal masses spaced at equal distance along its length (Qualitative discussion without any mathematical details).

4 Hours

One Dimensional Wave

Transverse oscillations (in a plane) of a slightly extensible, uniform string of mass per unit length *l* under a constant tension (*T*) with free ends.

3 Hours

Unit II Oscillations of a string of fixed length under a constant tension (*T*) with both ends rigidly clamped. Group velocity, Doppler Effect.

4 Hours

Sound Waves in Gases

Longitudinal disturbances in the pressure and density causing compressions and rarefactions of small volume elements of the gases, Deduction of the wave equation $\frac{\partial^2 y}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 y}{\partial t^2}$, Velocity of sound waves $c = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\gamma P}{\rho}}$, The energy (kinetic, potential, total) distribution in space for a sound wave in a gas (qualitative idea), Intensity of sound waves and units.

4 Hours

Elastic Waves in Bulk Solids

Longitudinal and transverse modes, the wave equations for each mode, Velocity of waves in each mode.

2 Hours

Superposition of Harmonic Waves

The wave equation supports the superposition principle, Superposition of electromagnetic waves treating the fields as scalar, Superposition of (a) Two harmonic plane waves of the same frequency – Idea of coherent sources and interference, (b) N harmonic waves with identical frequencies: (i) randomly phased sources of equal amplitudes, (ii) Coherent (constant phase relationship) sources of the same type) and in phase.

3 Hours

Interference

Wave front-a surface of constant phase at a given instant of time, Conditions of interference, Spatial and temporal coherence, Realization of coherent sources by division of a wave front: Young's double slit experiment, Fresnel's Bi-prism, Lloyd's Mirror.

Phase change on reflection: Stokes' treatment, Realization of coherent sources by division of amplitude, Interference in thin films: Parallel and wedge-shaped films, Fringes of equal inclination (Haidinger Fringes), Fringes of equal thickness (Fizeau Fringes), Newton's Rings: Measurement of wavelength and refractive index.

Michelson interferometer, Formation of the fringes,(No theory required), Applications: Determination of the (1) wavelength and (2) wavelength difference, (3) Refractive Index, Visibility of fringes.

Fabry-Perot interferometer, Formation of the fringes, Intensity distribution, Resolving Power, Superiority over Michelson interferometer.

10 Hours

Diffraction

The Huygens–Fresnel principle, Diffraction and interference, Fresnel diffraction and Fraunhofer diffraction.

Fraunhofer diffraction: Single slit diffraction, Double slit diffraction, N-slits diffraction or a diffraction grating, Rayleigh criterion for resolution, Resolving power of a grating, Grating spectra versus Prism spectra.

Fresnel Diffraction: Fresnel's assumptions, Fresnel's half-period zones for plane wave, Explanation of rectilinear propagation of light, Theory of a zone plate: Multiple foci of a zone plate, Fresnel's integral, Fresnel diffraction pattern of a straight edge, a slit and a wire.

10 Hours

Polarisation of Light

Types of polarized light: Plane polarized light, Circularly polarized light, Elliptically polarized light,

Production of polarized light(a) by reflection, Brewster angle, Malus law, (b) by dichroism, Pollaroids, (c) by double refraction, Doubly refracting crystals, Negative crystals, Positive crystals, Optic axis, Nicol prism, Huygen's theory of double refraction, Phase retardation plate: 1) Quarter wave plate 2) Half wave plate,

Detection of plane, circularly and elliptically polarized light.

Optical activity and its origin, Two types of optically active substance, Fresnel's theory of optical rotation, Polarimeter.

10 Hours

Course Outcome: ***The outcome of the paper includes the knowledge of vibrations, propagation of waves, vibrations of air column, and harmonics of the strings. The paper has another outcome of offering knowledge of wave properties of light & corresponding phenomena.***

Reference Books

1. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
2. The Physics of Waves and Oscillations, N K Bajaj, 1984, Tata McGraw-Hill.
3. Waves and Oscillations, N. Subramanyam and BrijLal, 2010, Vikas Publishing House Pvt. Ltd.
4. Waves and Optics: As per CBCS, M. N. Avadhanulu & TVS Arun Murthy, S. Chand Publishing.
5. Optics, Eugene Hecht, 2019, Pearson.

6. OPTICS at Graduate Level, Prof. Devanarayanan Sankara, 2019, Independently published.
7. Optics An Introduction, Sarhan M. Musa, 2017, Mercury Learning and Information.
8. Fundamentals of Optics, F.A. Jenkins and H.E. White, 2017, McGraw-HillEducation Ltd.
9. Principles of Optics, Max Born and Emil Wolf, 1999, Pergamon Press.

MAJOR-III: PHYS3012: Waves and Optics

Practical: **30 Hours**

List of Experiments

1. ***To draw n-l curve with the help of a sonometer and hence find the frequency of an unknown fork***
2. ***Determination of the frequency of ac mains with a sonometer using a magnetic wire***
3. ***Determination of the velocity of ultrasonic waves in a given liquid***
4. ***To determine the refractive index of the material of a prism using sodium source***
5. ***To determine the wavelength of sodium light using Fresnel Biprism***
6. ***To determine the wavelength of sodium light using Newton's Rings***
7. ***Determination of the width of a single slit producing a Fraunhofer diffraction pattern***
8. ***To determine wavelength of (1) Na source and (2) spectral lines of Hg sourceusing a plane diffraction grating***
9. ***Calibration of a polarimeter and determination of the concentration of an active solution***
10. ***To determine the resolving power of a plane diffraction grating***

Reference Books:

1. Advanced Practical Physics for students, B.L. Flint and H.T.Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
4. Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning.
5. A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani.

6. B.Sc. Practical Physics, Harnam Singh, Dr. P.S. Hemne, 2018, S. Chand.
7. Advanced Practical Physics, B. Ghosh and K. G. Majumdar, Shreedhar Publishers.
8. Advanced Course in Practical Physics, D Chattopadhyay, P C Rakshit, New Central Book Agency.

MULTIDISCIPLINARY COURSE-PHYSICS
Semester III

MULTI-DISCIPLINARY: PHYS3031: Electricity, Magnetism and Electronics (Credits: 03)
F.M.=50 (Theory-40, Practical–0, Internal Assessment–10)

Course Objective: ***This course is designed to give the students a basic understanding of electricity, magnetism and electronics. The student will also gain a preliminary knowledge of some electrical and electronic instruments.***

Theory: **45 Hours**

Basic Concepts of Electrostatics

Electric charge, Coulomb's law, Electric field, Electric field of a point charge, Electric potential, Electric potential of a point charge.

6 Hours

Dielectric, Capacitor and Capacitance

A dielectric or dielectric material, Dielectric polarization, Electric dipole moment (SI unit), Permittivity, Static dielectric constant, Capacitor and capacitance, Potential energy stored in a capacitor, Capacitance of a parallel plate capacitor, SI unit of capacitance, Relation between the dielectric constant and the capacitance of a dielectric, Types of capacitors: Aluminum electrolytic capacitor, Tantalum capacitor, Electric double layer capacitor, Ceramic capacitor, Film capacitor, Mica Capacitor.

9 Hours

Electrical Conductor

A conductor, Electric current, Resistance and conductance of a conductor and their units, Characteristics of good electrical conductor with examples, Ohm's law, Direct current and its sources, Uses of battery in electronic circuits: Cell phones, laptops, radios, flashlights, automobiles and other electronic gadgets, Alternating current and its sources, Uses in electrical/ electronic circuits.

7 Hours

Magneto-statics

Biot Savert law, Magnetic field and its SI unit, Magnetic flux and force, Ampere's circuital law.

8 Hours

Electromagnetic Induction and Inductors

Electromagnetic induction, Faraday's law of electromagnetic induction, Lenz's law and conservation of energy, Inductance and its SI unit, Principle of operation of an AC generator, Inductor as a component that allows DC current to flow but not AC current.

8 Hours

Basic Electrical/ Electronic Components and Devices

Resistors, Capacitors, Diodes, Light emitting diode (LED), Transistors, Inductors, Integrated circuit (IC), Fuse, Transformer, Electrical versus electronic devices, Working principle of a tube light, Working principle of an electric fan, Electronic circuits: Amplifier, Rectifier, Filter.

7 Hours

Reference Books

1. Electricity & Magnetism, Sehgal D. L., Chopra K.L., Sehgal N.K., 2020, Sultan Chand & Sons.
2. Electricity and Magnetism, S.P. Taneja, 2022, R. Chand and Company.
3. Electricity and Magnetism, R Murugeshan, 2017, S. Chand Publishing.
4. Basic Electrical and Electronics Engineering, S. K. Bhattacharya, 2011, Pearson Education India.
5. Basic Electronics, McGraw Hill Education, (2017).

Course Outcome: ***After successful completion of this paper students of other disciplines will be able to comprehend the basics of electricity, magnetism and electronics. The students will be acquainted with basic electrical and electronic devices.***

SEC-PHYSICS
Semester-III

SEC-3:PHYS3051: Basic Instruments and their Usage (Credits: 03)
F.M. = 50 (Theory - 40, Internal Assessment – 10)

Course Objective: ***This course is designed to give the students an exposure with various aspects of electrical and optical instruments and their applications in experimental physics.***
Theory: **45 Hours**
Electrical/ Electronic Instruments

Voltage and current sources, Principles of measurement of dc voltage & current, ac voltage& current and a resistance, Specifications of an electronic voltmeter/ multi-meter and their significance, Advantages of electronic voltmeterover conventional multi-meter for the measurement of voltage, Instrumental accuracy, Precision, Sensitivity, Resolution, Range*etc*., Errors in measurements and loading effects.

Cathode Ray Oscilloscope: Block diagram of basic CRO, Time base operation, Synchronization, Front panel controls, Specifications of a CRO and their significance, Use of CRO for the measurement of voltage (dc and ac), frequency, Special feature of dual trace.

Signal Generators: Block diagram, Explanation and specifications of low frequency signal generators, Pulse generators and function generators.

Digital Instruments: Principle and function of a digital meter, Characteristics of a digital meter, Comparison of analog & digital instruments.

22 Hours

Optical Instruments

Optical microscope: Simple microscope, Compound microscope, Electron microscope: Principal components, Working principle and uses.

Telescope: Principal components, Working principle and uses of different types of telescopes (Astronomical telescope, Terrestrial telescope, Reflecting telescope).

An objective lens and an eyepiece or ocular lens: Elements, Angular magnification of a telescope, Angular magnification of a microscope, Huygens eyepiece, Ramsden eyepiece.

Spectrometer: Principal components, Role of individual components, Uses, Ultraviolet-Visible (UV-VIS), Near-infrared (NIR) and Raman spectrometers.

23 Hours

Suggested Activities

1. To realize the importance of grounding, earthing and the methods for earthing
2. To know about the telescopes used at different observatories in and outside India

Demonstration Experiments

1. Use of an oscilloscope for the measurement of voltage, frequency, time period and phase

angle

2. An experiment for the determination of magnifying power of a microscope
3. Use of a digital multi-meter for measuring voltages (dc and ac), currents (dc and ac), resistances and its limitation for measuring high frequency voltage and current.

Reference Books

1. Modern electronic instrumentation and measurement techniques India, Albert D Helfrick &William D Cooper 1992, Prentice Hall India Learning Private Limited.
2. Basic Electrical and Electronics Engineering, S. K. Bhattacharya, 2011, Pearson Education India.
3. The Theory of Optical Instruments, E T Whittaker, 2023, Mjp Publishers

Course Outcome: ***After completion of this course, the students will gain knowledge the in setting up electrical and optical experiments.***

MAJOR-PHYSICS COURSE
Semester IV

MAJOR-IV: PHYS4011: Heat and Thermodynamics (Credits: Theory-04, Practicals-01)
F.M. = 75 (Theory-40, Practical–20, Internal Assessment–15)

Course Objectives*: The objective of the course is to infuse ideas of thermodynamic systems, thermodynamic variables, thermodynamic processes, and allied phenomena. It is designed to familiarize students with thermodynamic potentials, the kinetic theory of gases, and the theory of radiation.*

Theory: **60 Hours**

The Kinetic Theory of Gases

Objective of the theory (Knowledge of a macroscopic system from its microscopic constituents), Classical ideal gas and the ideal gas law, A microscopic view of an ideal gas and the basic postulates of the kinetic theory, The justifications and implications of the postulates, Mean free path, Collision probability, Estimates of mean free path, The kinetic interpretation of pressure P, Relation between pressure and translational kinetic energy of the molecules, Kinetic interpretation of temperature - the average molecular kinetic energy is proportional to the absolute temperature.

4 Hours

The equipartition theorem (statement only), Kinetic degrees of freedom (*f*), Thermal energy and specific heat of gases (C_p andC_v),γ- the ratio of C_p and C_v, Relation between $\gamma$and f, Specific heat of a monatomic, a diatomic gas (N_2)gas: the experimental value and its interpretation in terms of quantum effects restricting the active modes, Brownian motion and its significance.

3 Hours

Speeds of the molecules of an ideal gas in thermal equilibrium, Maxwell–Boltzmann distribution law (statement only): Probability density $\rho(c)$ as a function of speed c and its graphical representation, Important features of the graph and their significances: (a) Asymmetric, single peaked nature of the curve, (b)Changes in $\rho(c)$with (i) increasing temperature, and (ii)increasing mass of the single molecule of a gas *e.g.*, in the cases for He, Ne, Ar, Number of molecules (dN) of an ideal gas moving with a speed lying between c and $c + dc$, Important conclusions: (a) Heavy molecules are unlikely to have very high speeds, (b) Number of molecules with high speeds increases with the increasing temperature, (c) Area under the curve, equal to the total number of molecules does not change with changing temperature (T), Estimation of the fraction of molecules with speeds greater than c, Average or mean speed (C_{av}), Root mean square velocity (C_{rms}), Most probable speed (C_{mp}) from the distribution law, Comparison of C_{av}, C_{rms} andC_{mp} at a fixed temperature (T), Maxwell-Boltzmann distribution law of molecular energies from that of the speeds, Average kinetic energy.

8 Hours

Non equilibrium state and transport phenomenon in ideal gases: (1) Viscosity: Transport of momentum, Coefficient of viscosity (η) in terms of the mean free path (λ), (2) Thermal conductivity: Transport of thermal energy, Thermal conductivity (K) in terms of the mean free path (λ), Effect of temperature (T) on K, (3) Diffusion: Transport of mass, Coefficient of diffusion (D) in terms of the mean free path (λ), Effect of temperature (T) and pressure on D.

4 Hours

Real gases, Andrew's experiment on carbon dioxide: Principle, Result as isothermals (plots of the pressure versus the volume at different temperatures), Interpretation of the isothermals, Inferences from the experiment, Critical constants, Van der waals' equation of state: Correction for finite size of the molecule, Correction for intermolecular attraction, Comparison between the nature of the isothermals obtained from Andrew's experiment and plots of the pressure versus the volume of a gas obeying Van der waals' equation of state at different temperatures (similarities and differences), Expression for critical constants (T_c, p_c, and V_c) and critical coefficient, Limitations of the Van der waals' equation, Virial expansion: Concept, the Van der waals' equation of state in terms of a virial expansion, the Boyle temperature in terms of T_c.

5 Hours

Heat Conduction

Thermal conductivity (***K***), Diffusivity (***D***), Fourier's equation of heat conduction and its solution for the rectilinear flow of heat. Ingen Hausz's Experiment

3 Hours

Radiation

Blackbody radiation and its spectral distribution, Concept of the energy density, Derivation of the Planck's law, Deduction of the Stefan-Boltzmann law, the Rayleigh-Jean's law and the Wien's displacement law from Planck's law.

4 Hours

Thermodynamics

Definitions: A thermodynamic system and its surroundings, Open, closed, adiabatic and isolated systems, Thermodynamic variables: extensive and intensive, Steady state of a thermodynamic system, Thermodynamic equilibrium, Thermodynamic path, Thermodynamic processes: Cyclic, Quasi-static, Reversible and irreversible processes, Isothermal, Isobaric and Isochoric processes, Minimum number of state variables for a single and a multi component system, Equation of state, Functions of state and functions of path (Examples), Exact and inexact Differentials, Heat and Work, Standard temperature and pressure, Internal energy of a system (***U***).

3 Hours

The Zeroth law of thermodynamics and the concept of temperature, The first law of thermodynamics, exact and inexact differentials, Heat capacity: $\boldsymbol{C_V}$ and $\boldsymbol{C_p}$. Molar heat capacity $\boldsymbol{c_v}$ and $\boldsymbol{c_p}$, Ideal gas:Isothermal expansion, adiabatic transformation.

3 Hours

A heat engine, A heat reservoir, The second law of thermodynamics: Clausius' statement of the second law of thermodynamics, Kelvin's statement of the second law of thermodynamics, the efficiency ($\boldsymbol{\eta}$) of an engine and the coefficient of refrigeration ($\boldsymbol{\kappa}$), A Carnot engine, Carnot's theorem, Working substance, The Carnot cycle in a ***p-V*** diagram with an ideal gas as working substance and four stages: isothermal expansion, adiabatic expansion, isothermal compression, adiabatic compression, the work done and the heat exchange in each stage, The efficiency of a Carnot engine ($\boldsymbol{\eta}$) in terms of the ratio of $\boldsymbol{T_1}$ (temperature of the hot reservoir) and $\boldsymbol{T_2}$ (temperature of the cold reservoir), Equivalence of Clausius' and Kelvin's statements, A refrigerator and a heat engine, Clausius' theorem and Clausius inequality.

10 Hours

Definition of entropy, Change in entropy ($\boldsymbol{dS}$) for a thermally isolated system for a reversible change and an irreversible change, Application to the Universe, The first law revisited: $\boldsymbol{dU = TdS - pdV}$, $\boldsymbol{dU = dQ + dW}$ (always true), $\boldsymbol{dQ = TdS}$ (only true for reversible changes), $\boldsymbol{dW = -pdV}$(only true for reversible changes), $\boldsymbol{dU = TdS - p\ dV}$ (always true), For irreversible changes: $\boldsymbol{dQ \leq T\ dS}$, $\boldsymbol{dW \geq -pdV}$, Second law of thermodynamics in terms of entropy, The change of entropy in the gas, surroundings and the universe during Joule expansion of an ideal gas.

3Hours

Thermodynamic potentials: Internal Energy (***U***), Enthalpy (***H***), Helmholtz Free Energy (***F***), Gibb's Free Energy (***G***),T-dS equation, Maxwell's relations: Derivation and applications, $\boldsymbol{C_p - C_V = VT\beta^2\, p/\kappa T}$, Isothermal (κ_T) and adiabatic (κ_S) compressibilities, Ratio of κ_T and κ_S equal to C_p / C_V.

4 Hours

Free adiabatic expansion of a perfect gas, Joule-Thomson porous plug experiment. Joule-Thomson effect for real and Van der Waals' gases. Temperature of inversion.Joule-Thomson Cooling.

3 Hours

Third law of thermodynamics: Nernst's statement, Planck's statement, Simon's statement, Consequences: (a) Heat capacities tend to zero as $T \rightarrow 0$, (b) Thermal expansion stops, (c) No gases remain ideal as $T \rightarrow 0$, (d) Impossible to attain $T = 0$ in a finite number of steps.

3 Hours

Reference Books

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 198`McGraw-Hill.
2. Thermal Physics, S. Garg, R. Bansal and Ghosh, 1993, Tata McGraw-Hill.
3. A Treatise on Heat, MeghnadSaha, and B.N.Srivastava, 1958, Indian Press.
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
5. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger, 1988, Narosa.
6. An Introduction to Thermal Physics, Daniel V Schroeder, 2020, Oxford University Press.
7. Thermal Physics, A. B. Gupta and H. P. Roy,Books and Allied Ltd.

Course Outcome: ***On completion of this course, the students will learn the kinetic theory of gases, the basic laws of thermodynamics, the applications of the well-known Maxwell's relations, the underlying Physics behind the Joule Thompson effect and the spectral distribution of the blackbody radiation.***

MAJOR-IV: PHYS4011: Heat and Thermodynamics
Practical: 30 Hours

List of Experiments

1. ***To determine the coefficient of thermal conductivity of copper using Searle's apparatus***
2. ***To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method***
3. ***Determination of the value of the Stefan's constant***
4. ***To study the variation of thermo-emf across two junctions of a thermocouple with temperature***
5. ***To determine the temperature coefficient of resistance and the boiling point of a given liquid using Platinum resistance thermometer***
6. ***To calibrate a thermocouple for measuring the temperature in a specified range using i) null method, ii) direct measurement using OP AMP difference amplifiers***
7. ***To determine the coefficient of thermal expansion of a metallic rod using an optical lever***
8. ***To determine the temperature coefficient of resistance using the Carry Foster bridge***
9. ***To determine the coefficient of thermal expansion of a metallic rod using travelling microscope***
10. ***To determine the pressure coefficient of air by constant volume method***

Reference Books:

1. Advanced Practical Physics for students, B.L. Flint and H.T.Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
4. Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning.
5. A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani.
6. B.Sc. Practical Physics, Harnam Singh, Dr. P.S. Hemne, 2018, S. Chand.
7. Advanced Practical Physics, B. Ghosh and K. G. Majumdar, Shreedhar Publishers.

8. Advanced Course in Practical Physics, D Chattopadhyay, P C Rakshit, New Central Book Agency.

MAJORPHYSICS COURSE
Semester IV

MAJOR IV: PHYS4012: Mathematical Physics-II (Credits: Theory-04, Practicals-01)
F.M.=75 (Theory-40, Practical–20, Internal Assessment–15)

Course Objectives:*The emphasis of this course is on applications ofmathematical techniques in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.*

Theory: **60 Hours**

Fourier Series

Unit 1 Periodic functions, Orthogonality of sine and cosine functions, Dirichlet conditions (statement only), Expansion of periodic functions in a series of sine and cosine functions and the determination of Fourier coefficients, Complex representation of a Fourier series, Expansion of functions with arbitrary period, Expansion of non-periodic functions over an interval, Even and odd functions and their Fourier expansions.

Applications: Summing of infinite series, Term-by-term differentiation and integration of a Fourier series, Parseval identity.

12 Hours

Frobenius Method and Special Functions

Singular points of the second order linear equations and their importance, Frobenius method and its applications to differential equations, Legendre, Bessel, Hermite and Laguerre differential equations.

Properties of Legendre polynomials: Rodrigues formula, Generating function, Orthogonality, Simple recurrence relations, Expansion of function in a series of Legendre Polynomials.

Bessel functions of the First kind: Generating function, Simple recurrence relations, Zeros of Bessel functions and orthogonality.

14 Hours

Dirac Delta Function

Definition, Representation as a limit of a Gaussian function and a rectangular function, Properties of the Dirac delta function.

2 Hours

Some Special Integrals

Beta and Gamma functions and the relation between them, Expression of integrals in terms of Gamma functions, Error function (Probability integral).

4 Hours

Theory of Errors

Systematic and random errors, Propagation of errors, Normal law of errors, Standard and probable error.

2 Hours

Partial Differential Equations

Solutions to partial differential equations using the method of separation of variables: (1) the Laplace's equation in problems of rectangular, cylindrical and spherical symmetries,(2) the wave equation related to the vibration of a stretched string and the oscillations of membranes (rectangular and circular).

8 Hours

Introduction to Probability

Random experiments, Sample space, Events, Probability, Random variables and probability distributions: (1) Discrete distributions, Binomial distribution as an example (2) Continuous distributions Gaussian, and Poisson distribution as examples, Mean and Variance.

4 Hours

Complex Analysis

Brief revision of complex numbers and their graphical representation, Euler's formula, De Moivre's theorem, Roots of complex numbers, Functions of complex variables, Analyticity and Cauchy-Riemann conditions, Examples of analytic functions, Singular functions: poles and branch points, order of singularity, branch cuts, Integration of a function of a complex variable, Cauchy's Inequality, Cauchy’s Integral formula.

14 Hours

Course Outcome: ***After successful completion of this course, students will be able to formulate problems of Physics in the language of Mathematics.***

Reference Books

1. Mathematical Methods for Physicists, Arfken, Weber, 2005, Harris, Elsevier.
2. Fourier Analysis, M.R. Spiegel, 2004, Tata McGraw-Hill.
3. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
4. An Introduction to Ordinary Differential Equations, E.A Coddington, 1961, PHI Learning.

5. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
6. Partial Differential Equations for Scientists and Engineers, S.J. Farlow, 1993, Dover Publications.
7. Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books.

MAJOR IV: PHYS4012: Mathematical Physics-II
Practical: **30 Hours**

Course Objective: ***The aim of this Lab is to use the computational methods to solve physical problems. Course will consist of Hours (both theory and practical) in the Lab. Evaluation done not on the programming but on the basis of formulating the problem.***

List of Assignments

1. Introduction to Numerical Computation Software

Introduction to **Scilab/ Mathematica/Matlab/Python**, Advantages and disadvantages, Scilab/Mathematica/Matlab/Python environment, Command window, Figure window, Edit window, Variables and arrays, Initialising variables in Scilab/Mathematica/Matlab/Python,Multidimensional arrays, Subarray, Special values, Displaying output data, data file, Scalar and array operations, Hierarchy of operations, Built in Scilab/Mathematica/Matlab/Python functions, Introduction to 2D and 3D plotting.

Ohms law to calculate the resistance, Hooke's law to calculate the spring constant.

2. Inverse of a Matrix, Eigen Vctors and Eigen Values

Solution of mesh equations of electric circuits (3 meshes), Solution of coupled spring mass systems (3 masses), Generation of Special functions using user defined functions in Scilab/Mathematica/Matlab/ Python, Generating and plotting Legendre polynomials, Generating and plotting Bessel function.

3. ***Solution of Ordinary Differential Equations***

First order differential equation: Radioactive decay, Current in RC, LC circuits with DC sources, Newton's law of cooling, Classical equations of motion.

Second order differential Equation: Harmonic oscillators (no friction), Damped harmonic oscillators (Over damped, Critically damped, Oscillatory), Forced harmonic oscillators (Transient and steady state solutions), Solution of the equation $x^2\frac{d^2y}{dx^2} - 4x(1+x)\frac{dy}{dx} + 2(1+x) = x^3$ with the boundary conditionsat $x = 1, y = \frac{1}{2}e^2, \frac{dy}{dx} = -\frac{3}{2}e^2 - 0.5$, in the range $1 \le x \le 3$, Plot y and against $\frac{dy}{dx}$ in the given range on the same graph.

4. XCOS

Generating signals, Beat phenomenon, Superposition of two perpendicular SHMs.

Course Outcome: ***The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.***

Reference Books

1. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 2006, Cambridge University Press.
2. Computational Physics, D.Walker, 2015, Scientific International Pvt. Ltd.
3. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, Cambridge University Press.
4. Simulation of ODE/PDE Models with MATLAB, OCTAVE and SCILAB: Scientificand Engineering Applications: A.V. Wouwer, P. Saucez, C.V. Fernández, 2014,Springer.
5. Scilab (A Free Software to MATLAB) Er. Hema Ramchandran, Dr. Achuthsankar, S. Nair ,S. Chand.
6. Scilab: A Beginner's Approach, A. K. Verma, CENAGE, First Edition.

MAJOR-PHYSICS COURSE

Semester IV

MAJOR-IV: PHYS4013: Classical Mechanics and Special Theory of Relativity (Credits: Theory-05, Practicals-00)

F.M.=75 (Theory-60, Practical–00, Internal Assessment–15)

Course Objectives: ***This course covers the Lagrangian and the Hamiltonian formulation of mechanics in systems with constraints, rigid body dynamics, Generating functions for canonical transformations, invariants. The course also covers the Special theory of relativity.***

Theory: **60 Hours**

Lagrangian Mechanics

Constraints and their classifications with examples**,** Inconvenience of Newtonian formulation in practice, The principle of virtual work, D′ Alambert's principle, Generalized coordinates and momenta, Lagrangian function, Lagrange's equations of motion, Advantages of Lagrangian formulation over Newtonian one, Cyclic Coordinates, Hamilton's variational principle, Applications of Lagrangian formulation to simple systems.

15 Hours

Hamiltonian Formulation

Hamiltonian function and its physical significance, Hamilton's canonical equations of motion, Advantages of Hamiton's formalism over the Lagrangian formulation, Conservation of Energy, Applications of Hamilton's equations to simple systems, Poisson brackets, Canonical transformations, Generating functions.

15 Hours

Rigid Body Dynamics

Generalized coordinates of rigid body, body and space reference systems, Angular momentum and moment of inertia tensor of simple rigid body (cube, sphere, cylinder), Principle axes and principle moments of inertia, Kinetic energy of a rigid body, Euler equations of motion of rigid body.

15 Hours

Special Theory of Relativity

Michelson-Morley experiment and its outcome,Two events in two different inertial frames and its correspondence,Simultaneity and order of events, Postulates of special theory of relativity, Lorentz transformations, Lorentz contraction, Time dilation, Twin paradox, Proper time and Proper length Relativistic transformation of velocity and frequency, Time like, space like and light like intervals, Causality.

Addition of velocities and Lorentz transformations,Variation of mass with velocity, Massless particles and Mass-energy equivalence.

Four vector formalism, Minkowski diagram**,** The four velocity, Four acceleration, Four force/ four momentum, Conservation of four momentum, Energy conservation.

Relativistic Doppler effect, Longitudinal and transverse Doppler effect and aberration, Decay process.

Transformation of E and B fields, Invariance of Maxwell equations.

15 Hours

Course Objectives: ***On successful completion of this course the students will have in-depth understanding of Lagrangian and the Hamiltonian formulation of mechanics rigid body dynamics, and Special theory of relativity.***

Reference Books

1. Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002,Pearson Education.
2. Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
3. Classical Electrodynamics, J.D. Jackson, 3rd Edn. 1998, Wiley.
4. The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4th Edn. 2003, Elsevier.

5. Introduction to Electrodynamics, D.J. Griffiths, 2012, Pearson Education.
6. Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
7. Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press.

MINOR-PHYSICS COURSE
Semester IV

MINOR IV: PHYS4021: Thermal Physics Credit: 4
F. M. = 75 [Theory-40, Practical-20, Internal assessment-15]

Course Objective: ***The objective of the first part of the course is to infuse ideas of the Kinetic theory of gases, Thermodynamic laws, Thermodynamic potentials, and the Theory of radiation. The second part is devoted to giving a basic introduction to Statistical Mechanics.***

Theory: **45 Hours**

Kinetic Theory of Gases

Objective of the theory (Knowledge of a macroscopic system from its microscopic constituents), Classical ideal gas and the ideal gas law, The basic postulates of the kinetic theory, Mean free path, Collision probability, The kinetic interpretation of pressure P, Relation between pressure and translational kinetic energy of the molecules, Kinetic interpretation of temperature - the average molecular kinetic energy is proportional to the absolute temperature, Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (Zeroth Order), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case), Law of equipartition of energy (no derivation) and its applications to specific heat of gases; mono-atomic and diatomic gases.

10 Hours

Laws of Thermodynamics

Thermodynamic Description of a system,Zeroth Law of thermodynamics and temperature, First law and internal energy, conversion of heat into work, Various Thermodynamical Processes, Applications of First Law: General Relation between C_P and C_V, Work done during isothermal and adiabatic processes, Compressibility and expansion Coefficients, Reversible and irreversible processes, Second law and Entropy, Carnot's cycle & theorem, Entropy changes in reversible & irreversible processes, Entropy-temperature diagrams, Third law of thermodynamics, Unattainability of absolute zero.

20 Hours

Thermodynamic Potentials

Enthalpy, Gibbs free energy, Helmholtz free energy and Internal energy functions, Maxwell's relations and applications - Joule-Thompson Effect, Clausius-Clapeyron Equation, Expression for (C_P- C_V),C_P/C_V, TdS equations.

5 Hours

Theory of Radiation

Blackbody radiation, Spectral distribution, Concept of energy density, Derivation of Planck's law, Wien's distribution law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

5 Hours

Statistical Mechanics

Maxwell-Boltzmann law - distribution of velocity – Quantum statistics - Phase space - Fermi-Dirac distribution law - electron gas - Bose-Einstein distribution law - photon gas - comparison of three statistics.

5 Hours

Course Outcome: ***Upon completion of this course, the students will grasp the idea of laws of thermodynamics, the Blackbody the basics of Statistical mechanics.***

Reference Books

1. Thermal Physics, A. B. Gupta, Haripada Roy, Books & Allied Ltd.
2. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw- Hill.
3. A Treatise on Heat, MeghnadSaha, and B.N.Srivastava, 1958, Indian Press.
4. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw- Hill.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
6. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
7. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press.

MINOR-IV: PHYS4021:Thermal Physics

Practical: **30 Hours**

List of Experiments

1. ***To determine the Stefan's Constant***
2. ***To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus***
3. ***To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method***
4. ***To determine the temperature co-efficient of resistance by Platinum resistance thermometer***
5. ***To study the variation of thermo- emf across two junctions of a thermocouple with temperature***
6. ***To determine the coefficient of thermal expansion of a metallic rod using optical lever***
7. ***To determine the coefficient of thermal expansion of a metallic rod by travelling microscope***
8. ***To determine the pressure coefficient of air by constant volume air thermometer***
9. ***To determine the temperature coefficient of resistance using Carry Foster Bridge***

Reference Books

1. Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House
2. Advanced Practical Physics, Vol 1, B. Ghosh, K. G. Majumder, Sreedhar Publication.
3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book AgencymmLtd.
4. A Text Book of Practical Physics, I.Prakash& Ramakrishna, 11th Ed., 2011, KitabMahal.
5. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
6. A Laboratory Manual of Physics for undergraduate classes,D.P.Khandelwal,1985, Vani Pub.

MAJOR-PHYSICS COURSE
Semester V

MAJOR-V: PHYS5011: MATHEMATICAL PHYSICS-III (Credits: Theory - 03, Practical - 01)
F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: ***The objective of the course is to develop understanding of the basic concepts of Complex analysis, Matrix formulation and Integral transforms for their very useful applications in dealing with physics problems. The knowledge of vector space and matrix operations are useful in dealing problems of quantum mechanics.***

Theory: **60 Hours**

Complex Analysis: Functions of complex variables. Analyticity and Cauchy-Riemann equations, Examples of analytic functions, Singularities: Poles, Removable singularity, Essential singularity, Branch points, Branch cut.
Integration of a function of a complex variable, Cauchy-Goursat theorem, Cauchy's inequality, Cauchy's integral formula, Simply and multiply connected region, Laurent and Taylor's expansion, Residues and Cauchy's residue theorem, Application of contour integration in solving definite integrals.

15 Hours

Linear Vector Spaces: Definition of vector spaces with examples, Subspaces of a vector space, Linear dependence and linear independence of a set of vectors, Linear span, Basis and dimension of a vector space, Finite and infinite dimensional vector spaces with examples, Dual space of a finite dimensional vector space- definition and examples, Linear transformations on vector spaces and their examples, Algebra of linear transformations on a vector space, Matrix representation of a linear transformation on finite dimensional vector spaces.

8 Hours

Matrices and Eigenvalues: Addition and multiplication of matrices, Types: Null matrix, Diagonal matrix, Scalar and unit matrices, Transpose of a matrix, Symmetric and skew-symmetric matrices, Conjugate of a matrix, Hermitian and Skew-Hermitian matrices, Singular and non-singular matrices, Inverse of a matrix, Orthogonal and unitary matrices, Trace of a matrix, Inner product, Unitary transformations, Cayley-Hamiliton theorem, Diagonalization of matrices, Eigenvalues and eigenvectors of a matrix, Concept and the examples of degenerate and non-degenerate eigenvalues, Pauli spin matrices, Matrix representation of linear operators, Solutions of coupled linear ordinary differential equations, Functions of a matrix.

12 Hours

Integral Transforms: Dirichlet's conditions for existence of Fourier transform, Fourier integral theorem, Fourier sine and cosine integrals, Fourier's complex integral, Fourier transform with examples for different functions, Fourier sine transform and Fourier cosine transform with examples for different functions, Properties of Fourier transform: Linear property, Change of scale property, Shifting property, Modulation property, Fourier transform of derivatives, Inverse Fourier transform with examples, Parseval's theorem, Convolution theorem, Three dimensional Fourier transforms with examples, Application of Fourier Transforms to differential equations: One dimensional Wave, Diffusion and Heat flow equations.

8 Hours

Laplace transform: Laplace Transform (LT) of elementary functions, Properties of LTs: Linearity property, Change of scale property, Shifting property, LT of derivatives and integrals, Derivatives and Integrals of LTs, LT of: Unit step function, Dirac delta function, Periodic functions, Laplace transform of i) ***tf(t)*** and ii***) t-1f(t),*** Convolution theorem, Inverse Laplace transform, Application of Laplace transforms to 2nd order differential equations: Damped harmonic oscillator, Simple electrical circuits, Coupled differential equations of 1st order, Solution of heat flow along infinite bar using Laplace transform.

7 Hours

Tensors: Preliminaries: Three-dimensional physical space (Euclidean space) and four-dimensional space-time (Minkowski space), n-dimensional space, The Einstein's summation convention, Dummy index, Free index, The Krönecker delta and the associated properties, Transformation of coordinates, Covariant and contravariant vectors, Contravariant, Covariant and Mixed tensors of rank two, Tensors of higher order, Addition and subtraction of tensors, Multiplication of tensors (outer product of tensors), Contraction of a tensor, Inner product of two tensors, Symmetric tensors, Skew-symmetric tensor, Quotient law, (b) Tensorial formulation of geometry: The metric tensor, Raising and lowering indices, The metric tensor in Euclidean space, The Levi-Civita symbol in three dimensions, The Minkowski metric, The 4-vector potential, the field tensor and the Maxwell's equations in tensor form, Conjugate metric tensor, Associated tensor, Magnitude of a vector, Scalar product of two vectors, Angle between two vectors.

10 Hours

Course Outcome: ***At the end of this course, students will gain knowledge in vector space which will help the students to understand quantum mechanics. The knowledge of Fourier transform will help them to transform equations from co-ordinate space to momentum space and that of Laplace transform is to solve differential equations. The knowledge of tensors will be useful in comprehending the theory of relativity.***

Reference Books:

1. Mathematical methods for physicists: A Comprehensive Guide: George B. Arfken, Hans J. Weber, Frank E. Harris, 7th Edition, Academic Press.
2. Mathematical methods for physics and engineers: K.F. Riley, M.P. Hobson, S.J. Bence, 3rd Edition, Cambridge University Press.

3. Mathematical physics with applications, problems and solutions: V. Balakrishnan, Ane Books Pvt Ltd.
4. Complex variables and applications: J.W. Brown& R.V. Churchill, 7th Edition, Tata McGraw-Hill.
5. Complex Variables: Schaum's Outline Series, 2nd Edition, McGraw Hill Education.
6. Fourier transforms with applications: Dr.SudhanshuAggarwal&Dr.HimanshuPandey, KY Publications.
7. Laplace Transform: Schaum's Outline Series, M.R. Speigel, McGraw Hill Education.
8. A student's guide to Fourier transforms with applications in physics and engineering: J. F. James, 3rd Edition, Cambridge University Press.
9. Tensors and Their Applications: Nazrul Islam, New Age international.
10. Tensor Analysis: Spigel, Scahum Series.
11. Tensor for Physics: Siegfried Hess, Springer.
12. Mathematical Phsics: P.K.Chattopadhyay, New Age international.

MAJOR-PHYSICS COURSE

Semester V

MAJOR-V: PHYS5011: MATHEMATICAL PHYSICS-III

Practical: **30 Hours**

Experiments:

Scilab/ Python based Simulations Experiments on Problems:

1. Compute the Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) of the function e^{-x^2}given in tabulated form.
2. Perform circuit analysis of a general LCR (resistor, inductor, capacitor) circuit using Laplace's transform.
3. Solve KCL (Kirchhoff's Current Law) and KVL (Kirchhoff's Voltage Law) in a circuit using Laplace transform.
4. Find the charge and the current in a series LCR (resistor, inductor, capacitor)circuit using Laplace transform.
5. Write a program to multiply any two 3 x 3 matrices.
6. Write a program to find the inverse of a 3×3 matrix.
7. Find the eigenvalues and the eigenvectors of a 3×3 matrix and the same for Pauli spin matrices.
8. Determine the principal axes of inertia by diagonalizing the inertia tensor.
9. Define the position operator ($\hat{x}$) and momentum operator ($\hat{p}$) in the position representation and calculate the value of the commutator $[\hat{x}, \hat{p}]$.
10. Estimate the ground state energy and wave function of a quantum system using the variational method.

11. Study of geodesics in Euclidean and other spaces.

Reference Books:

1. Simulation of ODE/PDE models with MATLAB, OCTAVE, and SCILAB Scientific and Engineering Applications: A. VandeWouwer, P. Saucez, C.V. Fernandez, Springer.
2. Scientific Computing (With Matlab, OCTAVE and SCILAB): S. Mitra, Academic Publishers.
3. SCILAB by Example: M. Affouf, ISBN 978-1479203444.
4. SCILAB Image Processing: L.M.Surhone, Betascript Publication.
5. SCILAB (A Free Software to Matlab): H Ramachandran and A S Nair, S Chand & Company Ltd.
6. SCILAB A Beginner's Approach: A K Verma, CENGAGE.
7. Numerical Methods in Physics with Python, Alex Gezerlis (Cambridge University Press,2020).
8. A Student's Guide to Python for Physical Modeling: Second Edition, Jesse M. Kinder & Philip Nelson (Princeton University Press, 2021).
9. Python Programming and Numerical Methods: A Guide for Engineers and Scientists – Qingkai Kong, Timmy Siauw, & Alexandre Bayen, (1st Edition, Academic Press Inc., 2020).
10. Computational Physics: Problem Solving with Python, Rubin H. Landau, Manuel J. Páez Cristian C. Bordeianu, (Wiley-VCH, 2015).
11. Scientific Computing in Python, Abhijit Kar Gupta (3rd Edition, Techno World).

MAJOR-PHYSICS COURSE

Semester V

MAJOR-V: PHYS5012: ELEMENTS OF MODERN PHYSICS (Credit: Theory - 04, Practical - 01)
F.M. = 75 (Theory - 40, Practical - 20, Internal Assessment - 15)

COURSE OBJECTIVE: ***The objective of the course is to develop a profound understanding of the key concepts in modern physics that include the experimental background behind the advent of quantum mechanics, the theory of relativity, atomic and nuclear physics.***

Theory: **60 Hours**

Introduction to Modern Physics: Physics of the 20th century, Two components: The theory of relativity and quantum mechanics, Focus on ″the theory of relativity addresses the failure of classical physics to describe the behavior at high energies and high speeds″, and ″the quantum mechanics addresses the failure of classical physics to support the measurements for microscopic particles″.

5 Hours

Experimental Observations: Supporting the particle nature of light: (a) Black Body Radiation: Concept of a blackbody and the blackbody radiation, Intensity of the blackbody radiation as a function of wavelength, frequency and temperature, Planck's radiation formula, Planck's constant, Conclusion – ″Light is a collection of photons″, (b) Photo Electric Effect: Photo electric effect and the experimental observation of photoelectric emission. Theoretical explanation - Einstein's photoelectric equation supporting the ″Quantum nature of light″, (c) Compton Effect: Experimental study and the theoretical explanation supporting the ″Quantum nature of light″.

15 Hours

Wave Nature of Particles: The two-slit thought experiment with photons, Interference pattern and its interpretation, The principle of linear superposition, Conclusion - ″A single Photon can interfere with itself″, Davisson-Germer experiment: Observation of electron diffraction from a nickel crystal suggesting the ″Wave nature of electrons ″.

5 Hours

Wave Particle Duality: de Broglie hypothesis, Matter waves, de Broglie wavelength, Localized particles as wave packets, Group velocity and phase velocity, Heisenberg's uncertainty principle, Heisenberg's gamma-ray microscope thought experiment, Position-momentum uncertainty, Consequences of the uncertainty principle, Estimation of the minimum energy of a confined particle using the uncertainty principle, Energy-time uncertainty principle and its application to virtual particles as well as the range of an interaction, Physical significance of ″wave function″, ″wave amplitude″, ″phase″ and the ″particle probability density″.

10 Hours

Atomic Physics: Bohr's model of an atom, Sommerfeld theory of elliptical orbits, Quantized energy levels in an atom, Energy levels of a Hydrogen atom, Emission and absorption spectra of Hydrogen – Origin and key features, Correspondence principle.

3 Hours

X-rays: Generation, detection and uses of X-rays, X-ray spectra: Continuous and characteristic X-rays, Moseley Law.

2 Hours

Nuclear Physics: Basic properties of a Nucleus: a) Constituents of a nucleus: Symbol - ${}^{A}_{Z}X_{N}$, Z - Atomic number (number of protons), N - number of neutrons, A - Mass number (the total number of protons and neutrons) inside a nucleus of an element X, Argument based on the uncertainty principle to show that electrons cannot exist inside a nucleus, Isotope, Isotone and

Isobar, b) Size of a Nucleus of radius R ,Nuclear density c) Electric quadrupole moment, d) Nuclear spin ($\vec{I}$) and nuclear magnetic dipole moment ($\vec{\mu}$),Nuclear magneton, Nuclei with odd numbers of protons/ neutrons have non-zero spin while those with even numbers of both protons and neutrons often have zero spin, e) Mass defect (Δm), f) Binding energy (E) , Binding energy curve (Plot of binding energy per nucleon against the mass number), The stability of a nucleus, g) Radioactive Decay, Three types of decay: α, β and γ – their fundamental nature and properties, Other decay modes like electron capture and positron emission, Laws governing a radioactive decay, Decay constant, Mean life and half-life, Units of radioactivity - Becquerel and Curie, Radioactive Series, h) Nuclear fission and fusion, Nuclear explosion, Examples and related equations.

Nuclear Models: (a) Liquid drop model, Semi-empirical mass formula (b) Nuclear shell model - Analogy to atomic shells, Pauli′s exclusion principle, Magic numbers, Independent particle Model, Spin-orbit coupling.

20 Hours

COURSE OUTCOME: ***On completion, the students will have a comprehensive understanding of the fundamental principles and theories of modern physics, and will be able to apply their knowledge to solve problems in various areas of modern physics and related fields.***

Reference Books:

1. Quantum physics of atoms, molecules, solids, nuclei, and particles: Robert Eisberg and Robert Resnick, 2nd Edition, New Delhi Wiley.
2. Introduction to modern physics: F. K. Richtmyer, E.H. Kennard, John N. Cooper, Tata McGraw-Hill.
3. Concepts of modern physics: Arthur Beiser, Shobhit Mahajan and S. Rai Choudhury, 7th Edition, McGraw Hill Education.
4. Theory and Problems of Modern Physics, Schaum’s outline: R. Gautreau and W. Savin, Tata McGraw-Hill Publishing Co. Ltd.
5. Nuclear Physics: Dr. S. N. Ghoshal, S. Chand & Company Pvt. Ltd.
6. Atomic and Nuclear Physics: A. B. Gupta and Dipak Ghosh, Books and Allied (P) Ltd.
7. Modern Physics: R. Murugeshan and Er. K. Sivaprasath, S. Chand & Company Ltd.

PHYS5012: ELEMENTS OF MODERN PHYSICS

Practical: **30 Hours**

Experiments:

1. To determine the electronic charge (e), the work function (Φ) of a cathode material and Planck’s constant from the plot of the stopping potential (V_s) versus frequency (ν) [or $1/\lambda$] using a photocell with a light source of adjustable frequencies.

2. To determine the Planck's constant using at least four LEDs of different colors from the plot of the cut-off voltage (V_o) versus wavelength (λ).

3. To calculate the wave number and the wavelength of the *H-alpha* line in the *Balmer* series of the hydrogen emission spectrum.

4. To determine the excitation potentials of mercury by *Franck-Hertz* experiment.

5. To determine the value of ***e/m*** by (a) magnetic focusing method or (b) using a bar magnet.

6. To setup the *Millikan* oil drop apparatus and determine the charge of an electron.

Reference Books

1. Advanced practical physics for students: B.L. Flint and H.T. Worsnop, Asia Publishing House.
2. Advanced level physics practicals: Michael Nelson and Jon M. Ogborn, 4th Edition, Heinemann Educational Publishers.
3. A text book of practical physics: I. Prakash & Ramakrishna, 11th Edition, Kitab Mahal.
4. B.Sc. practical physics: C. L. Arora, S. Chand and Company Limited.
5. B.Sc. practical physics: Harnam Singh and Dr. P.S. Heme, S. Chand and Company Limited.
6. Laboratory manual of physics: Madhusudan Jana, Books and Allied Pvt. Limited.
7. An advanced course in practical physics: D. Chottopadhyay, P. C. Rakshit, Books and Allied Pvt. Limited.

MAJOR-PHYSICS COURSE

Semester V

MAJOR-V: PHYS5013: ANALOG SYSTEMS AND APPLICATIONS (Credit: Theory - 04, Practical - 01)

F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: ***The course is designed to impart the basic knowledge of different components of analog systems and their applications e.g., semiconductor diodes, bipolar junction transistors, operational amplifiers and their applications in real circuits e.g., the amplifiers, oscillators etc. This will also help them to understand modulation and demodulation techniques used in communicating signals.***

Theory: **60 Hours**

Physics of Semiconducting Materials: Classification of metals, conductors and semiconductors (a) on the basis conductivity, (b) on the basis of energy bands, Elemental and compound semiconductors with examples, Intrinsic semiconductors – electrons and holes as charge carriers, Extrinsic semiconductors - doping and dopants, *n*- type and *p*- type semiconductors, *p-n* junction – diffusion current and drift current, Depletion region, Barrier potential, Semiconductor diode - *p-n* junction diode under forward bias, *p-n* junction diode under reverse bias, *V-I* characteristics of a p-n junction diode (a) in forward bias, (b) in reverse bias, Ideal diode equation.

6 Hours

Different Diodes and their Applications:

Standard silicon diode: Rectification and rectifiers - half-wave, full-wave rectifiers (centre-tapped and bridge), ripple factor and rectification efficiency. Zener diode: Voltage regulation.

Light emitting diode (LED): Displays indicators, and other lighting applications.

Schottky diode: Fast switching speed suitable for high-frequency applications.

Photodiode: Optical communications, light detection in remote controls, and medical instruments.

Tunnel diode: High-speed switching, high-frequency oscillators, and applications requiring fast switching and low power consumption.

6 Hours

Bipolar Junction Transistor (BJT): Structure - n-p-n and p-n-p transistors, Physical construction- emitter, base, collector and doping characteristics, BJT biasing Characteristics of CB, CE and CC configurations, Current gains α and β and relations between α and β, Load line analysis of transistors, DC Load line and Q-point, Concept of biasing, Active, cut-off and saturation regions.

6 Hours

BJT Biasing: Biasing Techniques: Exploration of fixed bias, collector-to-base bias, and voltage divider bias, Advantages and disadvantages of each biasing.

2 Hours

BJT Amplifiers: Configurations: Study of common-emitter, common-collector, and common-base amplifier configurations, their advantages, and disadvantages, Amplifier Analysis: Analyzing small-signal equivalent circuits, Calculating voltage and current gain, input and output impedances, Coupled Amplifier: RC coupled amplifier, Frequency response and gain band width product.

8 Hours

Feedback in Amplifiers: Concepts of feedback and the effects of positive and negative feedback on amplifier performance: Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.

4 Hours

Sinusoidal Oscillators: Understanding the principles of oscillation,Barkhausen's Criterion for self-sustained oscillations, Common Oscillator Circuits: RC phase shift oscillator, Wien Bridge oscillator, Hartley oscillator and Colpitts oscillator.

4 Hours

Modulation and Demodulation: Need for modulation in communication systems, Basic components of a communication system (transmitter, channel, receiver), Understanding the concept of carrying information using a carrier wave, Amplitude Modulation (AM): Definition and principle of AM, Time domain and frequency domain representation of AM signals, Power relations in AM waves, Modulation index and its significance, Generation and detection of AM waves using various techniques like square law modulator, switching modulator, and envelop detection, Frequency Modulation (FM) : Definition and principle of FM, Mathematical analysis of FM and PM.

8 Hours

Operational Amplifiers: (Black Box approach) Characteristics of an ideal and practical op-amp, (IC 741), Open-loop and Closed-loop gain, Frequency response, CMRR, Slew rate and concept of virtual ground.

5 Hours

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator.

6 Hours

A/D Conversion: Resistive network, (weighted and R-2R ladder), Accuracy and resolution, A/D Conversion (successive approximation).

5 Hours

COURSE OUTCOME: ***At the end of the course the students will be able to design basic circuits with diodes, BJT and Op amp. They will also learn to perform DC and AC analysis of different circuits. On completion of this course, the student must be able to perform different problems which are extremely essential to study theoretical and experimental physics.***

Reference Books:

1. Integrated Electronics: J. Millman and C.C. Halkias, Tata Mc-Graw Hill.

2. Electronics: Fundamentals and Applications: J.D. Ryder, Prentice Hall.

3. Solid State Electronic Devices: B.G. Streetman & S.K. Banerjee, 6th Edition, PHI Learning.

4. Electronic Devices &Circuits: S. Salivahanan & N.S.Kumar, 3rd Edition, Tata Mc-Graw Hill.

5. OP-Amps and Linear Integrated Circuit: R. A. Gayakwad, 4th Edition, Prentice Hall.

6. Microelectronic circuits: A.S. Sedra, K.C. Smith, A.N. Chandorkar, 6th Edition, Oxford University Press.

7. Electronic circuits: Handbook of design & applications: U. Tietze, C. Schenk, Springer.

8. Semiconductor Devices: Physics and Technology: S.M. Sze, 2nd Edition, Wiley India.

9. Microelectronic Circuits: M.H. Rashid, 2nd Edition, Cengage Learning.

PHYS5013: ANALOG SYSTEMS AND APPLICATIONS

Practical: 30 Hours

Experiments:

1. To study V-I characteristics of PN junction diode, and Light emitting diode.
2. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
3. Study of V-I & power curves of solar cells, and find maximum power point & efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. To study the frequency response of voltage gain of a RC-coupled transistor amplifier.
6. To study a Wien bridge oscillator for given frequency using an op-amp.
7. To design an inverting / non-inverting amplifier using Op-amp (741) for dc voltage of given gain.
8. To add two dc voltages using Op-amp in inverting and non-inverting mode.
9. To investigate the use of an op-amp as an Integrator / Differentiator.

Reference Books:

1. Advanced practical physics for students: B.L. Flint and H.T. Worsnop, Asia Publishing House.
2. Advanced level physics practicals: Michael Nelson and Jon M. Ogborn, 4th Edition, Heinemann Educational Publishers.
3. A text book of practical physics: I. Prakash & Ramakrishna, 11th Edition, Kitab Mahal.
4. B.Sc. practical physics: C. L. Arora, S. Chand and Company Limited.
5. B.Sc. practical physics: Harnam Singh and Dr. P.S. Heme, S. Chand and Company Limited.
6. Laboratory manual of physics: Madhusudan Jana, Books and Allied Pvt. Limited.
7. An advanced course in practical physics: D. Chottopadhyay, P. C. Rakshit, Books and Allied Pvt. Limited.

MAJOR-PHYSICS COURSE

Semester VI

MAJOR-VI: PHYS6011: QUANTUM MECHANICS (Credits: Theory-04, Practical - 01)
F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: ***The aim of this course is to introduce the students with the basic concepts of quantum mechanics and available mathematical techniques to deal with the physical system that are important prerequisites for physics courses.***

Theory: **60 Hours**

Introduction: The Schrödinger's equation for a particle moving in one dimension, Wave function $\Psi(x, t)$ – the solution of the Schrödinger's equation, Statistical interpretation of the wave function, Particle probability density and probability current density.

5 Hours

Basic Postulates of Quantum Mechanics:

Postulate I – *The state of a quantum mechanical system is completely specified by the wave function* $\Psi(x, t)$ *that depends on the spatial coordinate* x *and the time coordinate* t *of the particle,* Conditions for physical acceptability of wave functions: $\Psi(x, t)$ *must be single-valued, finite, continuous and square-integrable,* Concept of normalization

Postulate II – *To every observable or dynamical variable in classical mechanics, there exists a linear operator in quantum mechanics,*

Postulate III – *In any measurement of an observable, the result of a measurement will be any one of the eigenvalues of the corresponding operator* $\hat{A}$ *which satisfy the eigenvalue equation* $\hat{A}\phi_n = a_n\phi_n$ (a) Eigenvalues (a_n) must be real → (b) Operator $\hat{A}$ must be Hermitian, (c) Eigen functions ϕ_n are orthonormal.

Postulate IV – *If a system is in a state specified by a normalized wave function* $\Psi(x, t)$ *then the average measured value of the observable* A *is* $\langle A \rangle = \int_{-\infty}^{+\infty} \Psi^* \hat{A} \Psi dx$,

Postulate V – *The wave function of a system evolves in time according to the time dependent Schrödinger equation* $i\hbar\frac{\partial \Psi}{\partial t} = \hat{H}\Psi$, $\hat{H}$ is the Hamiltonian operator or the total energy operator.

15 Hours

Operators: Position, momentum and Hamiltonian operators in terms of spatial and/or time coordinates, their actions on the wave function, Commutator of two operators $\hat{A}$ ***and*** $\hat{B}$ – $[\hat{A},\hat{B}] = \hat{A}\hat{B} - \hat{B}\hat{A}$, Canonical commutation relations: Commutator of the position operator ($\hat{x}$) and the momentum operator ($\hat{p}$), $[\hat{x}, \hat{p}] = i\hbar$, Position and momentum cannot be simultaneously known with perfect accuracy, *Heisenberg* uncertainty principle.

10 Hours

Time independent Schrodinger equation: Time independent Hamiltonian, Solution of the time dependent Schrodinger equation by separation of variables, Time independent Schrodinger equation, Characteristics of the solutions: (i) multiple states of definite total energy, (ii) each state is a stationary state and (iii) the general solution is a linear combination of such stationary states.

8 Hours

Solving time-independent Schrödinger equation for different types of potentials:

One dimensional square well potential, Step potential and Infinite square well Potential.

Estimation of the expectation values: $\langle \boldsymbol{x} \rangle$, $\langle \boldsymbol{x^2} \rangle$, $\langle \boldsymbol{p} \rangle$, $\langle \boldsymbol{p^2} \rangle$, $\langle \Delta \boldsymbol{x} \rangle$, and $\langle \Delta \boldsymbol{p} \rangle$ for the nth stationary state of the infinite square well.

9 Hours

Quantum theory of a particle bound by a one dimensional simple harmonic oscillator potential: Time independent *Schrodinger* equation, Solving the *Schrodinger* equation by analytic method known as *Frobenius* method, Energy levels and energy eigen functions, Hermite polynomials, Ground state, Zero-point energy and the uncertainty principle.

6 Hours

Quantum theory of Hydrogen-like atoms: Time independent *Schrodinger* equation in spherical polar coordinates, Solving the Schrodinger equation by “Separation of variables method”, Energy levels and energy eigenfunctions, Ground state.

7 Hours

COURSE OUTCOME: ***On completion, the students will be familiar with the development of quantum mechanics from the experiments, learn the central concepts and principles in quantum mechanics such as the Schrödinger equation, the wave function and its interpretation, the uncertainty principle etc. And gain experience in using analytical and numerical methods on quantum mechanical problems***

Reference Books:

1. Quantum physics of atoms, molecules, solids, nuclei, and particles: Robert Eisberg and Robert Resnick, 2nd Edition, New Delhi Wiley.
2. Introduction to quantum mechanics: David J. Griffiths, Darrell F. Schrofter,3rdEdition, Cambridge University Press.
3. Quantum mechanics: concepts and applications: Nouredine Zettili, 2nd Edition, Wiley India.
4. Quantum mechanics: G. Aruldas, 2nd Edition, Prentice Hall India.
5. Quantum mechanics: B.H. Bransden & C.J. Joachain, 2nd Edition, Pearson India.

PHYS6011: QUANTUM MECHANICS

Practical: **30 Hours**

Use Scilab/Python for solving the following problems based on quantum mechanics

Experiments:

1. ***Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:***

$$\frac{d^2y}{dr^2} = A(r)U(r),\ A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

where $V(r) = -\frac{e^2}{r}$

Here, m is the reduced mass of the system (which can be chosen to be the mass of an electron). Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -**13.6 eV**. Take **e = 3.795 (eVÅ)$^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511x10^{6}eV/c2.**

2. ***Solve the s-wave radial Schrodinger equation for a hydrogen atom:***

$$\frac{d^2y}{dr^2} = A(r)U(r),\ A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

Where ***m*** is the reduced mass of the system(which can be chosen to be the mass of an electron), and the Coulomb potential $V(r) = -\frac{e^2}{r}$. Obtain the energy (in *eV*) of the ground state of the atom and plot the corresponding wave function. Given: Ground state energy value ≈ **- 13.6** ***eV***, ***e*** **= 3.795 (*eVÅ*)$^{1/2}$**, ***ħc*** **= 1973 (*eVÅ*)** and ***m*** **= 0.511×10^6*eV/c^2***.

3. ***Solve the s-wave radial Schrodinger equation for a Hydrogen atom:***

$$\frac{d^2y}{dr^2} = A(r)U(r),\ A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

Where ***m*** is the reduced mass of the system (which can be chosen to be the mass of an electron) and the screened Coulomb potential $V(r) = -\frac{e^2}{r}e^{-r/a}$. Obtain the energy (in *eV*) of the ground state of the atom to an accuracy of three significant digits and plot the corresponding wave function. Given: ground state energy value ≈ **-13.6 *eV***, ***e*** **= 3.795 (*eVÅ*)$^{1/2}$**, ***ħc = 1973 (eVÅ)*** and ***m*** **= 0.511× 10^6 *eV/c^2***, and ***a*** = **3** *Å*, *5Å*, *7Å*.

4. ***Solve the s-wave radial Schrodinger equation for the vibrations of a Hydrogen molecule:***

$$\frac{d^2y}{dr^2} = A(r)U(r),\ A(r) = \frac{2\mu}{\hbar^2}[V(r) - E]$$

Where μ is the reduced mass of the molecule of two atoms for the Morse potential $V(r) = D(e^{-2\alpha r'} - e^{-\alpha r'})$ and $r' = \frac{r - r_0}{r_0}$. Find the lowest vibrational energy (***MeV***) of the molecule to an accuracy of three significant digits and plot the corresponding wave function. Given: μ= **940 × 10^6*eV/c^2***, ***D*** **= 0.755501 *eV***, ***α*** **= 1.44**, ***r$_0$*** **= 0.131349 *Å***

Reference Books:

1. Schaum's outline of programming with C++: J. Hubbard, McGraw Hill Publication.
2. Numerical recipes in C: The art of scientific computing: W.H. Pressetal, 3rd Edition, Cambridge University Press.
3. An introduction to computational physics: T. Pang, 2ndEdition, Cambridge University Press.
4. Simulation of ODE/PDE models with MATLAB®,OCTAVE and SCILAB: Scientific & engineering applications: A. Vande Wouwer, P. Saucez, C.V. Fernández, Springer.
5. Scilab (free software to Matlab): H. Ramchandran, A.S. Nair, S. Chand & Co.
6. A guide to MATLAB: B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 3rdEdition, Cambridge University Press.

MAJOR-PHYSICS COURSE

Semester VI

MAJOR-VI: PHYS6012: ELECTROMAGNETIC THEORY (Credits: Theory - 03, Practical - 01)

F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: ***The objective of this course is to provide an in-depth understanding of the basic principle of propagation of electromagnetic waves and apply them to practical situation.***

Theory: **60 Hours**

Maxwell Equations: Maxwell's equations (differential equations)in a linear, isotropic, homogeneous dielectric medium with their integral counterpart (SI Unit), Physical significance of Maxwell's equations: (*i*) Gauss's law in electrostatics (the net electric flux through a closed surface is proportional to the total charge enclosed) $\rightarrow$ Electric charge is the source of an electric field $\vec{\boldsymbol{E}}$ (*ii*) Gauss's law of magnetism (the net magnetic flux lines always form a closed loop) $\rightarrow$ Non-existence of a magnetic monopole, (*iii*) Faraday's law of electromagnetic induction $\rightarrow$ A changing magnetic field can create an electric field and (*iv*) Ampere′s circuital law with Maxwell′s introduction of the displacement current $\rightarrow$ A magnetic field is produced due to the combined effect of the conduction current due to free charges and the displacement current due to bound charges $\rightarrow$ Total charge density (ρ) = free charge density ($\boldsymbol{\rho_f = \varepsilon_0\, \nabla\cdot\vec{E}}$) + bound charge density ($\boldsymbol{\rho_b = \nabla\cdot\vec{P}}$), Concept of the free ($\vec{\boldsymbol{J}}$) and the bound ($\boldsymbol{\vec{J}_b = \nabla\times\vec{M}}$) current densities, The conservation of charge within a closed volume and the equation of continuity, Displacement field - $\boldsymbol{\vec{D} = \varepsilon\vec{E} = \varepsilon_0\vec{E} + \vec{P}}$, $\varepsilon\,(\varepsilon_0) -$ the dielectric permittivity of the material medium (free space), Magnetic field $\boldsymbol{\vec{B} = \mu\vec{H} =}$

$\mu_0(\vec{H}+\vec{M})$, μ (μ_0) - the permeability of the material medium (free space), $\varepsilon, \varepsilon_0$, μ, μ_0 - Scalars (linearity) with a Constant value everywhere (isotropic and homogeneous property) homogeneous medium, Magnetizing field $\vec{H} = \frac{\vec{B}}{\mu}$, Vector potential $(\vec{A})$ defined as $\vec{B} = \nabla\times\vec{A}$ and scalar potential (ϕ) defined as $\vec{E} = -\nabla\phi$, Gauge transformations, Gauge fixing: Lorentz gauge and Coulomb gauge, Maxwell's equations in vacuum, Maxwell's equations in a charge free ($\rho = 0$), and non-conducting ($\vec{J} = 0$)) simple dielectric, The wave equation in a simple dielectric/ (vacuum): $\nabla^2\vec{F}$ - $\mu\varepsilon(/\mu_0\varepsilon_0)\frac{\partial^2\vec{F}}{\partial t^2} = 0$ ($\vec{F}$= either $\vec{E}$ or $\vec{B}$) - a second-order partial differential equation representing an EM wave propagating with a speed (dielectric)/ vacuum $c = \frac{1}{\sqrt{\mu\varepsilon}} / \frac{1}{\sqrt{\mu_0\varepsilon_0}}$, The wave equation in a conductor (Ohmic - $\vec{J} = \sigma\vec{E}$) - $\nabla^2\vec{E}$ - $\mu\sigma\frac{\partial\vec{E}}{\partial t} = \mu\varepsilon\frac{\partial^2\vec{E}}{\partial t^2} = 0$

20 Hours

EM Wave Propagation in Unbounded Media: Plane wave solutions of the wave equation $\nabla^2\vec{F}$ - $\mu\varepsilon\frac{\partial^2\vec{F}}{\partial t^2} = 0$ ($\vec{F} = \vec{E}$ or $\vec{B}$): $\vec{E}(\vec{r},t) = \vec{E}_0 e^{i(\vec{k}\cdot\vec{r}-\omega t+\phi_0)}$, $\vec{B}(\vec{r},t) = \vec{B}_0 e^{i(\vec{k}\cdot\vec{r}-\omega t+\phi_0')}$, wave vector $\vec{k} = \frac{\omega}{c}\hat{n}$, Dispersion relation $\omega = ck$, Transverse nature of EM wave ($\vec{E}_0$, $\vec{B}_0$ and $\vec{k}$-mutually perpendicular), Impedance of the medium ($Z = \frac{E_0}{H_0} = \sqrt{\frac{\mu}{\varepsilon}}$), Refractive index, Relative phase between $\vec{E}$ and $\vec{H}$, Poynting vector ($\vec{S} = \vec{E}\times\vec{H}$),, Electromagnetic (EM) energy density (equal sharing between $\vec{E}$ and $\vec{H}$) and same c for $\vec{E}$ and $\vec{H}$, Time average of the of the Poynting vector over a cycle = Intensity of radiation (I), Time average of the of the energy density over a cycle = $I \times c$, Propagation through conducting media: Complex k - Electric field decays with time, Relaxation time, Skin depth, the phase velocity and the group velocity.

10 Hours

EM Wave Propagation in Bounded Media: Boundary conditions on $\vec{E}$ and $\vec{B}$ at a plane interface between two media, Reflection & refraction of plane waves at plane interface between two dielectric media- Laws of reflection & refraction, Fresnel's Formulae for perpendicular & parallel polarization.

5 Hours

EM Wave Propagation in Anisotropic Media: Anisotropic media- Polarization vector $\vec{P}$ is not in the direction of electric field $\vec{E}$, Dielectric tensor and dielectric susceptibility tensor, Dielectric tensor of crystals with different optical symmetries (Isotropic, Uniaxial crystal), Crystal systems and the optical symmetry: Isotropic (Cubic), Uniaxial (Tetragonal, Trigonal, Hexagonal), Biaxial (Orthorhombic, Monoclinic, Triclinic), Principal axes of a crystal ($\hat{x}, \hat{y}, \hat{z}$ –three principal axes), Wave equation for a plane EM wave of frequency ω and wave vector $\vec{k}$, Normal surface or surface of refractive indices, Wave equation and the normal surface for the isotropic ($\boldsymbol{n_x = n_y = n_z \equiv n_0}$), and uniaxial materials ($\boldsymbol{n_x = n_y \equiv n_o}$, $\boldsymbol{n_z \equiv n_e}$), Ordinary ray and Extraordinary ray and the corresponding refractive indices, Group velocity in anisotropic materials, Ellipsoid of indices, Review of Polarization: Linear, circular and elliptical polarization of electromagnetic waves, Phase retardation plates: Quarter-wave and Half-wave Plates, Polarization by reflection, Production & analysis of polarized light, Babinet Compensator and its Uses, Optical rotation, Estimation of angle of rotation, Specific rotation, Laurent's half-shade and biquartz polarimeters.

15 Hours

Transmission lines, Wave Guides and Optical Fibres (preliminary idea): Transmission Lines: Definition, Mechanism, Efficiency, Important applications, Advantages, Wave Guides: Basic features, Types, Mechanism, Efficiency, Important applications, Advantages,

10 Hours

Course Outcome: ***At the end of this course, students willto solve electromagnetic problems using Maxwell's equations for time-varying fields in Cartesian, cylindrical, and spherical coordinate systems and the skill will help them to investigate the behaviour of EM waves in different media.***

Reference Books:

1. Introduction to Electrodynamics: D.J. Griffiths, 3rd Edition, Benjamin Cummings.
2. Elements of Electromagnetics: M.N.O. Sadiku, Oxford University Press.
3. Introduction to Electromagnetic Theory: T.L. Chow, Jones & Bartlett Learning.
4. Fundamentals of Electromagnetics: M.A.W. Miah, Tata McGraw Hill.
5. Electromagnetic field Theory: R.S. Kshetrimayun, Cengage Learning.
6. Electromagnetic Field Theory for Engineers & Physicists: G. Lehner, Springer.
7. Electromagnetic Fields & Waves: P. Lorrain & D. Corson, W.H. Freeman & Co.
8. Electromagnetics, J.A. Edminster: Schaum Series, Tata McGraw Hill.
9. Electromagnetic field theory fundamentals: B. Guru and H. Hiziroglu, Cambridge University Press.

MAJOR-VI: PHYS6012: ELECTROMAGNETIC THEORY

Practical: **30 Hours**

1. ***To verify the law of Malus for plane polarized light.***
2. ***To analyze elliptically polarized light by using Babinet's compensator.***
3. ***To study the phenomenon of double refraction using double image prism and to determine the type of crystal (positive or negative).***
4. ***To verify Stefan's law and to determine Stefan's constant by electrical method.***
5. ***To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.***
6. ***To determine the Boltzmann constant using V-I characteristics of PN junction diode.***
7. ***Verification of Cauchy's relation by plotting a dispersion curve using a Prism Spectrometer.***
8. ***Verification of Brewster's law and finding of the Brewster's angle.***

Reference Books:

1. Advanced practical physics for students: B.L. Flint and H.T. Worsnop, Asia Publishing House.
2. Advanced level physics practicals: Michael Nelson and Jon M. Ogborn, 4th Edition, Heinemann Educational Publishers.
3. A text book of practical physics: I. Prakash& Ramakrishna, 11th Edition, KitabMahal.
4. B.Sc. practical physics: C. L. Arora, S. Chand and Company Limited.
5. B.Sc. practical physics: Harnam Singh and Dr. P.S. Heme, S. Chand and Company Limited.
6. Laboratory manual of physics: Madhusudan Jana, Books and Allied Pvt. Limited.
7. An advanced course in practical physics: D. Chottopadhyay, P C Rakshit, Books and Allied Pvt. Limited.

Semester VI

MAJOR-VI: PHYS6013: DIGITAL SYSTEMS AND APPLICATIONS (Credit: Theory- 03, Practical - 01)
F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: ***The aim of this course is to acquire the basic knowledge of digital logic levels and application of this knowledge to understand various digital circuits. This course is also to prepare students to perform the analysis and design of various digital electronic circuits.***

Theory: **60 Hours**

Number System: Binary number system: Binary numbers, Conversion between binary, decimal, hexadecimal, and octal number systems with examples, Binary addition and subtraction using 1's Complement and 2's complement method, Signed and unsigned binary numbers, 1's and 2's complement representation of negative numbers.

10 Hours

Digital circuits: Introduction of switching algebra, Huntington's postulates, Combinational logic, Truth table, Introduction of basic logic functions: AND, OR and NOT, Realization of OR, AND, NOT gates using Diodes and Transistors, De Morgan's Theorems, NAND and NOR Gates as Universal Gates, XOR and XNOR gates and application as Parity Checkers, Circuit representation of gates (both usual and IEEE symbols), Introduction to different logics like DTL, TTL, Product term and sum term in logical expression, Sum of Product (SOP), and Product of Sum (POS) and mixed expression, Minterm and maxterm in the expressions, Conversion between truth table and logical expression, Simplification of logical expressions using Karnaugh Maps (4 variables).

10 Hours

Combinational Logic circuits:
Design and testing of half adder, full adder, half subtractor and full subtractor.
Design and testing of a 4-bit binary adder and subtractor using IC 7483.

10 Hours

Flip-Flops and Sequential Circuits:
Construction and testing of SR, D, JK, and T flip-flops using ICs (NAND gates), Master-slave JK flip-flop and understanding of race conditions, Design of 4-bit shift registers (Serial-in-Serial-out, Parallel-in-Parallel-out) using D-type Flip-Flops.

15 Hours

Counters and Timers:
Construction of 4-bit binary counters (asynchronous and synchronous), Design of astable and monostable multivibrators using IC 555 timer.

10 Hours

Data Conversion: Digital to analog (D/A) conversion using ladder and weighted resistance methods, Analog to digital (A/D) conversion basics.

5 Hours

COURSE OUTCOME: ***This optimized course helps to understand the structure of various number systems and its application in designing digital circuits. It also gives a comprehensive understanding of the fundamental concepts and techniques used in digital electronics. The practical component ensures the students enrichment on hands-on experience to develop skill to build, and troubleshoot digital circuits.***

Reference Books:

1. Digital Principles and Applications: A.P. Malvino, D. P. Leach and Saha, 7th Edition, Tata McGraw Hill.
2. Fundamentals of Digital Circuits: Anand Kumar, 2nd Edition, PHI Learning Pvt. Ltd.
3. Digital Circuits and systems: Venugopal, Tata McGraw Hill.
4. Digital Electronics: G K Kharate, Oxford University Press.

5. Digital Systems: Principles & Applications: R. J. Tocci, N. S. Widmer, PHI Learning.
6. Logic circuit design: Shimon P. Vingron, Springer.
7. Digital Electronics: Subrata Ghoshal, Cengage Learning.
8. Digital Electronics: S.K. Mandal, 1st Edition, McGraw Hill.

MAJOR-VI: PHYS6013: Digital Systems and Applications

Practical: **30 Hours**

Experiments:

1. To construct AND, OR, NOT gates using diodes and transistors.
2. To verify the operation of basic gates AND, OR, NOT, XOR, NOR, NAND using ICs.
3. To design and test the operation of half adder, full adder, half subtractor, and full subtractor.
4. To design and test the operation of a 4-bit binary adder and subtractor using IC 7483.
5. To construct and test of SR, D, JK, and T flip-flops using ICs (NAND gates).
6. To design and test the operation of Master-slave JK flip-flop and check the race conditions.
7. To design 4-bit shift registers (Serial-in-Serial-out, Parallel-in-Parallel-out) using D-type Flip-Flops.
8. To design 4-bit binary counters (asynchronous and synchronous).
9. To design astable and monostablemultivibrators using IC 555 timer.

Reference Books:

1. Advanced practical physics for students: B.L. Flint and H.T. Worsnop, Asia Publishing House.
2. Advanced level physics practicals: Michael Nelson and Jon M. Ogborn, 4th Edition, Heinemann Educational Publishers.
3. A text book of practical physics: I. Prakash & Ramakrishna, 11th Edition, KitabMahal.
4. B.Sc. practical physics: C. L. Arora, S. Chand and Company Limited.
5. B.Sc. practical physics: Harnam Singh and Dr. P.S. Heme, S. Chand and Company Limited.
6. Laboratory manual of physics: Madhusudan Jana, Books and Allied Pvt. Limited.
7. An advanced course in practical physics: D. Chottopadhyay, P C Rakshit, Books and Allied Pvt. Limited.
8. Basic Electronics: A Text Lab Manual by P.B. Zbar, A.P. Malvino, McGraw-Hill.

MAJOR-PHYSICS COURSE

Semester VI

MAJOR-VI: PHYS6014: ATOMIC AND MOLECULAR PHYSICS (Credit: Theory - 03, Practical - 01)

F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: ***The objective of this course is to provide the basic concepts of atomic, molecular and laser physics to an undergraduate student. Theoretical treatments are basically quantum mechanical or semi-classical. The student learns to explain or even to predict, the experimental observations of spectroscopy. An introduction of basic laser physics will enrich them.***

Theory: **60 Hours**

One-electron/Hydrogen-like Atoms: Definition - a single electron orbiting a nucleus, Examples: Spectra of Hydrogen atom, Hydrogen-like atom *i.e*, ions like $\boldsymbol{He^{+}}$, $\boldsymbol{Li^{2}}$, Significance - Only exactly solvable quantum system, Spherically symmetric Hamiltonian (Coulomb potential dependent on r only), Atomic orbitals - Wave function solutions of the Schrödinger equation - $\boldsymbol{\psi(r,\theta,\phi) = R_{nl}(r)Y_{lm}(\theta,\phi)}$, Shapes of the probability densities for the ground and the first excited states, Quantum numbers (***n, l, m***) and their significance, Bohr radius, Rydberg unit of energy, Energy eigenvalues, Degeneracy of energy levels Angular momentum: Orbital ($\vec{\boldsymbol{L}}$) and Spin $\vec{\boldsymbol{S}}$.

6 Hours

Many–Electron Atoms: Identical particles, Symmetric and antisymmetric wavefunction, Pauli's exclusion principle, Spin-singlet and spin-triplet states of a two electron system, Ortho- and para- helium as an example, For a multi electron system $\vec{L} = \sum \vec{L}_i$and $\vec{S} = \sum \vec{S}_i$, Total angular momentum$\vec{J} = \vec{L} + \vec{S}$, L-S coupling and J-J Coupling, Hund's Rule, Electron's magnetic moment, Gyromagnetic ratio, Bohr Magneton.

6 Hours

Atoms in External Magnetic Fields: Energy associated with a magnetic dipole placed in magnetic field, Larmor's theorem, Stern-Gerlach experiment.

4 Hours

Atomic Spectra: Excitation, De-excitation, Emission spectra, Absorption Spectra, Atomic transitions and selection rules (qualitative discussion), Spectra of alkali atoms (Na etc.), difference between hydrogen spectra and alkali spectra, Fine structure of Hydrogenic atoms Spin-orbit interaction, Fine structure and Hyperfine structure of spectral lines, Zeeman effect.

10 Hours

Molecular Physics: Molecular structure: Molecular orbitals, The Born-Oppenheimer approximation, Concept of bonding and antibonding, Potential energy curve for a diatomic molecule, Equilibrium bond length, Classification of molecular states of diatomic molecule, Electronic states - Characterized by the electronic configuration of the molecule, Potential energy curve for an electronic state, Morse potential, Each electronic state has a series of vibrational energy levels - indexed by vibrational quantum numbers, Vibrational states: Characterized by the vibrational motion of the nuclei about their equilibrium positions, Each vibrational state within an electronic state has its own set of rotational energy levels - indexed by rotational quantum numbers, Molecular spectra of diatomic molecule: Rotational Spectra (rigid and non-rigid rotor), Vibrational Spectra (harmonic and anharmonic), Vibration-Rotation Spectrum of a diatomic molecule, Isotope effect, Intensity of spectral lines,.

13 Hours

Raman Effect: Classical theory (with derivation) of Raman effect, pure rotational Raman lines, Stoke's and Anti-Stoke's lines, comparison with Rayleigh scattering.

5 Hours

Lasers: Radiative and non-radiative transitions, Absorption, spontaneous and stimulated emission, Einstein's A and B coefficients, Idea of metastable state, Population inversion, Necessary condition for lasing, Threshold population inversion, Two-level system: unattainability of population inversion, Three-level and four-level systems: rate equations and necessary condition for population inversion, Basic components of a laser system — Active medium, pumping system and optical resonator, Characteristics of laser light, Free spectral range, Line broadening mechanism — natural broadening and pressure broadening (qualitative discussion), Doppler broadening, Ruby laser, He-Ne laser.

12 Hours

COURSE OUTCOME: ***This course in atomic and molecular physics serves as the foundation for further progress towards the study of physics at graduate or post-graduate level. Upon completion of the course, the student will be able to apply basic principle of atomic and molecular physics to different systems associated with atoms and Molecules.***

Reference Books:

1. Physics of Atoms and Molecules: B. H. Bransden and C. J. Jochain, 2nd Edition, Pearson.
2. Fundamentals of Molecular Spectroscopy: C.N. Banwell and E.M. McCash, Tata McGraw – Hill.
3. Atomic physics: B. Rajam and foreword by Louis De Broglie, S. Chand & Co.
4. Atoms, Molecules and Photons: W. Demtroder, 2nd Edition, Springer.
5. Introduction to Spectroscopy: D. L. Pavia, G. M. Lampman, G. A. Kriz and J. R. Vyan, 5th Edition, Brookes/Cole.
6. Concept of Nuclear Physics: B. L. Cohen, Tata McGraw – Hill.
7. Nuclear Physics: S. N. Ghoshal, 1st Edition, S. Chand Publication.
8. Introducing Nuclear Physics: K. S. Krane, Wiley India.
9. Laser fundamentals: W T Silfvast, Cambridge University Press.
10. Laser Fundamentals and Applications: K Thyagarajan and A Ghatak, TRINITY.
11. Optical fiber and laser- principles and applications: Anuradha De, New Age International Publishers.

MAJOR-VI: PHYS6014: ATOMIC AND MOLECULAR PHYSICS

Practical: **30 Hours**

Experiments:

1. Determination of the principal refractive index for the O-ray and E- ray.
2. To calibrate a prism spectrometer with a Mercury vapour lamp.
3. Verification of Hartmans′ dispersion formula using a constant deviation spectrometer.
4. Determination of the value of Rydberg constant for the hydrogen.
5. Determination of the wavelength of a laser beam using plane diffraction grating.
6. To determine the wavelength of a laser beam using diffraction from a single slit.

Reference Books:

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

2. Advanced level Physics Practicals: Michael Nelson and Jon M. Ogborn, 4th Edition, Heinemann Educational Publishers.
3. A Text Book of Practical Physics: I. Prakash & Ramakrishna, 11th Editionn, Kitab Mahal.
4. B.Sc. Practical Physics: C L Arora, S Chand and Company Limited.
5. B.Sc. Practical Physics: Harnamsingh and dr P S Heme, S Chand and Company Limited.
6. Laboratory manual of Physics: Madhusudan Jana, Books and Allied Pvt. Ltd.
7. An advanced Course in Practical Physics: D Chottopadhyay, P C Rakshit, B Saha, Books and Allied Pvt. Ltd.

MAJOR-PHYSICS COURSE
Semester VII

MAJOR-VII: PHYS7011: Advanced Quantum Mechanics

(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment – 15)
Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Tutorial) – 05, Practical (Sessional Viva-voce) - 05]

COURSE OBJECTIVE: *The aim of this course is to provide an in-depth understanding of the various topics of quantum mechanics and available mathematical techniques to deal with the physical system that are important prerequisites for physics courses.*

Theory: **60 Hours**

GENERAL PRINCIPLES OF QUANTUM MECHANICS: Postulates of Quantum Mechanics and meaning of measurement, Linear vector space, Ket and Bra vectors, Scalar product of vectors and their properties, Dirac delta function, probability interpretation, Degeneracy, Schmidt method of orthogonalization, Expansion theorem, Completeness and closure properties of the basis set, Coordinate and momentum representations, compatible an Incompatible observables, Commutator algebra, uncertainty relation as a consequence of non-commutability, minimum uncertainty wave packet, Representations of Ket and Bra vectors and operators in matrix form, Unitary transformation of basis vectors and operators.

5 Hours

Momentum Representation: Momentum wavefunction, Significance of momentum wavefunction, Box Normalization, Superposition of plane waves, Momentum wavefunction for a free particle, Momentum wavefunction for a particle in one dimensional box, Formulation of Schrodinger equation in momentum representation.

5 Hours

Spherically Symmetrical Systems: Schrodinger equation for spherically symmetric potentials, Three-dimensional harmonic oscillator, The hydrogen atom, Energy eigen values for the hydrogen atom, Degeneracy, The normal state of the hydrogen atom.

5 Hours

Operator formalism in Quantum mechanics: Operators and linear operators, Operators and their expectation values, Dirac Notations, Adjoint operators, Unitary Operators, Expectation values of dynamical variables and physical interpretation of Hermitian operators, Inverse operators, Eigen values and eigen functions, orthonormality of eigen vectors, The operators in quantum mechanics, Momentum operator, Hamiltonian operator, Orthogonal systems, Hermitian operator, Properties of Hermitian operator, Superposition of eigen states, Commutativity and simultaneous eigen functions, The parity operator, Schwarz inequality, Heisenberg's uncertainty principle derived from operators, Equation of motion, Ehrenfest's theorem. **10 Hours**

Matrix formalism in Quantum mechanics: Linear transformations, Orthogonal and Unitary transformations, Eigen values, Eigenvectors, Characteristics equation of a matrix, Diagonalization of matrices, Cayley-Hamilton theorem, Important theorems on eigen values and eigen vectors, Hilbert space, Matrix form of wavefunction, Unitary transformation, Significant properties of unitary transformation, Dirac's BRA and KET vectors, Matrix theory of harmonic oscillator. **8 Hours**

Identical Particles and Spin: Symmetrical and Anti-symmetrical wave-function, Particle exchange operator, Distinguishability of identical particles, The Pauli's exclusion principle, Spin angular momentum, Electron spin hypothesis, Pauli spin matrices for electron, Commutation relations, Pauli eigen values and eigen functions, Electron spin functions, Spin matrices and eigen functions, Symmetric and Anti-symmetric wave functions of hydrogen molecule. **7 Hours**

Angular Momentum and their Properties: Orbital angular momentum operators as generators of rotation, L_x, L_y, L_z and $L^2$and their Commutation relations, Raising and Lowering operators (L+ and L-), L_x, L_y, L_z and L^2in Spherical Polar coordinates, Eigen values and Eigen functions of L_z and L^2(operator method), Matrix representation of L_x, L_y, L_z and L^2.

Spin ½ particles, Pauli spin matrices and their properties, Eigen values and Eigen functions, Spin and rotations. Total angular momentum: Total angular momentum J, Eigen value problem of J_z and J^2, Angular momentum matrices, Addition of angular momentum and C. G. coefficients for the states with (i) $j_1 = ½$ and $j_2 = ½$ (ii) $j_1 = 1$ and $j_2 = ½$.

10 Hours

The Independent Quantum Approximation Methods: Stationary perturbation theory (Non degenerate case), Physical applications of non degenerate perturbation theory- (i) Helium atom, (ii) Harmonic oscillator, (iii) Zeeman effect. Time-dependent perturbation theory, constant perturbation and the Fermi Golden rule, harmonic perturbation (Einstein's A and B coefficients).

The Variation Method, Physical applications of Variation method- (i) Ground state of helium, (ii) Zero point energy of one dimensional harmonic oscillator **10 Hours**

Course Learning Outcomes: *On successful completion of this course the student should know: 1. Revise the knowledge of advanced Quantum Mechanics. 2. Learn different Quantum Dynamics and apply them to solve standard Quantum mechanical problems. 3. Understand Invariance Principle and Conservation laws for linear momentum, angular momentum, energy and parity*.

Reference Books:

1. Thankappan, V.K., "Quantum Mechanics", Wiley Eastern

2. "AText Book of Quantum Mechanics"by P. M. Mathews. And Venkatesan ,Tata McGraw Hill.

3. Messiah, A., "Quantum Mechanics", North-Holland Publishing Co.

4. "Quantum Mechanics",L.I. Schiff L.I 3rd Ed, McGraw Hill Book Co.

6. Ghatak, A., Quantum Mechanics", Narosa Publishing House, New Delhi.

7. Agarwal, B. K., "Quantum Mechanics', PHI

8. Landau, L.D. & Lifshitz, E.M., "Quantum Mechanics", Pergman Press

9. Introduction to Quantum Mechanics by D. J. Griffiths. II Edn., Pearson Education

10. Hours on Quantum Mechanics, Ashok Das, University of Rochester, USA (Second edition; Hindustan Book Agency

11. Quantum Physics by Robert Eisberg and Robert Resnick (John Wiley and sons).

12. Quantum Mechanics: Theory and Applications by A. K. Ghatak and S. Lokanathan.

13. Quantum Mechanics by Claude Cohen-Tannoudji.

14. Advanced quantum mechanics by B. S. Rajput

15. Quantum Mechanics, B.H. Bransden and C. J. Joachin, Pearson Education, New Delhi.

MAJOR-VII: PHYS7011: Advanced Quantum Mechanics

Practical: **30 Hours**

Python / Scilab Based Computational Problems

1. A particle of mass m is confined in a one-dimensional box of length L (from $x = 0$ to $x = L$). The normalized position-space wavefunction for the ground state is $\psi(x) = \sqrt{\frac{2}{L}\sin\left(\frac{\pi x}{L}\right)}$. Compute the momentum wave function $\phi(p)$ using the integral transform $(p) = \frac{1}{\sqrt{2\pi\hbar}}\int_0^L \psi(x)e^{-ipx/\hbar}dx$. Plot the probability density in momentum space $|\phi(p)|^2\ for\ L = 1$ using a range of p value.
2. Write a Python/Scilab program to construct the Hamiltonian matrix for 1D Quartic oscillator and find it's first 4 energy levels. Plot the potential $V(x)$ and overlay the probability density $|\psi(x)|^2$ for the first four eigen states, shifted by their respective energy eigen value.
3. Determine the ground state and the first excited state energy of the hydrogen atom numerically. Plot the radial probability density $P(r) = r^2|R(r)|^2$ against the radial distance r.
4. Use numerical integration to find the optimal variational parameter α that minimizes the energy of a 1D quantum harmonic oscillator, and compare it with the exact analytical zero-point energy. Plot the Expectation Value of Energy $\langle E\rangle$versus the variational parameter α, highlighting the distinct minimum point.
5. Compute the standard deviations Δx and Δp for a particle in the ground state and the 2nd excited state of a 1D infinite square well. Verify that $\Delta x\,.\Delta p \geq {}^{\hbar}/_{2}$ holds true. Numerically evaluate the action of the commutator $[\hat{x},\hat{p}]\psi(x)$ to show it approximates $i\hbar\psi(x)$. Scatter plot demonstrating the $\Delta x\,.\Delta p$ product for the first 10 states of the infinite well, with a horizontal line drawn at the theoretical minimum ${}^{\hbar}/_{2}$
6. Initialize an electron spin in the $+z$ eigenstate. Subject it to a constant magnetic field purely in the x-direction. Compute the time-dependent expectation values$\langle S_x(t)\rangle$, $\langle S_y(t)\rangle$and $\langle S_z(t)\rangle$. Plot the three expectation values as a function of time to visualize Larmor Precession.
7. Write a script to generate J_x, J_y,J_z, and $J^2$for a $j = {}^{3}/_{2}$ system. Numerically compute the commutator $[J_x\,,J_y]$ and verify it exactly equals $\hbar J_z$. Show that J^2 is a diagonal matrix proportional to the identity. Use matplotlib.pyplot.matshow or spy to visualize the sparsity and non-zero structures of the J_+, J_-,J_x and J_y matrices.
8. Compute the energy-momentum dispersion relation for a free relativistic particle using matrix diagonalization. Plot the Energy E versus momentum p. The plot should

clearly display the upper positive energy branch and the lower negative energy branch, separated by the $2mc^2$ mass gap.

9. Solution of Boundary Value Problem (BVP) using shooting method.
10. Solution of Schroedinger equation by shooting method:

    Particle in an infinite square well potential (One dimensional case)
11. Solution of Schroedinger equation by shooting method: Harmonic oscillator problem in one dimension
12. Solution of Hydrogen atom problem using matrix method.

Reference Books:

1. Python for Beginners, Dr Srikumar Mukherjee, ISBN 9798896996330
2. Scientific Computing in Python, Abhijit Kar Gupta, Techno World.

MAJOR-PHYSICS COURSE
Semester VII

MAJOR-VII: PHYS7012: Nuclear and Particle Physics (Credits 06)

F.M. = 75 (Theory - 60, Internal Assessment – 15)
Internal Assessment [Class Attendance – 05, Class Test/ Assignment/ Tutorial – 10]

Theory: **75 Hours**

COURSE OBJECTIVE: *The objective of the course is to develop a profound understanding of the key concepts in Nuclear Physics that include the experimental background behind the advent of different Nuclear phenomena.*

Radioactive decay: (a) Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy.
(b) β-decay: Beta spectrum and energetics; Fermi‟s theory of beta decay, Columb correction and Fermi-Kurieplot; allowed and forbidden transitions, selection rules; Non-conservation of parity in beta decay: Wu‟s experiment; detection of the neutrino and its helicity;
(c) Gamma decay: Gamma rays emission & kinematics, selection rules, internal conversion. **6 Hours**

Two-nucleon problem and nuclear forces: Deuteron problem: Properties of deuteron; Solution of Schrödinger equation for deuteron ground state and excited states; range and depth of nuclear potential; deuteron radius.

Two-nucleon scattering: Partial wave analysis; phase-shift; scattering length and significance of its sign; Low and high energy n-p and p-p scattering, spin dependence, charge symmetry and charge independence of nuclear forces; Exchange nature of nuclear forces and singlet and triplet potentials; the necessity of tensor forces; Yukawa‟s meson theory and form of Yukawa potential.

6 Hours

Nuclear Models: Need for models; Independent Particle and Strong Interaction models. Fermi gas model: Derivation of Fermi energy and ground state kinetic energy for nucleons; Shell model: Extreme single-particle model: Spin-orbit interactions and reproduction of magic numbers; Predictions of shell model (Ground state spin parity; magnetic moment-Schmidt lines and electric quadrupole moment); Single-particle model, Total spin „J‟ for various configurations; electric quadrupole moment; configuration mixing; independent particle model, Nilsson model; Introduction to Collective model.

6 Hours

Nuclear Reactions: Different kinds of nuclear-reactions, Direct reactions: Kinematics and theory of stripping, pick up and reverse reactions; Reciprocity theorem; experimental verification of Bohr‟s independence-hypothesis, resonance reactions, Breit-Wigner one-level formula, Transfer reactions; Optical model of nuclear reaction; Heavy-ion induced nuclear reaction and various phenomena.

5 Hours

Interaction of Nuclear Radiation with matter: Energy loss due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.**5 Hours**

Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT).Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector. **7 Hours**

Particle Accelerators: Accelerator facility available in India, Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Betatron, Synchrotron and synchrocyclotron: **6 Hours**

Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness, Symmetry classification of elementary particles: baryon and meson octet and decuplet; quark hypothesis, charm, beauty and truth, gluons, quark-confinement, asymptotic freedom.

6 Hours

Cosmic Rays: Discovery, General properties of cosmic rays- latitude effect, Altitude effect, East-West symmetry, Composition of cosmic rays, Origin of cosmic rays, Secondary cosmic rays, Cosmic ray shower, Soft and hard cosmic rays.

5 Hours

Fundamentals of Nuclear Fission: Fission fuels, Prompt and delayed neutrons, Chain reaction, Multiplication factor, Condition for criticality, Breading phenomena. Diffusion of neutrons, Neutron current density, The equation of continuity, Fick's law, The diffusion equation, Measurement of diffusion parameters.

5 Hours

Reactor Physics: Slowing down of neutrons in a moderator; average log decrement of energy; slowing down power and moderating ratio, Fermi age equation; Four-factor formula; buckling and critical size of reactors. **3 Hours**

COURSE OUTCOME: *On completion, the students will have a comprehensive understanding of the fundamental principles and theories of Nuclear physics, and will be able to apply their knowledge to solve problems in various areas of nuclear physics related fields.*

Reference Books:

1. Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
2. Concepts of nuclear physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
3. Introduction to the physics of nuclei & particles, R.A. Dunlap. (Thomson Asia, 2004).
4. Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press
5. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
6. Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
7. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOP-Institute of Physics Publishing, 2004).
8. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
9. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
10. Theoretical Nuclear Physics, J.M. Blatt &V.F.Weisskopf (Dover Pub.Inc., 1991)
11. Nuclear Physics, S.N. Ghoshal, S. Chand Publication
12. Nuclear and Particle Physics A.B. Gupta, Books and Allied Private Ltd.
13. Theory of Nuclear Structure, M.K. Pal

MAJOR-PHYSICS COURSE

Semester VII

MAJOR-VII: PHYS7013: SOLID STATE PHYSICS (Credits: Theory-04, Practical - 02)

F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: *The aim of this course is to provide an understanding of the basic principles of the solid state physics that are important prerequisites for physics courses.*

Theory: **75 Hours**

Crystal Structure: Solids,Amorphous and Crystalline Materials. Lattice Translation Vectors.Lattice with a Basis – Central and Non-Central Elements. Elements of symmetry, The fourteen Bravais lattices and the seven crystal systems, Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones.

6 Hours

Crystal Diffraction: Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor, Scattering from an atom, Scattering from a crystal, The reciprocal lattice and x-ray diffraction, Scattering from liquids, Experimental techniques.

5 Hours

Crystal Bonding: Interatomic forces, types of bonding, ionic bonding, bond dissociation energy of NaCl molecule, cohesive energy of ionic crystals, evaluation of Madelung constant for NaCl structure, Madelung potential, The Born-Haber cycle, covalent bonding, directional nature of the covalent bond, Metallic bonding, Hydrogen bonding, van der Waals' bonding.

5 Hours

Lattice Vibrations: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons.Qualitative Description of the Phonon Spectrum in Solids.Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids.

7 Hours

Free electron theory of metals: Energy levels and density of orbitals in one dimension. Free electron gas according to Sommerfield model. Free electron gas in three dimensions, Derivation of Ohm's law according to free electron model and electrical conductivity. Heat capacity of free electron gas.Widemann Franz law.Failure of free electron theory.

6 Hours

Band theory of Solids: Energy bands in solids – the Bloch theorem, Kronig Penny model. Band Gap.Conductor, Semiconductor (P and N type) andinsulator.Conductivity of Semiconductor, mobility, Hall Effect.Measurement of conductivity (Four-probe method) & Hall coefficient.

8 Hours

Superconductivity: Experimental Results. Critical Temperature.Critical magnetic field.Meissner effect.Type-I and Type-II Superconductors, London's Equation andPenetration Depth. Isotope effect.Idea of BCS theory. **6 Hours**

Magnetic Properties of Matter: Dia-, Para-, Ferri-and Ferromagnetic Materials. Classical Langevin Theory of Dia- and Paramagnetic Domains.Quantum Mechanical Treatment of Paramagnetism, Curie'slaw, Weiss's Theory of Ferromagnetism and Ferromagnetic domains.Discussion of B-H Curve.Hysteresis and Energy Loss.

6 Hours

Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom.Depolarization Field.Electric Susceptibility.Polarizability.Clausius Mosotti Equation.Classical Theory of Electric

Polarizability.Normal and Anomalous Dispersion.Cauchy and Sellmeir relations.Langevin-Debye equation.Complex Dielectric Constant.Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes.

6 Hours

Ferroelectric Properties of Materials: Structural phase transition, Classification of crystals, Piezoelectric effect, Pyro-electric effect, Ferroelectric effect, Electrostriction, Curie-Weiss Law, Ferroelectricdomains, PE-hysteresis loop. **5 Hours**

Reference Books:

1. IntroductiontoSolidStatePhysics,CharlesKittel,8thEdition,2004,WileyIndiaPvt.Ltd.
2. ElementsofSolidStatePhysics,J.P.Srivastava,4thEdition,2015,Prentice-HallofIndia
3. IntroductiontoSolids,LeonidV.Azaroff,2004,TataMc-GrawHill
4. SolidStatePhysics,N.W.AshcroftandN.D.Mermin,1976,CengageLearning
5. Solid-statePhysics,H.IbachandH.Luth,2009,Springer
6. SolidStatePhysics,RitaJohn,2014,McGrawHill
7. ElementarySolidStatePhysics,1/eM.AliOmar,1999,PearsonIndia
8. SolidStatePhysics,M.A.Wahab,2011,NarosaPublications.
9. Crystallography Applied to Solid State Physics by A.R.Verma and O.N.Srivastava
10. Applied Solid State Physics by Rajnikant

Course learning outcomes: *After completing this course content, student will be able to understand, the correlation between bonding and the properties of solids Basic principles of structure of materials, crystallography and crystal defects. Space efficient arrangement of constituent particles in a crystal lattice.*

MAJOR-VII: PHYS7013: SOLID STATE PHYSICS

Practical: **30 Hours**

1. To determine the Coupling Coefficient of a Piezo-electric crystal.
2. To measure the Dielectric Constant of a dielectric Materials with frequency
3. To determine the band gap using a thermistor.
4. To study the PE-Hysteresis loop of a Ferroelectric Crystal.
5. To trace B-H curve for ferromagnetic specimen and determine coercivity, retentivity and magnetic induction field
6. To determine the Hall coefficient and the carrier concentration of the sample material.
7. To determine band gap of given semiconducting material by using Four Probe method.

8. Study of dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibrations.

Reference Books:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, AsiaPublishing House.

2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.

3. A Text Book of Practical Physics, I.Prakash& Ramakrishna, 11th Edn, 2011,Kitab Mahal.

4. B.Sc. Practical Physics, C L Arora, S Chand and Company Limited.

5. B.Sc. Practical Physics, Harnam singh and dr P S Heme, S Chand and Company Limited.

6. Laboratory manual of Physics, Madhusudan Jana, Books and Allied Pvt. Ltd.

7. An advanced Course in Practical Physics, D Chottopadhyay, P C Rakshit, B Saha, Books and Allied Pvt. Ltd.

MAJOR-PHYSICS COURSE

Semester VII

MAJOR-VII: PHYS7014: COMMUNICATION SYSTEMS

(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)
Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Tutorial) – 05, Practical (Sessional Viva-voce) - 05]

Course objective: *The aim of the syllabus to build an overall knowledge on principle of communication and its applications to physical systems.*

Theory: **75 Hours**

Electronic communication: Introduction to communication – means and modes. Need for modulation. Block diagram of an electronic communication system. Brief idea of frequency allocation for radio communication system in India (TRAI).Electromagnetic communication spectrum, band designations and usage.Channels and base-band signals.Concept of Noise, signal-to-noise (S/N) ratio. **8 Hours**

Analog Modulation: Amplitude Modulation, modulation index and frequency spectrum. Generation of AM (Emitter Modulation), Amplitude Demodulation (diode detector), Concept of Single side band generation and detection. Frequency Modulation (FM) and Phase Modulation (PM), modulation index and frequency spectrum, equivalence between FM and PM, Generation of FM using VCO, FM detector (slope detector), Qualitative idea of Super heterodyne receiver.

12 Hours

Analog Pulse Modulation: Channel capacity, Sampling theorem, Basic Principles- PAM, PWM, PPM, modulation and detection technique for PAM only, Multiplexing.

9 Hours

Digital Pulse Modulation: Need for digital transmission, Pulse Code Modulation, Digital Carrier Modulation Techniques, Sampling, Quantization and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Binary Phase Shift Keying (BPSK). **10 Hours**

Introduction to Communication and Navigation systems: Satellite Communication– Introduction, need, Geosynchronous satellite orbits**,** geostationary satellite advantages of geostationary satellites. Satellite visibility, transponders (C - Band), path loss, ground station, simplified block diagram of earth station. Uplink and downlink.

10 Hours

Mobile Telephony System: –Basic concept of mobile communication, frequency bands used in mobile communication, concept of cell sectoring and cell splitting, SIM number, IMEI number, need for data encryption, architecture (block diagram) of mobile communication network, idea of GSM, CDMA, TDMA and FDMA technologies, simplified block diagram of mobile phone handset, 2G, 3G and 4G concepts (qualitative only).

10 Hours

GPS Navigation System (qualitative idea only). **1 Hour**

Reference Books:

1. Electronic Communications, D. Roddy and J. Coolen, Pearson Education India.
2. Advanced Electronics Communication Systems- Tomasi, 6th edition, Prentice Hall.
3. Electronic Communication systems, G. Kennedy, 3rd Edn., 1999, Tata McGraw Hill.
4. Principles of Electronic communication systems – Frenzel, 3rd edition, McGraw Hill
5. Communication Systems, S. Haykin, 2006, Wiley India
6. Electronic Communication system, Blake, Cengage, 5th edition.
7. Wireless communications, Andrea Goldsmith, 2015, Cambridge University Press
8. Analog Electronics: Devices and Circuits: B. C. Sarkar and S. Sarkar, Damodar Group.

MAJOR-VII: PHYS7014: COMMUNICATION SYSTEMS
Practical: **30 Hours**

1. To design an Amplitude Modulator using Transistor
2. To study envelope detector for demodulation of AM signal
3. To study FM - Generator and Detector circuit
4. To study AM Transmitter and Receiver
5. To study FM Transmitter and Receiver

Reference Books:
1. Electronic Communication systems, G. Kennedy, 1999, Tata McGraw Hill.
2. Electronic Communication system, Blake, Cengage, 5th edition.

Course learning outcomes: *After completing this course content, student will be able to understand the Basic principles of communication and their uses in daily life.*

MINOR-PHYSICS COURSE
Semester VII
MINOR-VII: PHYS7021: Electricity, Magnetism and Wave Optics

(Credits: Theory-03, Practicals-01)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)
Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Tutorial) – 05, Practical (Sessional Viva-voce) - 05]

COURSE OBJECTIVE: *The objectives of this course is to provide an in-depth understanding of the principles of Electricity, Magnetism, waves and apply them to solve problems related with Electricity and Magnetism.*

Theory: **45 Hours**
Electrostatics: Electrostatic Field, electric flux, Gauss's theorem of electrostatics. Applications of Gauss Theorem-Electric field due to point charge, infinite line of charge, uniformly charged spherical shell and solid sphere, plane charged sheet, charged conductor.

3 Hours

Electric potential as line integral of electric field, potential due to a point charge, electric dipole, uniformly charged spherical shell and solid sphere. Calculation of electric field from potential. **3 Hours**

Capacitance of an isolated spherical conductor.Parallel plate, spherical and cylindrical condenser.Energy per unit volume in electrostatic field.Dielectric medium, Polarization, Displacement vector.Gauss's theorem in dielectrics. Parallel plate capacitor completely filled with dielectric. **3 Hours**

Magnetostatics: Biot-Savart's law & its applications- straight conductor, circular coil, solenoid carrying current. Divergence and curl of magnetic field. Magnetic vector potential.Ampere's circuital law. **4 Hours**

Electromagnetic Induction:Faraday's laws of electromagnetic induction, Lenz's law, self and mutual inductance, L of single coil, M of two coils. Energy stored in magnetic field.

3 Hours

Maxwells Equation: Equation of continuity of current, Displacement current, Maxwell's equations, Poynting vector, energy density in electromagnetic field, electromagnetic wave propagation through vacuum and isotropic dielectricmedium, transverse nature of EM waves, polarization. **5 Hours**

Superposition of Two Collinear Harmonic oscillations: Linearity and Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). **2 Hours**

Superposition of Two Perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses.

3 Hours

Wave Optics: Electromagnetic nature of light.Definition and Properties of wavefront.Huygens Principle. **2 Hours**

Interference: Interference: Division of amplitude and division of wavefront. Young's Double Slit experiment.Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: measurement of wavelength and refractive index.

7 Hours

Diffraction: Fresnel Diffraction: Half-period zones. Zone plate.Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis.

Fraunhofer diffraction: Single slit; Double Slit. Multiple slits & Diffraction grating.

5 Hours

Polarization: Transverse nature of light waves. Plane polarized light – production and analysis. Circular and elliptical polarization. **5 Hours**

MINOR-VII: PHYS7021: Electricity, Magnetism and Wave Optics
Practical: 30 Hours

1. To compare capacitances using De'Sauty's bridge.

2. To study the a series LCR circuit and determine its (a) Resonant Frequency, (b) Quality Factor

3. To determine a Low Resistance by Carey Foster's Bridge.

4. To determine the horizontal component of earth's magnetic field.

5. To determine the resistance of a suspended coil galvanometer by half deflection method and hence calculate the sensitivity of the galvanometer.

6. To determine the Refractive Index of the Material of a given Prism using Sodium Light.

7. To determine wavelength of sodium light using Newton's Rings.

8. To determine wavelength of Sodium light using plane diffraction Grating.

9. To determine the refractive index of a liquid by travelling microscope.

10. To determine the focal length of a concave lens by combination method.

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

2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11thEdition, 2011, Kitab Mahal, New Delhi.

COURSE OUTCOME: *This course in Electricity, Magnetism and waves serves as the foundation for further progress towards the study of physics at graduate or post-graduate level. On completion of this course, the student must be able to perform different problems which are extremely essential to study theoretical and experimental physics.*

MAJOR-PHYSICS COURSE

Semester VIII

MAJOR-VIII: PHYS8011: STATISTICAL MECHANICS
(Credits: Theory-04, Practicals-02)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)
Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Tutorial) – 05, Practical (Sessional Viva-voce) - 05]

COURSE OBJECTIVE: ***The objective of the course is to develop a profound understanding of the key concepts in statistical physics that include the experimental background behind the advent of quantum statistics.***

Theory: 60 Hours

Classical Statistics: Macrostate & Microstate, Phase Space, Concept of Ensemble – Micro-canonical, canonical and Grand-canonical ensembles. Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function,Thermodynamic parameters in terms of Partition Function,Ortho- and Para-Hydrogen, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression using Micro-canonicalensemble, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature.

20 Hours

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

5 Hours

Bose-Einstein Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law. **15 Hours**

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

20 Hours

Reference Books:

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

MAJOR-VIII:PHYS8011: STATISTICAL MECHANICS

Practical : 30 Hours

Use C/C++/Scilab/Python/other numerical simulations for solving the problems based on Statistical Mechanics like

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:

a) Study of local number density in the equilibrium state (i) average; (ii)fluctuations

b) Study of transient behavior of the system (approach to equilibrium)

c) Relationship of large N and the arrow of time

d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution

e) Computation and study of mean molecular speed and its dependence on particle mass

f) Computation of fraction of molecules in an ideal gas having speed near the most probable speed

2. Computation of the partition function Z(β) for examples of systems with a finite number of single particle levels (e.g., 2 level, 3 level, etc.) and a finite number of non-interacting particles N under Maxwell-Boltzmann, Fermi-Dirac and Bose- Einstein statistics:

a) Study of how Z(β), average energy <E>, energy fluctuation ΔE, specific heat at constant volume Cv,depend upon the temperature, total number of particles N and the spectrum of single particle states.

b) Ratios of occupation numbers of various states for the systems consideredabove

c) Computation of physical quantities at large and small temperature T andcomparison of various statistics at large and small temperature T.

3. Plot Planck"s law for Black Body radiation and compare it with Raleigh-JeansLaw at high temperature and low temperature.

4. Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature and low temperature and compare them for these two cases.

5. Plot the following functions with energy at different temperatures

a) Maxwell-Boltzmann distribution b) Fermi-Dirac distribution c) Bose-Einstein distribution

Reference Books:

1. Elementary Numerical Analysis, K.E.Atkinson, 3r d Edn. 2007, Wiley India Edition
2. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
3. Introduction to Modern Statistical Mechanics, D. Chandler, Oxford University Press, 1987
4. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
6. Statistical and Thermal Physics with computer applications, Harvey Gould and Jan Tobochnik, Princeton University Press, 2010.

Course Outcome: *On completion of this course, the students will learn the basic laws of different statistics and their applications in various fields*

MAJOR-PHYSICS COURSE

Semester VIII

MAJOR-VIII:PHYS8012: Astronomy & Astrophysics (Credits: 04)
(Credits: Theory-04, Practicals-00)
F.M. = 75 (Theory - 60, Internal Assessment – 15)
Internal Assessment [Class Attendance – 05, Class Test/ Assignment/ Tutorial) – 10]

COURSE OBJECTIVE: *The objective of the course is to develop a profound understanding of the key concepts in Astronomy and Astrophysics that include the different Astronomical techniques.*

Theory: **60 Hours**

Astronomical Scales: Astronomical Distance, Mass and Time, Scales, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature. Basic concepts of positional astronomy: Celestial Sphere, Geometry of a Sphere, Spherical Triangle, Astronomical Coordinate Systems, Geographical Coordinate Systems, Horizon System, Equatorial System, Diurnal Motion of the Stars, Conversion of Coordinates. Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Calendar. Basic Parameters of Stars: Determination of Distance by Parallax Method; Brightness, Radiant Flux and Luminosity, Apparent and Absolute magnitude scale, Distance Modulus; Determination of Temperature and Radius of a star; Determination of Masses from Binary orbits; Stellar Spectral Classification, Hertzsprung-Russell Diagram.

10 Hours

Astronomical techniques: Basic Optical Definitions for Astronomy (Magnification Light Gathering Power, Resolving Power and Diffraction Limit, Atmospheric Windows), Optical Telescopes (Types of Reflecting Telescopes, Telescope Mountings, Space Telescopes, Detectors and Their Use with Telescopes(Types of Detectors, detection Limits with Telescopes). Physical principles: Gravitation in Astrophysics (Virial Theorem, Newton versus Einstein), Systems in Thermodynamic Equilibrium.

8 Hours

The Sun (Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere.Corona, Solar Activity, Basics of Solar Magneto-hydrodynamics.Helioseismology). The solar family (Solar System: Facts and Figures, Origin of the Solar System: The Nebular Model, Tidal Forces and Planetary Rings, Extra-Solar Planets. Stellar spectra and classification Structure (Atomic Spectra Revisited, Stellar Spectra, Spectral Types and Their Temperature Dependence, Black Body Approximation, H R Diagram, Luminosity Classification).

10 Hours

The Milky Way: Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way (Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus. **10 Hours**

Galaxies: Galaxy Morphology, Hubble‟s Classification of Galaxies, Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleus Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo) The Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms. **7 Hours**

Large scale structure & expanding universe: Cosmic Distance Ladder (An Example from Terrestrial Physics, Distance Measurement using Cepheid Variables), Hubble‟s Law (Distance- Velocity Relation), Clusters of Galaxies (Virial theorem and Dark Matter).

15 Hours

Reference Books:

1. Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
2. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
3. The physical universe: An introduction to astronomy, F.Shu, Mill Valley: University Science Books.
4. Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
5. K.S. Krishnasamy, „Astro Physics a modern perspective,‟ Reprint, New Age International (p) Ltd, New Delhi,2002.
6. Baidyanath Basu, „An introduction to Astro physics‟, Second printing, Prentice - Hall of India Private limited, New Delhi,2001.
7. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.
8. Astrophysics for Beginers, B. Malakar and C K Karmakar, Spellbound Publishers & Distributors, Kolkata, 2025

ISBN: 978-81-980966-3-0

COURSE OUTCOME: *On completion, the students will have a comprehensive understanding of the fundamental principles and theories of Astronomy and Astrophysics and* *will be able to apply their knowledge to solve problems in various areas of Astrophysics physics and related fields.*

MAJOR-PHYSICS COURSE

Semester VIII

MAJOR-VIII: PHYS8013: LASER AND FIBER OPTICS
(Credits: Theory-03, Practical - 01)
F.M. = 75 (Theory – 40, Practical – 20, Internal Assessment –15)

COURSE OBJECTIVE: *The objectives of this course is to provide an in-depth understanding of the basic principle of Laser physics and apply them to solve problems involving the systems associated with laser.*

Theory: **45 Hours**

Basic Laser Theory: Historical background of laser, Ideas of stimulated and spontaneous emission. Characteristics of laser light.Optical Pumping, Rate Equations for Three-level and Four-level lasers, Optimum output power, Laser pumping requirements, threshold power calculation. **6 Hours**

Coherence: Temporal Coherence and Spatial Coherence. **2 Hours**

Laser Beam Propagation: Paraxial ray analysis, applications- lens, concave mirror, refraction in concave surface, propagation and properties of Gaussian beam, Gaussian beam in lens like medium, ABCD law, Gaussian beam focusing, M2 parameter. **4 Hours**

Resonators: Optical resonator, Modes of a resonator, various types of stable resonators, qualitative discussion on ‘g’ parameters, Stability of resonators, unstable resonator and their application. **4 Hours**

Basic Laser Systems & some applications: Basic concept of construction of laser system, pumping cavities for solid state laser system Solid State Lasers: Host material and its characteristics, doped ions, Nd:YAG laser, Argon ion Laser, CO_2 laser, Excimer Laser, Organic Dye laser, Semiconductor laser **6 Hours**

Q-Switching: Principle of Q-switching, different methods of Q-switching, Different active and passive Q-switching techniques: mechanical Q-switching, electrooptic Q-switching, Pockels and Kerr Q-switching, Pockels cell **4 Hours**

Nonlinear Optics: Origin of nonlinearity, Anharmonic oscillator model, nonlinearities of the polarization, Introduction to Second order Nonlinear optical processes- SHG, SFG, DFG. **4 Hours**

Detection of optical radiation: Human eye, thermal detector (pyro-electric), photon detector (photoconductive detector, photovoltaic detector), p-i-n photodiode, APD photodiode. **4 Hours**

Fibre Optics: Basic structure of optical fibre and propagation of signal, Acceptance angle. Numerical Aperture. Optical fibre communication system- its components, applications, advantages and disadvantages. **4 Hours**

Classification of Optical Fibres: Mono-mode and multimode, step-index fibre and graded index, and their comparison, Number of modes, cut-off wavelength. **3 Hours**

Attenuation in Optical Fibres: Material losses- Intrinsic and Extrinsic, Linear and non-linear scattering losses, leaky modes, bending losses. Dispersion in Optical Fibre- intermodal dispersion, material (chromatic) dispersion, waveguide dispersion. **4 Hours**

Reference Books:

1.Principles of Lasers: O Svelto

2. Lasers- Theory and Applications, K Thyagarajan and A K Ghatak, MACMILLAN

3. Laser Fundamentals, W T Silfvast, Cambridge University Press, 2nd Edition.

4. An Intriduction to Lasers and their Applications, D C O'Shea, W R Callen and W T Rhodes, Addison-Wesley Publishing company.

5. Industrial Application of Lasers – J F Ready

6. Quantum Electronics- A Yariv

7. Optical Electronics: A K Ghatak and K Thyagarajan

8. Laser and Electro-Optics: C C Davis

9. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill

10. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, R. Eisberg and R. Resnick, John Willey & Sons

11.Laser Spectroscopy- Basic Concepts and Instrumentations, W Demtroder, Springer.

Course learning outcomes: *The course aims to present the fundamentals of radiation-matter interaction and the principle of laser including resonator cavity and generation of pulsed laser. It includes adequate knowledge to students regarding the principle, design, and working of different laser systems (solid-state, gas, liquid, semiconductor). This course provides a brief overview of applications of lasers in fields of science, holography, industry, medical science, military, ranging, etc. The course will provide the students with practical applicable information in the laboratory setting. On the completion of the course studentsshould be able to understand Interaction of radiation with matter in the form of absorption, spontaneous and stimulated emission of radiations.*

MAJOR-VIII:PHYS8013: LASER AND FIBER OPTICS

Practical : **30 Hours**

List of Experiments

1. To determine the power distribution within the light beam.
2. To determine the spot size of a laser beam.
3. To measure the divergence of a laser beam.
4. To measure the wedge angle of a glass plate using interference fringes obtained with the help of He-Ne laser.
5. To determine the width of a wire or narrow slit using laser.
6. To determine the wavelength of Laser light with a transmission grating.
7. Determination of grove spacing of a CD by diffraction method and hence determination of wavelength of unknown source.
8. To determine the wavelength of He-Ne laser using double slit by interference method.
9. To determine Brewster's angle of a glass plate by using laser light and hence the refractive index of the glass plate.
10. To measure the Numerical Aperture of an optical fibre

Reference Books:

1. A Course of Experiments with He-Ne Laser, R S Sirohi, Wiley Eastern Limited.
2. B.Sc. Practical Physics, C L Arora, S Chand and Company Limited.
3. B.Sc. Practical Physics, Harnam singh and Dr P S Heme, S Chand and Company Limited.
4. Laboratory manual of Physics, Madhusudan Jana, Books and Allied Pvt. Ltd.
5. An advanced Course in Practical Physics, D Chottopadhyay, P C Rakshit, B Saha, Books and Allied Pvt. Ltd.

MAJOR-PHYSICS COURSE
Semester VIII

MAJOR-VIII:PHYS8014: Materials Science
(Credits: Theory-04, Practicals-00)
F.M. = 75 (Theory - 60, Practical – 00, Internal Assessment – 15)
Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Tutorial) – 05, Practical (Sessional Viva-voce) - 05]

COURSE OBJECTIVE: *The objective of this course is to provide the basic concepts of Materials physics to an undergraduate student. The student learns to explain or even to* *predict, the experimental observations of Material science. An introduction of basic materials physics will enrich them.*

Theory: **60 Hours**

Nanoscale Systems: Length scales in physics, Nanostructures: 1D, 2D and 3D nanostructures (nanodots, thin films, nanowires, nanorods), Band structure and density of states of materials at nanoscale, Size Effects in nano systems, Theory of Quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences.

10 Hours

Synthesis of Nanostructure Materials: Top down and Bottom up approach, Photolithography. Ball milling.Gas phase condensation.Vacuum deposition.Physical vapor deposition. (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD).Sol-Gel.Electro deposition. Spray pyrolysis. Hydrothermal synthesis.Preparation through colloidal methods.MBE growth of quantum dots.

10 Hours

Characterization: X-Ray Diffraction, Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy. Atomic Force Microscopy. Scanning Tunneling Microscopy

8 Hours

Optical Properties: Quasi-particles and excitons. Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi-particles and excitons, charging effects. Radiative processes: General formalization-absorption, emission and luminescence. Optical properties of heterostrctures and nanostructures. **12 Hours**

Electron Transport: Carrier transport in nanostrcutures. Coulomb blockade effect, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects. **8 Hours**

Applications : Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron transfer devices (no derivation). CNT based transistors. Nanomaterial Devices: Quantum dots heterostructure lasers, optical switching and optical data storage. Magnetic quantum well; magnetic dots - magnetic data storage. Nanoscale Sensors, Biomedical Applications, Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS).

12 Hours

Reference books:

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt. Ltd.).
2. S.K. Kulkarni, Nanotechnology: Principles & Practices (Capital Publishing Company)
3. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (PHI Learning Private Limited).
4. Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).

5. M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama, Nanoparticle Technology Handbook (Elsevier, 2007).
6. Introduction to Nanoelectronics, V.V. Mitin, V.A. Kochelap and M.A. Stroscio, 2011, Cambridge University Press.
7. Bharat Bhushan, Springer Handbook of Nanotechnology (Springer-Verlag, Berlin, 2004).
8. Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons) C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt. Ltd.).

COURSE OUTCOME: *This course in Nano-materials serves as the foundation for further progress towards the study of physics at graduate or post-graduate level. Upon completion of the course, the student will be able to apply basic principle of Nano Technology to different systems.*

MINOR-PHYSICS COURSE
Semester VIII

MINOR-VIII:PHYS8021: Modern Physics
(Credits: Theory-03, Practicals-01)
F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)
Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Tutorial) – 05, Practical (Sessional Viva-voce) - 05]

COURSE OBJECTIVE: *The objective of the course is to develop a profound understanding of the key concepts in modern physics that include the experimental background behind the advent of quantum mechanics, the theory of relativity, atomic and nuclear physics.*

Theory: **45 Hours**

Atomic Physics: Problems with Rutherford model- instability of atoms and observation of discrete atomic spectra, Bohr's quantization rule and atomic stability; energy levels for hydrogen like atoms and their spectra. Singly ionized helium, Wilson-Sommerfeld quantization rule.

3 Hours

Excitation and Ionization potentials, metastable states .Franck- Hertz experiment.

2 Hours

Orbital angular momentum and magnetic moment of an electron moving in a Bohr orbit. Bohr magneton. Energy associated with a magnetic dipole placed in magnetic field. Larmor’s theorem. **4 Hours**

Quantum Mechanics: Radiation and its nature, Black body Radiation, Planck's quantum hypothesis, Photoelectric effect, Lenard's experiment, photoemission characteristics, Failure of EM wave theory, Photoelectric equation, photocells. **3 Hours**

Compton effect, Energy of scattered radiation and recoil electron, Experimental studies of Compton effect. **2 Hours**

De Broglie wavelength and matter waves.Wave-particle duality.Davisson-Germer experiment,Wave description of particles by wave packets. Group and Phase velocities and relation between them **2 Hours**

Heisenberg uncertainty principle, Position measurement, γ-ray microscope thought experiment. Uncertainty principle and concept of Bohr orbit.

2 Hours

Schrodinger equation for non- relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of wavefunction, Probabilities and Normalization; Probability and probability current densities in one dimension. One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions

3 Hours

Nuclear Physics: Constituents of nucleus and their Intrinsic properties, quantitative facts about size, mass, charge density (matter energy), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle; Isotopes, isobars, isotones.Nature of nuclear force between nucleons, N-Z graph, Semi-empirical mass formula and binding energy.

4 Hours

Law of radioactive decay; Mean life & half-life, α-decay, β-decay, γ-ray emission.

3 Hours

Nuclear Fission and fusion, Nuclear reactor. **2 Hours**

Fundamental particles and their families.Fundamental particle interactions and their basic features.Symmetries and conservation laws, baryon number, lepton number, isospin, hypercharge, and strangeness. Quark model, quark structure of hadrons. **3 Hours**

Electronics: Semiconductor Diodes: p and n type semiconductors. Barrier Formation in PN Junction Diode. Qualitative Idea of Current Flow Mechanism in Forward and Reverse Biased Diode.PN junction and its characteristics. Static and Dynamic Resistance.Principle and structure of (1) LEDs (2) Photodiode (3) Solar Cell. **3 Hours**

n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations.Active, Cutoff, and Saturation Regions.Current gains α and β. Relations between α and β.

3 Hours

Characteristics of an Ideal and Practical Op-Amp (IC 741), Open-loop & Closed-loop Gain.CMRR, concept of Virtual ground. Applications of Op-Amps: (1) Inverting and Non-inverting Amplifiers, (2) Adder, (3) Subtractor. **3 Hours**

Difference between Analog and Digital Circuits.Binary Numbers. Decimal to Binary andBinary to Decimal Conversion, Binary Addition, Binary Subtraction AND, OR and NOT Gates (Realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates.De Morgan's Theorems.Boolean Laws. Simplification of Logic Circuit using Boolean Algebra.

3 Hours

MINOR-VIII: PHYS8021: Modern Physics
Practical: **30 Hours**

1. To determine value of Boltzmann constant using V-I characteristic of PN diode.
2. To determine value of Planck's constant using LEDs of at least 4 different colours.
3. To determine the excitation potential of mercury/argon by Franck-Hertz experiment.
4. To determine the wavelength of H-alpha emission line of Hydrogen atom.
5. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
6. To determine the value of e/m by magnetic focusing method.
7. To verify and design AND, OR, NOT and XOR gates using NAND gates.
8. To minimize a given logic circuit.
9. To study I-V characteristics of PN diode and Zener diode.
10. To study the characteristics of a Transistor in CE configuration.

Reference Books:

1. Advanced Practical Physics for students, B.L.Flint & H.T.Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4thEdition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, InduPrakash and Ramakrishna, 11thEdition, 2011, Kitab Mahal, NewDelhi.
4. B.Sc. Practical Physics, C L Arora, S Chand and Company Limited.

5.B.Sc. Practical Physics, Harnam singh and dr P S Heme, S Chand and Company Limited.

6. Laboratory manual of Physics, Madhusudan Jana, Books and Allied Pvt. Ltd.
7. An advanced Course in Practical Physics, D Chottopadhyay, P C Rakshit, B Saha, Books and Allied Pvt. Ltd.

COURSE OUTCOME: *On completion, the students will have a comprehensive understanding of the fundamental principles and theories of modern physics, and will be able to apply their knowledge to solve problems in various areas of modern physics and related fields.*

FORWARDED

Abhijit Chakrabarty

Professor & Head

Department of Physics

The University of Burdwan

Burdwan-713104

08.06.2026