B.Sc. PHYSICS (Honours) Syllabus

Four Year Undergraduate Program (FYUGP)

JUNE 2023

DEPARTMENT OF PHYSICS

BHATTADEV UNIVERSITY, BAJALI

www.bhattadevuniversity.ac.in

Introduction

The University Grants Commission (UGC) has initiated several measures to bring equity, efficiency and excellence in the Higher Education System of country. The important measures taken to enhance academic standards and quality in higher education include innovation and improvements in curriculum, teaching-learning process, examination and evaluation systems, besides governance and other matters. But due to the variuous diversities present in the system of higher education, there are multiple approaches followed by universities towards examination, evaluation and grading system. However, the academic reforms recommended by the UGC in the recent past have led to overall improvement in the higher education system. On the basis of the recommendation, apart from the flexibility and freedom in designing the examination, there is a need to devise a sensible system for awarding the grades based on the performance of students.

The NEP2020 based **Four-Year Undergraduate Programme (FYUGP)**, being adopted by Bhattadev University, is an 8-semester (4-year) programme of 160 credits with multiple exit and entry options at the successful completion of courses assigned at the end of each year.

• Students who opt to exit after completion of the first year and have secured 40 credits will be awarded a **certificate** if, in addition, they complete one vocational course of 4 credits during the summer vacation of the first year.

• Students who opt to exit after completion of the second year and have secured 80 credits will be awarded the **diploma** if, in addition, they complete one vocational course of 4 credits during the summer vacation of the second year.

• Students who opt to exit after completion of the third year and have secured 120 credits will be eligible for the **Bachelor degree** in the Major discipline without Honours.

• Students after completion of the fourth year and have secured 160 credits will be eligible for the **Bachelor degree with Honours** in the Major discipline.

• Students are allowed to re-enter the degree programme within three years and complete the degree programme within the stipulated maximum period of seven years.

Outline of Courses :

The broad categories of courses and minimum credits required for the 4-year Honours degrees as per the UGC document are as follows:

1. **Major (Core) course/paper :** 80 credits
2. **Minor course/paper :** 32 credits
3. **Interdisciplinary course/paper (IDC) :** 9 credits
4. **Ability Enhancement Course/paper (AEC) :** 8 credits
5. **Skill Enhancement Course/paper (SEC) :** 9 credits
6. **Value Added Course/paper (VAC) :** 8 credits
7. **Summer Internship :** 2 credits
8. **Research Project/ Dissertation :** 12 credits (for Honours with Research degree)

The following points may be noted:

• In lieu of the Research Project, a student may study 3 courses each of 4 credits (i.e. total 12 credits), leading to an Honours degree (without Research).

• For the 4-year Honours degrees the Major subject/ discipline requires 80 credits and the . Minor subject/ discipline requires 32 credits.

• For a Double Major, the minimum credit requirements are 48 (3-year degree) and 60 (4- year Honours degree) respectively in a subject/ discipline other than the original Major.

• In the UGC framework, papers in Major and Minor disciplines are categorized into levels of 100, 200, 300 and 400. Therefore, a course (paper) offered by a Department, say with 4 credits and of level 200, may be taken both as a Major (Core) course by one student and as a Minor course by another student having a different Major discipline, possibly in different semesters.

Definition of Keywords

In FYUGP the terminlogies those are relevant to the B.Sc. curricula have been briefly described below.

Academic Year: Two consecutive (one odd + one even) semesters constitute one academic year.

Semester: Each semester will consist of 15 weeks of regular academic work. The odd semester may be scheduled from July to December and even semester from January to June under normal circumstance.

Programme: An educational programme leading to award of a Certificate, Diploma or Degree (B.Sc., B.A., etc.)

Discipline: This means a particular subject.

Course: Each programme is equipped with a number courses of various disciplines/subjects. The course of a particular discipline/subject refers to the content of the papers the students have to study in that discipline/subject required in obtaining a degree. The courses should define learning objectives and learning outcomes. A course may be designed to comprise lectures /tutorials/laboratory work/ field work/outreach activities/project work /seminars /assignments / presentations etc. or a combination of any of these.

Honours: A particular discipline/subject that a student opts as major subject. (e.g. honours in Physics)

Core Course (CC): A discipline/subject specific compulsory basic course.

Skill Enhancement Course (SEC): A course designed by a department for enhancement of skill of the students in a particular discipline/subject.

Minor Course (M): A course in a discipline/subject corresponding to a subject other than the major subject.

Value Added Course (VAC): Value-based education to include managment of biological resources and biodiversity for the development of humanistic, ethical, sustainable development and living, constitutional, and universal human values of truth, righteous conduct, peace, love, nonviolence, scientific temper, citizenship values, and life skills.

Ability Enhancement Compulsory Course (AECC): These are compulsory courses. For science programme there will be two of them. AECC-1 is Communicative English & AECC-2 is Environmental Science.

Vocational Course (VOC): A vocational course is focused on practical work, preparing students for a particular trade or skilled profession. These courses are best for students who have a good idea of their career path and want to gain the knowledge to get there.

Levels of Courses:
100 - 199 : Foundation or introductory courses.
200 - 299 : Intermediate level courses.
300 - 399 : Higher level courses.
400 - 499 : Advanced courses.

Credit: A unit by which the course work is measured. It determines the number of hours of instructions required per week. **Theory/Tutorial classes:** 1 credit = 1 hour / week and **Practical classes:** 1 credit = 2 hours / week

Credit Point: It is the product of grade point and number of credits for a course.

Letter Grade: It is an index of the performance of students in a said course.

Grade Point: It is a numerical weight allotted to each letter grade on a certain point scale. The following table explains the above two points

Letter Grade	Grade Point	Performane	Letter Grade	Grade Point	Performane
O	10	Outstanding	C+	5	Average
A+	9	Excellent	C	4	Pass
A	8	Very Good	F	0	Fail
B+	7	Good	I	0	Absent/Incomplete
B	6	Above Average			

Semester Grade Point Average (SGPA): It is a measure of performance of work done in a semester. It is ratio of total credit points secured by a student in various courses registered in a semester and the total course credits taken during that semester. It shall be expressed up to two decimal places. If C_i = credit point in the ith course/paper and G_i = grade point obtained by a student in the ith course/paper then the grade point average in the ith Semeter ie SGPA is given by $S_i = \frac{\sum C_i G_i}{\sum C_i}$.

Cumulative Grade Point Average (CGPA): It is a measure of overall cumulative performance of a student over all semesters. The CGPA is the ratio of total credit points secured by a student in various courses in all semesters and the sum of the total credits of all courses in all the semesters. It is expressed up to two decimal places. If S_i = Semester Grade point average in the ith Semeter and S = total number of semesters in the program, then the cumulative grade point average ie CGPA scored by the student is given by $C = \frac{\sum S_i}{\sum S}$.

Grade Sheet/Report: Based on the grades earned, a grade certificate shall be issued to all the registered students after every semester. The grade certificate will display the course details (code, title, number of credits, grade secured) along with SGPA of that semester and CGPA earned till that semester.

LISTS OF COURSES

CC :: Core Course/Papers [For Degree with Physics (Major), 3 years UG program]

1. PHY1104C : **Mechanics & Properties of Matter** (**Level**: 100-199)
2. PHY2104C : **Wave & Optics** (**Level**: 100-199)
3. PHY3104C : **Mathematical and Computational Physics** (**Level**: 200-299)
4. PHY3204C : **Heat & Thermodynamics** (**Level**: 200-299)
5. PHY4104C : **Electricity & Magnetism** (**Level**: 200-299)
6. PHY4204C : **Quantum Mechanics & Applications** (**Level**: 200-299)
7. PHY4304C : **Ancient Indian Astronomy** [course based on Indian Knowledge System] (**Level**: 200-299)
8. PHY5104C : **Electronics & Network Analysis** (**Level**: 300-399)
9. PHY5204C : **Classical & Relativistic Mechanics** (**Level**: 300-399)
10. PHY5304C : **Atomic & Nuclear Physics** (**Level**: 300-399)
11. PHY5404C : **Research Methodology**
12. PHY6104C : **Condensed Matter Physics** (**Level**: 300-399)
13. PHY6204C : **Statistical Physics** (**Level**: 300-399)
14. PHY6304C : **Electromagnetic Theory** (**Level**: 300-399)
15. PHY6404C : **Project** (**Level**: 300-399)

SEC :: Skill Enhancement Course/Papers

1. PHY1103SE : **Digital Photography and Editing Skills**
2. PHY2103SE : **Graphic design Skills for Digital Advertising**
3. PHY3103SE : **Video editing Skills**

IDC :: Interdisciplinary Course/Papers [Offered to the students of **other discipline**]

1. PHY1103ID : **Renewable Energy and Energy Harvesting**
2. PHY2103ID : **Weather Forecasting**
3. PHY3103ID : **Ancient Astronomy**

CC :: Core Course/Papers [Additional Core Courses for degree with Physics (Honours) & Physics (Honours with Research)]

1. PHY7104C : **Advanced Mathematical Physics** (**Level**: 400-499)
2. PHY7204C : **Astronomy & Astrophysics** (**Level**: 400-499)
3. PHY7304C : **Advanced Quantum Mechanics** (**Level**: 400-499)
4. PHY7404C : **Electrodynamics** (**Level**: 400-499)
5. PHY8104C : **Laser & Spectroscopy** (**Level**: 400-499)
6. PHY8204C : **Experimental Techniques** (**Level**: 400-499)
7. PHY8304C : **Plasma Physics** (**Level**: 400-499)

8. PHY8404C : **Nano Physics** (**Level**: 400-499)

Research Project [For Physics (Honours with Research)]

1. PHY8512C : **Research Project** : In lieu of PHY8204C, PHY8304C, PHY8404C a, **Research Project** of Credit 12 has to be choosen for degree, Physics(Honours) with Research

Minor Courses/Papers (For students from other discipline)

1. PHY1104M : **Introduction to Mechanics & Properties of Matter** (**Level**: 100-199)
2. PHY2104M : **Introduction to Wave & Optics** (**Level**: 100-199)
3. PHY3104M : **Mathematical Physics** (For Single Major) (**Level**: 200-299)
4. PHY3204M : **Thermal Physics** (Additional Course to be chosen for Double Major along with PHY3104M) (**Level**: 200-299)
5. PHY4104M : **Electricity & Magnetism** (For Single Major) (**Level**: 200-299)
6. PHY4204M : **Fundamentals of Quantum Mechanics** (Additional Course to be chosen for Double Major) (**Level**: 200-299)
7. PHY5104M : **Elements of Electronics & Network Analysis** (For Single Major) (**Level**: 200-299)
8. PHY5204M : **Classical & Relativistic Mechanics** (Additional Course to be chosen for Double Major) (**Level**: 200-299)
9. PHY5304M : **Atomic & Nuclear Physics** (Additional Course again to be chosen for Double Major along with PHY5104M & PHY5204M) (**Level**: 200-299)
10. PHY6104M : **Condensed Matter Physics** (For Single Major) (**Level**: 200-299)
11. PHY6204M : **Statistical Physics** (Additional Course to be chosen for Double Major) (**Level**: 200-299)
12. PHY6304M : **Electromagnetic Theory** (Additional Course again to be chosen for Double Major along with PHY6104M & PHY6204M) (**Level**: 200-299)
13. PHY7104M : **Higher Level Mathematical Physics** (For Single Major) (**Level**: 300-399)
14. PHY7204M : **Astronomy & Astrophysics** (Additional course to be chosen for Double Major) (**Level**: 300-399)
15. PHY8104M : **Modern Optics** (For Single Major) (**Level**: 300-399)
16. PHY8204M : **Experimental Techniques** (Additional Course to be chosen for Double Major) (**Level**: 300-399)

Course Structure for BSc Physics (H) under FYUGP

Semester	CC 1	CC 2	AEC	SEC	IDC	VAC	Internship
SEM 1	Mechanics & Properties of Matter	To be chosen from other department like Chemistry or Mathematics*	A common course of Cr-2	Digital Photography & Editing Skills	To be chosen from other department	A common course of Cr-2	N/A
SEM 2	Wave & Optics	To be chosen from other department like Chemistry or Mathematics*	A common course of Cr-2	Graphic design Skills for Digital Advertising	To be chosen from other department	A common course of Cr-2	N/A

To **EXIT** with a Certificate after one year, a mandatory VOC of credit 4 has to be chosen or Proceed to the 2nd year.

Semester	Major/CC	Minor	AEC	SEC	IDC	VAC	Internship
SEM 3	Mathematical and Computational Physics I Heat & Thermodynamics	Course from Chemistry or Mathematics**	A commonly designed course of Cr-2	Video editing Skills	To be chosen from other department	A commonly designed course of Cr-2	N/A
SEM 4	Electricity & Magnetism Quantum Mechanics & Applications Ancient Indian Astronomy	Course from Chemistry or Mathematics**	A commonly designed course of Cr-2	N/A	N/A	N/A	Has to be engaged in an summer internship of Cr-2

To **EXIT** with a Diploma after one year, a mandatory VOC of credit 4 has to be chosen or Proceed to the 3rd year.

Semester	Major/CC	Minor	AEC	SEC	IDC	VAC	Internship
SEM 5	Electronics & Network Analysis Classical & Relativistic Mechanics Atomic & Nuclear Physics Research Methodology	Course from Chemistry or Mathematics**	N/A	N/A	N/A	N/A	N/A
SEM 6	Condensed Matter Physics Statistical Physics Electromagnetic Theory Project	Course from Chemistry or Mathematics**	N/A	N/A	N/A	N/A	N/A

EXIT Option with a Bachelor degree after three years or Proceed to the 4th year.

Semester	Major/CC	Minor	AEC	SEC	IDC	VAC	Internship
SEM 7	Advanced Mathematical Physics Astronomy & Astrophysics Advanced Quantum Mechanics Electrodynamics	Course from Chemistry or Mathematics**	N/A	N/A	N/A	N/A	N/A
SEM 8	Laser & Spectroscopy Experimental Techniques Plasma Physics Nano Physics In lieu of Experimental Techniques, Plasma Physics & Nano Physics a **Research Project** of Cr-12 may also be chosen	Course from Chemistry or Mathematics**	N/A	N/A	N/A	N/A	N/A

Completion of Bachelor degree with Honours/ with Honours with Research

* For Physics students it is suggestive that the other core course should be taken as Mathematics

** Whatever is the other core course opted in Sem I & Sem II that course is to be carried on subsequent semesters as minor.

CC :: CORE Courses/Papers

PHY1104C : Mechanics & Properties of Matter

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: The objective of this course is to introduce the students to the world of mechanics and properties of matter that exists in different phases ie solid liquid and gas. Laws of motion and its application to various systems studied in this paper is of fundamental in nature and will enable the students to handle different types problems which prerequisites for many advances courses in physics and chemistry.

Course Outcome: Learner will be able to apply the equation of motion to one or two dimensions of the system in order to understand kinematics of the body under the various conditions of applied force along with ability to apply knowledge in understanding the various properties of solids and flow of liquids.

Theory Part

Section I : Laws of Motion *(Lectures 12)*

Frames of reference. Newton's Laws of motion. Dynamics of a system of particles. Centre of Mass. Conservation of momentum. Work and energy. Conservation of energy. Motion of rockets. Angular velocity and angular momentum. Torque. Conservation of angular momentum. Moment of inertia, Parallel and Perpendicular axis theorem (no proof required).

Section II : Gravitation *(Lectures 12)*

Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution, Kepler's Laws.

Section III : Elasticity *(Lectures 11)*

Hooke's law - Stress-strain diagram - Elastic moduli-Relation between elastic constants - Poisson's Ratio Expression for Poisson's ratio in terms of elastic constants – Work done in stretching and work done in twisting a wire - Twisting couple on a cylinder - Determination of Rigidity modulus by static torsion - Torsional pendulum-Determination of Rigidity modulus and moment of inertia $-q$, η and σ by Searles method.

Section IV : Fluid Mechanics *(Lectures 10)*

Viscosity, Stoke's law, Streamline, Turbulent motion of fluids, Derivation of Poiseulle's Equation, Effect of temperature on viscosity, Bernoulli's theorem, Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.

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) Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
4) Analytical Mechanics, G. R. Fowles and G. L. Cassiday. 2005, Cengage Learning.
5) Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.
6) University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
7) Mechanics, D. S. Mathur, S. Chand and Company Limited, 2000

Lab Part⋆

1. Measurements of length (or diameter) using a vernier calliper, screw gauge and Spherometer.
2. To determine the Moment of Inertia of a Symmetrical body about an axis by the torsional oscillation method.
3. To determine the Young's Modulus of the material of a wire by Searle's apparatus.
4. To determine the Modulus of Rigidity of a Wire Static method.
5. To determine the elastic Constants of a wire by Searle's method.
6. To determine the value of g using Bar Pendulum.
7. To determine the value of g using Kater's Pendulum.

⋆ Experiments will be allotted depending upon the availability of apparatus in each lab part.

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY2104C : Waves & Optics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course builds on the ideas of harmonic motion to cover in depth the concept of waves in physics with particular emphasis on light waves as an example. This will help the students to acquire skills to identify and apply formulas of optics, understand the properties of light like interference, diffraction and polarization and then to apply the skills to understand the resolving power of different optical instruments.

Course Outcome: Upon successful completion, students will have the knowledge and skills to Understand the role of the wave equation and appreciate the universal nature of wave motion in a range of physical systems by different phenomena like interference diffraction & polarisation etc

Theory Part

Section I : Wave Motion and its superposition *(Lectures 12)*

General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity. Linearity & Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency (1:2) and their uses.

Section II : Interference *(Lectures 11)*

Electromagnetic nature of light. Definition and Properties of wave front. Huygens Principle. Division of amplitude and division of wavefront. Young's Double Slit experiment. Lloyd's Mirror and Fresnel's Biprism. Newton's Rings: measurement of wavelength

Section III : Diffraction *(Lectures 11)*

Fresnel and Fraunhofer diffraction . Fresnel's Half-Period Zones for Plane Wave. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel diffraction at a straight edge. Fraunhofer diffraction due to a Single slit, Diffraction grating . Resolving power of a grating.

Section IV : Polarization *(Lectures 11)*

Transverse nature of light waves. Polarisation by reflection, Polarisation by refraction, Brewster's law, Malus law, Double Refraction, Huygen's theory of double refraction, Optic axis, Nicol Prism, Retarding Plates : Half wave plate & quarter wave plate, Production and Detection of Polarised light Plane, circular and elliptically polarized light

Reference Books

1) Fundamentals of Optics, F. A. Jenkins and H.E. White, 1981, McGraw-Hill

2) Optics, Ajoy Ghatak, 2008, Tata McGraw Hill

3) The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

4) The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.

5) Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.

Lab Part⋆

1. To determine the Frequency of an Electrically Maintained Tuning Fork by Melde's Experiment and to verify λ^2 -T Law.
2. To determine the focal length of a convex mirror with the help of convex lens .
3. To determine the refractive index of a liquid by using plane mirror and convex lens.
4. Familiarization with Schuster's focussing; determination of angle of prism.
5. To determine the Refractive Index of the Material of a Prism using Sodium Light.
6. To determine wavelength of sodium light using Newton's Rings.

⋆ Experiments will be allotted depending upon the availability of apparatus in each lab part.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY3104C : Mathematical and Computational Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This part of the course builds on the Essential Mathematics module to develop further mathematical skills as an aid to understanding and exploring physics concepts. The computational part of the course consists of a series of assessed exercises, with classroom support, with an intend to develop their logical understanding problem solving skills.

Course Outcome: The students will have the understanding of basic and advanced mathematical tools required for Physics Problems and will also develop computational problem solving skills, and link in with the mathematics covered elsewhere.

Theory Part

Section I : Vector Calculus *(Lectures 13)*

Revision: 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. Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Ordinary Integrals of Vectors. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes' Theorems and their applications.

Section II : Ordinary Differential Equations *(Lectures 12)*

First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Wronskian and general solution.Exact and inexact differentials. Integrating factor, with simple illustration. Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Hermite Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Solutions to PDE, using separation of variables: Wave equation & Diffusion Equation.

Section IV : Matrix *(Lectures 10)*

Properties of matrices, Special type of matrices with their properties: Transpose matrix, complex conjugate matrix, Hermitian matrix, Anti-Hermitian matrix, special square matrix, unit matrix, diagonal matrix, symmetric matrix, antisymmetric matrix, unitary matrix, orthogonal matrix, trace of a matrix, inverse matrix. Determinant, Eigen value, Eigen vector and diagonalisation of matrix. Cayley-Hamilton's theorem

Section IV : Curvilinear Coordinates & Special Integrals *(Lectures 10)*

Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. Definition of Dirac delta function & its Properties. Beta and Gamma Functions and Relationship between them. Expression of Integrals in terms of Gamma Functions.

Reference Books

1) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, and F. E.. Harris, 2013, 7th Edn., Elsevier.

2) An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI

3) Learning Differential Equations, George F. Simmons, 2007, McGraw Hill.

4) Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book

5) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge University Press

Lab Part

1) Review of Python Programming Introduction to Python Language, Python Language Syntax, Python Keywords and Identifiers, Python Variables, Data Types, Operators, Variables, Basic Operators, Boolean Values, Conditional Execution, Loops, Lists etc

2) Programs Sum & average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order

3) Random number generation Area of circle, area of square, volume of sphere, value of pi (π)

4) Numerical Integration (Trapezoidal and Simpson rules), for a given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop

5) Solution of Ordinary Differential Equations (ODE) First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods First order differential equation (a) Radioactive decay (b) Newton's law of cooling.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY3204C : Heat & Thermodynamics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course aims to provide a good platform to the physics students to understand, model and appreciate concept of dynamics involved in thermal energy transformation along with the understanding of thermodynamic fundamentals before applying them to other allied fields.

Course Outcome: To appreciate concepts learnt in fundamentals laws of thermodynamics from which learning ideas how to sustain in energy crisis and think beyond curriculum in the field of alternative and renewable sources of energy.

Theory Part

Section I :Distribution of Velocities *(Lectures 11)*

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds, Maxwell's mean free path

Section II : Real Gases *(Lectures 11)*

Behaviour of Real Gases, Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States, The Virial Equation

Section III : Laws of Thermodynamics *(Lectures 12)*

Zeroth Law of Thermodynamics & Concept of Temperature, First Law of Thermodynamics, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature

Section IV : Entropy *(Lectures 11)*

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of En- tropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero. Maxwell's thermodynamic relations and their applications

Reference Books

1) Heat and Thermodynamics, M. W. Zemansky, Richard Dittman, 1981, McGraw-Hill.

2) A Treatise on Heat, Meghnad Saha, and B. N.Srivastava, 1958, Indian Press

3) Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill

4) Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa. 5) Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

Lab Part

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY4104C : Electricity & Magnetism

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: To develop the knowledge about Fundamental laws and concepts in electricity and magnetism along with a conception of space and time adequate for understanding electrodynamics along with the training for problem-solving skills.

Course Outcome: The candidate should among other things will have especially with regard to Maxwells laws- Electrical circuits with the most common components with the abilty to perform quantitative calculations in situations involving electric and magnetic fields, and demonstrate knowledge of the relevant basic units, vector addition, and application of basic calculus. Students will be able to assess answers to questions for plausibility.

Theory Part

Section I :Electric Field and Electric Potential *(Lectures 11)*

Electric field: Electric field lines. Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a Parallel-plate capacitor, isolated conductor. Solution of Laplace's equations in Cartesian & spherical co-ordinates. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere.

Section II : Dielectric Properties of Matter *(Lectures 11)*

Electric Field in matter. Polarization, Polarization Charges. Types of polarization :(1) Electric polarization, (2) Ionic polarization, (3) Orientation polarization (4) Space charge polarization and Calculation of their polarizabilty, Clausius-Mossoti equation, Dielectric loss, Electrical Susceptibility and Dielectric Constant, Frequency Dependence of dielectric constant. Capacitor(parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss' Law in dielectrics.

Section III : Magnetic Field *(Lectures 12)*

Magnetic Force on a point charge, definition and properties of magnetic field B. Biot-Savart's law and its simple application: straight wire and circular loop. Magnetic Force on a current carrying wire. Torque on a current loop in a uniform magnetic field. Ballistic Galvanometer. Curl and Divergence of magnetic field. Ampere's circuital law and its application to Solenoid and Torus. Vector potential A. Current loop as a magnetic dipole and its dipole moment. Magnetization vector (M), Magnetic Intensity (H). Magnetic Susceptibility and permeability. Relationship among B, H and M.

Section IV : Electromagnetism and AC Circuits *(Lectures 11)*

Faraday's Law. Lenz's Law. Self-Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge conservation and Displacement current. AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: Resonance, Power Dissipation, Quality Factor, and Band Width. Parallel LCR Circuit.

Reference Books

1) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
2) Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
3) Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
4) Elements of Electromagnetics, M. N. O. Sadiku, 2010, Oxford University Press.
5) Electricity and Magnetism, J. H. Fewkes & J. Yarwood. Vol. I, 1991, Oxford Univ. Press.

Lab Part

1) Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2) To study the characteristics of a series RC Circuit.
3) To determine an unknown Low Resistance using Potentiometer.
4) To determine an unknown Low Resistance using Carey Foster's Bridge.
5) To compare capacitances using DeSauty's bridge.
6) Measurement of field strength B and its variation in a solenoid (determine $\frac{dB}{dx}$).
7) To determine self inductance of a coil by Anderson's bridge.

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY4204C : Quantum Mechanics & Application

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: The main objective of this course is to make students aware about the basic formulations in quantum mechanics how the evolution of the microscopic physical systems occurs and its connection to actual observables.

Course Outcome: After taking this course students will be able to appreciate the beauty of quantum mechanics which plays an important role in the microscopic world while measuring the observables with a statistical interpretation.

Theory Part

Section I :Quantum Theory and Blackbody Radiation *(Lectures 12)*

Quantum theory of light; photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. group and phase velocities and relation between them. Two-slit experiment with electrons. Probability. wave amplitude and wave functions.

Section II : Uncertainty and Wave-Particle Duality *(Lectures 10)*

Position measurement : gamma ray microscope thought experiment; wave-particle duality, Uncertainty principle (Uncertainty relations involving Canonical pair of variables): Derivation from wave packets, impossibility of a particle following a trajectory; estimating minimum energy of a confined particle using uncertainty principle; energy-time uncertainty principle- application to virtual particles and range of an interaction.

Section III : Schrödinger Equation *(Lectures 12)*

Two slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Schrödinger equation for non- relativistic particles; momentum and energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; probability and probability current densities in one dimension.

Section IV : One-dimensional Box and Step Barrier *(Lectures 11)*

One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; quantum dot as example; quantum mechanical scattering and tunnelling in one dimension-across a step potential and rectangular potential barrier.

Reference Books

1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.

2) Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill

3) Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.

4) Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.

5) Modern Physics, G. Kaur and G. R. Pickrell, 2014, McGraw Hill

6) Quantum Mechanics: Theory & Applications, A. K. Ghatak & S. Lokanathan, 2004, Macmillan

Lab Part

1) Measurement of Planck's constant using black body radiation and photo-detector.

2) Photo-electric effect Photo current versus intensity and wavelength of light; maximum energy of photo- electrons versus frequency of light.

3) To determine work function of material of filament of directly heated vacuum diode.

4) To determine the Planck's constant using LEDs of at least 4 different colours.

5) To determine the wavelength of H-α emission line of hydrogen atom.

6) To determine the value of e/m by (a) magnetic focusing or (b) bar magnet.

7) To show the tunneling effect in tunnel diode using IV characteristics.

8) To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY4304C : Ancient Indian Astronomy

Total lectures : 60(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: This introductory course on ancient Indian astronomy for the students that aims to provide a functional understanding of how astronomy and mathematical ideas and techniques, starting from the Vedic period was practised in ancient India, around tenth century CE.

Course Outcome: At end of this course students will come to know the evolution and growth of Astronomy along with some ancient cultures on Indian subcontinentthrough ages.

Theory Part

Section I : Basics of Positional Astronomy *(Lectures 15)*

Algorithms for determining geocentric longitudes of the planets ' determination of direction and place (latitude of the observer) ' finding time from shadow measurements ' computation of exact moment of conjunction/opposition of sun and moon ' elevation of the cusps of the moon, The solar system and the markers in the sky, sun, planets and the moon, features and the coordinate systems, precision of the equinox and its effects, *grahanas* (eclipses), *dhumketu* (comets) and meteors.

Section II : Pre Siddhaantic astronomy *(Lectures 15)*

Pre Vedic, Vedic and Vedaanga periods, *Ra'si* and Naksatra divisions of ecliptic ' Concept of time 'its division based on solar and lunar reckoning, 5 year *Yuga* system; *ayanas*, months; *tithis* and seasons; time units; sun and moon's motion; *nakshatra* system; *Vedaanga Jyotish.*

Section III : Siddhaantic astronomy *(Lectures 15)*

Important siddhaantic astronomers – Aryabhatta I, Varahamihira, Brahmagupta, Bhaskar and others; interaction with Greek astronomy – 7 day week syatem and the Zodiacal signs; *Yuga*, *Mahayuga* and *Kalpa* system and epochs; determination of *ahargana*, *tithi* and *nakshatra*; mean motion of the sun, moon and planets; corrections to find out true positions; *ayanachalana* and zero-precision year; alphabetical representation of numbers and Katapayaadi system.

Section IV : Astronomy in medieval India *(Lectures 15)*

Interaction with west Asian astronomy; Zij astronomy in medieval India; Astrolabes and armillary spheres; instruments for naked-eye astronomy; Jai Singh and his observatories; late siddhaantic astronomy and Samanta Chgandra Sekhar

Reference Books

1) "Astronomy", Vol I Part 2 of "History of Science in India", by Amitabha Ghosh, The National Academy of Sciences India and Rama Krishna Mission Institute of Culture, Gol Park,Kolkata, 2014

2) "Indian Astronomy-An Introduction" by S.Balachandra Rao, Universities Press, 2000

3) Dr.S.Balachandra Rao, "Indian Mathematics and Astronomy", Landmarks Publisher, Revised 3rd Edition, 2012.

4) "Bharatiya Jyotishs Sastra" by Shankar Balakrishna Dixit (Eng Translation), India Meteorological Department, New Delhi,1968

5) Chander Mohan "The story of Astronomy in India" Editor: I Pyblisher, 2015.

PHY5104C : Electronics & Network Analysis

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course provides the student with the fundamental skills to understand the basic of semiconductor and components like diodes, transistors and operational amplifiers, logic gates and their usage in digital circuits. It will build mathematical and numerical background for design of electronics circuit & component value.

Course Outcome: Students equipped with the knowledge and training provided in the course will be able to participate in design , development and operation in the different area of electronics system .

Theory Part

Section I :Network Theorems and Transistor and Amplifiers *(Lectures 12)*

Ideal voltage and current Sources. Thevenin theorem, Norton theorem, Maximum Power Transfer theorem. CB, CE and CC Configurations of Transistors. Current gains α and β. Transistor Biasing Circuits - Base Bias, Fixed Bias, Emitter Bias, Voltage Divider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of RC-coupled amplifier and its frequency response.

Section II : Oscillators and OPAMPS *(Lectures 11)*

Positive and Negative Feedback. Advantages of Negative Feedback (Qualitative). Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator. Differential Amplifier and OPAMP. Characteristics of an Ideal OPAMP. Offset Voltage and Current. CMRR. Applications of OPAMP as (1) Inverting amplifier, (2) Non-inverting amplifier, (3) Adder, (4) Differentiator, (5) Integrator.

Section III : Introduction to Digital Algebra *(Lectures 12)*

Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD. Binary Addition. Binary Subtraction using 2's Complement. Digital Logic Gates (AND, OR, NOT, NAND. NOR, XOR, XNOR). Laws of Boolean Algebra. De Morgan's Theorems. Idea of Minterms and Maxterms. Minimization with Karnaugh Map Method (up to four variables). Design Procedure – Half Adder, Full Adder, Half Subtractor, Full Subtractor.

Section IV : Data Processing Circuits *(Lectures 10)*

Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders. SR, JK, MSJK, D and T Flip-Flops. SISO, SIPO, PISO and PIPO Shift Registers (up to 4-bit). Asynchronous counter, Synchronous Counter, Decade Counter (up to 4-bit).

Reference Books

1) Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, Tata McGraw

2) Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.

3) Digital Electronics G. K. Kharate ,2010, Oxford University Press

4) Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer, 2001, PHI Learning

5) Logic circuit design, Shimon P. Vingron, 2012, Springer.

6) Microprocessor Architecture Programming & applications with 8085, 2002, R. S. Goankar, Prentice Hall.

Lab Part

1) To design a switch (NOT gate) using a transistor.

2) To verify and design AND, OR, NOT and XOR gates using NAND gates.

3) Half Adder, Full Adder and 4-bit binary Adder.

4) Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder IC.

5) To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.

6) To build JK Master-slave flip-flop using Flip-Flop ICs .

7) To design an inverting amplifier using Op-amp (741/351) for dc voltage of given gain .

8) To design inverting amplifier using Op-amp (741/351) and study its frequency response.

9) To design non-inverting amplifier using Op-amp (741/351) & study its frequency response.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY5204C : Classical & Relativistic Mechanics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This part of the course is introduced to understand the Lagrangian & Hamiltonian Approach formulation of Newtonian mechanics. Then to realize the reduction of a two-body problem to a one-body problem in a central force system and to study the behaviour of systems under extremely high speed.

Course Outcome: Upon successful completion of this course it is intended that a student will be able to understand about the alternate approach to the Newtonian mechanics and the fascinating facts derived from special theory of relativity.

Theory Part

Section I :Central Force Problem & Newtonian Mechanics *(Lectures 12)*

Central force motion, two body central force motion, two body motion as a one body problem, general properties of central force motion, Application of central force problem to motion under inverse square force field (e.g. Keplerian motion). Differential equation of orbit, nature of the orbits as hyperbolic, parabolic, elliptic and circular. Energy equation involving only the radial motion, energy diagram and nature of orbits.

Section II : Lagrangian Mechanics *(Lectures 12)*

Constraints, generalized co-ordinates, generalised force, principle of virtual work, D' Alembert's principle, Lagrange equations from D' Alembert's principle, cyclic coordinates and conservation theorem. Applications of Lagrangian formulation in (i) simple pendulum (ii) compound pendulum, (iii) Keplerian motion

Section III : Hamiltonian Mechanics *(Lectures 11)*

Hamilton's principle as a fundamental principle, Lagrange equations from Hamilton's principle, significance of Hamilton's principle. Hamiltonian of a system, Physical meaning of Hamiltonian, Hamilton's canonical equations of motion, Applications of Hamiltonian formulation in (i) simple pendulum (ii) compound pendulum, (iii) Keplerian motion

Section IV : Special theory of Relativity *(Lectures 10)*

Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Relativistic Kinematics, Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Twin paradox, Relativistic force law, Relativistic transformation of velocity. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect.. Transformation of Energy and Momentum.

Reference Books

1) Classical Mechanics, S.N. Biswas (Books and Allied (P) Ltd).

2) Classical Mechanics, H. Goldstein (Narosa Publishing House).

3) An Introduction to Mechanics, Kleppner and Kolenkow (Tata McGraw- Hill).

4) Introduction to Classical Mechanics, Takwale and Puranik (Tata McGraw-Hill).

5) Classical Mechanics A modern Perspective, Barger & Olsson (McGraw Hill International).

6) Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.

Lab Part

1) Python Program to Model a simple pendulum using (a) Lagrangian mechanics, (b) Hamiltonian mechanics

2) Python Program to Model a compound pendulum using (a) Lagrangian mechanics, (b) Hamiltonian mechanics

3) Python Program to Model a double pendulum using (a) Lagrangian mechanics, (b) Hamiltonian mechanics

4) Exploration of relativistic phenomenon using EinsteinPy

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY5304C : Atomic & Nuclear Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: Students completing this module should be able to describe the structure of the atom, the constituents of the nucleus, some basic terms. It has been the intend also, to familirize the behaviour of atoms under fundamental forces & nuclear decay schemes. Also to give the basic idea about particle accelerators & detectors.

Course Outcome: Upon successful completion of this course the atomic physics part of this course is to provide a comprehensive introduction to atomic structure allowing one to understand atomic spectra, the behaviour of angular momentum in quantum mechanical systems, understanding of the period table of elements and many-electron atoms along with nuclear unstabilities, models and nuclear instruments.

Theory Part

Section I : Atomic Models *(Lectures 12)*

Rutherford's nuclear atom model, α- scattering expt; deduction of the scattering formula. Atomic spectra: Bohr's theory of hydrogen spectra; energy level diagram; Pauli's exclusion principle, Ritz combination principle; resonance, excitation, critical and ionization potentials; fine structures of the spectral lines; Hund's rule of maximum multiplicity, Aufbau Principle, Electronic configuration, Sommerfeld's extension of the Bohr's theory. Vector Atom model: Spin-orbit coupling in atoms: LS and JJ couplings. Term symbols, Spectra of Hydrogen and Alkali Atoms (Na etc.)

Section II : Atoms in Electric & Magnetic Fields *(Lectures 11)*

Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. Zeeman Effect: Normal and Anomalous Zeeman Effect. Paschen-Back Effect and Stark Effect (Qualitative Discussion only).

Section III : Nuclear Structure, Models & Radioactivity *(Lectures 12)*

Brief review of Size and structure of atomic nucleus, nature of nuclear force, N-Z graph, liquid drop model: semi-empirical mass formula and binding energy, nuclear shell model (qualitative discussions) and magic numbers. Alpha decay, impossibility of an electron being in the nucleus, β decay energy released, spectrum and Pauli's prediction of neutrino. Gamma ray emission, Cause of alpha decay, basic α-decay process, range and energy of α-decay, Geiger Nuttle rules, Qualitative discussion on the Gamow's theory of α-decay, Conditions of β^+ & β^-- decay and K- capture, γ-rays and their origin and interaction with matter.

Nuclear Reactions: Types of nuclear reactions, Q-value of nuclear reactions, Direct reactions, Compound nucleus formation process.

Section IV : Nuclear Accelerators & Detectors *(Lectures 10)*

The necessity of charge particle acceleration – construction and working principle of linear accelerator (LINAC). Construction and working principle of Cyclotron Detectors, Energy loss techniques by charge particles and by γ photons, Bethe-Bloch Equation, Construction and working principle of gas-filled detectors. Ionization chamber – its construction & working principle, Scintillation detectors NaI(Tl)

Reference Books

1) Atomic Physics - John Yarwood
2) Concept of Modern Physics - A. Beiser
3) Atomic and Nuclear Physics - S. N. Ghosal
4) Atomic Physics- J. B. Rajam
5) Introductory Nuclear Physics, 3^{rd} edition (Indian Adaptation), Kenneth, S. Krane

Lab Part

1) To determine the Planck's constant using LEDs of at least 4 different colours.
2) To determine the wavelength of H- α emission line of hydrogen atom.
3) To determine the ionization potential of mercury.
4) To determine the absorption lines in the rotational spectrum of iodine vapour
5) To determine the value of $\frac{e}{m}$ by (a) magnetic focusing or (b) bar magnet.
6) To setup the Millikan oil drop apparatus and determine the charge of an electron.

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY5404C : Research Methodology

Total lectures : 45(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: The main objective of this course is to introduce the basic concepts in research methodology in Physical science. This course addresses the issues inherent in selecting a research problem and discuss the techniques and tools to be employed in completing a research project. This will also enable the students to prepare report writing and framing Research proposals.

Course Outcome: By the end of the subject students should be able to demonstrate the ability to choose methods appropriate to research aims and objectives, skills in qualitative and quantitative data analysis and presentation, advanced critical thinking & writing skills.

Theory Part

Section I : Research Introduction & Design *(Lectures 12)*

Research: Meaning, Criteria of Good Research, Problem identification, formulation and evaluation , Research characteristics and types - Descriptive, Analytical, Applied, Fundamental, Conceptual, Empirical, Scientific reasoning-inductive and deductive, empirical and general method,, Comparison of fundamental research and action research. Meaning of Research Design: Need, Importantance, Concepts, Criteria of a good problem, Importance of literature review in defining a problem. Literature review – Primary and Secondary sources, Identifying gap areas from literature review, Development of working hypothesis : Testing methods Preparation of synopsis

Section II : Data Analysis *(Lectures 11)*

Data collection - Concept, importance and limitation of data, data types, data sources, data treatment, data representation, analysis (with statistical package), interpretation - Basic elements of modelling and stimulation, Data, Sampling - types and procedures

Section III : Scientific Writing *(Lectures 10)*

Steps to better writing, flow method, Structure and components of scientific reports preparation – Layout (Introduction, Review, Experiments, Results and Discussion, Conclusion and References), Structure and language of typical reports – Illustrations and tables, Bibliography, Referencing.

Section IV : IPR & Research Ethics *(Lectures 12)*

Introduction to IPR, Patent laws, process of patenting a research finding, copyright, cyber laws, Ethics: definition, moral philosophy, nature of moral judgements and reactions, Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconduct : Falsification, Fabrication and Plagiarism (FFP), Redundant publication: duplicate and overlapping publications, salami slicing, Selective reporting and misinterpretation of data

Reference Books

1) Kothari, CR. Research Methodology Methods and Techniques (New Age International Publishers, New Delhi, 2009).

2) Ackoff, Russell L. The Design of Social Research (Chicago Press, 1961).

3) Ackoff, Russell L. Scientific Method (New work: John Wiley & Sons, 1962.

4) Kuhn, T. (1962) : The Structure of Scientific Revolution, CUP, Chicago.

5) Garg, B. I., Karadla, R. , Agarwal, F. and Agarwal, G.K., An introduction to research methodology 2002., RBSA Publishers.

6) Wadehra, B. L., Law relating to Patents, Trademarks, Copywrite designs and Geographical indications, 2000, Universal Law Publishing.

7) Sidhu, K. S., Methodology of research in Education, 2018, Sterling Publishers (P) Ltd.

PHY6104C : Condensed Matter Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: Students completing this course should have the theoretical concepts of the condensed matter physics with the various aspects of the interactions effects. It's also aim to bridge the gap between basic solid state physics and quantum theory of solids along with the ability to solve the problems related to metal-insulator transition and superconductivity.

Course Outcome: Upon successful completion of this course students will be able to differentiate between different Lattice types and explain the concepts of reciprocal lattice and crystal diffraction. They will also be able to understand & explain various types of magnetic phenomenon, physics behind them, along with the properties, important parameters related to superconductivity, its possible applications.

Theory Part

Section I : Crystal Structure & Lattice Dynamics *(Lectures 12)*

Amorphous and Crystalline Materials. Lattice Translation Vectors. Symmetry operations, Lattice with a Basis Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor. 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. T^3 law.

Section II : Magnetic, Dielectric & Ferroelectric Properties of Matter *(Lectures 12)*

Dia, Para, Ferri, and Ferromagnetic Materials. Classical Langevin Theory of Dia and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of BH Curve. Hysteresis and Energy Loss. Polarization. Local Electric Field at an Atom. Electric Susceptibility. Polarizability. Clausius-Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

Section III : Free Electron Theory of Metals *(Lectures 11)*

Electrical and thermal conductivity of metals, Wiedemann-Franz law. Elementary band theory: Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (4-probe method) & Hall coefficient.

Section IV : Superconductivity *(Lectures 12)*

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. DC Josephson effect. AC Josephson effect. Inverse AC Josephson effect and Shapiro jumps. Superconducting quantum interference device (SQUID). Isotope effect and its significance. Attractive interaction and the formation of Cooper pairs. BCS wave function (detailed treatment not required) as a coherent wave function with a well-defined phase. Energy gap and experimental evidence.

Reference Books

1) Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
2) Elements of Solid State Physics, J. P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
3) Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning
4) Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
5) Solid State Physics, M. A. Wahab, 2011, Narosa Publications

Lab Part

1) Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method).
2) To determine the Coupling Coefficient of a Piezoelectric crystal.
3) To measure the Dielectric Constant of a dielectric Materials with frequency.
4) To study the PE Hysteresis loop of a Ferroelectric Crystal.
5) To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
6) To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150^o C) and to determine its band gap.
7) To determine the Hall coefficient of a semiconductor sample.

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY6204C : Statistical Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course extends the undergraduate thermal physics to a more advanced level so as to prepare the graduate students for the research literature on the subjects of modern statistical physics.

Course Outcome: By the end of the course, students will be able to converse with correct concepts of thermodynamics and statistical mechanics, understand statistics of particles and statistics of fields, perform mean field calculations, understand various (classical & quantum) models in statistical mechanics.

Theory Part

Section I : Classical Theory of Radiation *(Lectures 10)*

Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula. Rayleigh-Jean's Law. Ultraviolet Catastrophe.

Section II : Classical Statistics *(Lectures 12)*

Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, 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.

Section III : Quantum Theory of Radiation *(Lectures 11)*

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.

Section IV : Quantum Statistics *(Lectures 12)*

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. Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals.

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) Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer

Lab Part

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

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

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

4) Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at high temperature and low temperature.

5) 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.

6) Plot the following functions with energy at different temperatures (a) Maxwell-Boltzmann distribution (b) Fermi-Dirac distribution (c) Bose-Einstein distribution

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY6304C : Electromagnetic Theory

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course is designed to review the fundamentals and application of electromagnetic field theory. This course also enables the students to understand all Maxwell's equation in time varying field. In this course the students will also learn about Transmission line and reflection and refraction on plane as well oblique plane. The students will also be able to understand to solve real life problem related to electromagnetics

Course Outcome: At the end of the course the student should be able to illustrate the physical concepts of static electric & magnetic fields, Apply the maxwell equations to solve problems in electromagnetic field theory, Analyze the propagation of wave in different media and features of fibre optics.

Theory Part

Section I : Maxwell Equations *(Lectures 11)*

Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density.

Section II : EM Wave Propagation in Bounded & Unbounded Media *(Lectures 12)*

Boundary conditions 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 cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere.

Section III : Polarization of Electromagnetic Waves *(Lectures 11)*

Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Analysis of Polarized Light.

Section IV : Wave guides & Optical Fibres *(Lectures 11)*

Wave Guides: Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission. Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibres, Properties of TEM, TE and TM modes in waveguides (Concept and Definition Only).

Reference Books

1) Introduction to Electrodynamics, D. J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2) Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.
3) Introduction to Electromagnetic Theory, T. L. Chow, 2006, Jones & Bartlett Learning
4) Electromagnetic field Theory, R. S. Kshetrimayun, 2012, Cengage Learning

Lab Part

1) To verify the law of Malus for plane polarized light.
2) To determine the specific rotation of sugar solution using Polarimeter.
3) To analyze elliptically polarized Light by using a Babinet's compensator.
4) To study the reflection, refraction of microwaves.
5) To study Polarization and double slit interference in microwaves.
6) To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
7) To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY6404C : Project

Total lectures : 120 (P) **Credits : 4 (Theory: 00, Lab: 04)**

Course Objective: The aim of this course is to inculcate scientific bent of mind and attitude relevant to science such as concern for efficiency, accuracy and precision, objectivity, integrity, enquiry, effective communication, ethical responsibilities, Initiative and Inventiveness.

Course Outcome: At the end of the course the student will get the flavour of the opportunity to pursuing high end research by making the students technically and analytically skilled.

The Project work is divided into three parts :

1. Theoritical Essay or Educational Tour Reports
2. Preparation of the working Model
3. Presentation or Viva

General Information to the students :

• Each students has to prepare one detailed essay based on any topic from below (suggestive) which should include the principles of physics or based on any theory of physics or application of physics. If the project requires an educational tour they have to submit a detailed report of that tour also.

• If the project requires a working model, students have to prepare the same explaining the principle , working and application of the same.

• The project work can be chosen by a group (Maximum of three students in a group) or can also be perfomed by an indivisual. However, the project report has be submitted separetely by each and every one.

• The project-in-charge will extend guidance in preparation/troubleshooting of the working model or in presenation of the same.

• The project work will be evaluated by external/faculty members of the department based on the presenation of the report by the students and conducting viva voce on the same in Research Project 8512C

Suggestive Project Titles :

1) Design And Construction Of An Antenna Booster
2) Possible Effects Of Electromagnetic Fields (Emf) On Human Health
3) The Design And Construction Of The Hearing Aid Device
4) Design And Construction Of Digital Distance Measuring Instrument
5) Construction And Application Of Heat Sensor
6) Construction Of A Module Of Zener Diode
7) Design And Construction Of A Micro-Controller Based Automatic Fire Extinguishing System
8) Design And Construction Of A Ceiling Fan Remote Control
9) Design Of Sun Tracker For A Pv System
10) The Phenomenology Of Jets In Astrophysics
11) The Physics Of Stars And Their Astronomical Identification

Note : Students can also choose other topics from allied sciences as deem fit.

PHY7104C : Advanced Mathematical Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: The course aims to demonstrate the utility and limitations of a variety of powerful calculational techniques and to provide a deeper understanding of the mathematics underpinning theoretical physics.

Course Outcome: The students will be able to give mathematical form to the laws of physics. They will be able to apply abstract concepts of pure mathematics to the concrete problems of Nature.

Theory Part

Section I : Linear Vector Spaces *(Lectures 10)*

N -dimensional linear vector space, orthonormal basis, Inner product, Hilbert space, Gram-Schmidt orthonor- malisation, outer product. Linear operators and their algebra, matrix representation of operators, similarity transformation, diagonalisation of Hermatian, symmetric, complex and complex symmetric matrices, Cayley- Hamilton theorem.

Section II : Integral Transform *(Lectures 12)*

Fourier Transform (FT), FT of trigonometric functions, FT of derivatives, Inverse FT, Convolution theorem (Statement only). Properties of FTs (translation, change of scale, complex conjugation). Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. Inverse LT. Application of Laplace Transforms to 2nd order Differential Equations: Damped Harmonic Oscillator.

Section III : Tensor Algebra & Calculus *(Lectures 12)*

Introduction to tensor, Transformation of co-ordinates, Einsteins summation convention. contravariant and co- variant tensor, tensorial character of physical quantities, symmetric and antisymmetric tensors, kronecker delta, Levi-Civita tensor. Quotient law of tensors, Raising and lowering of indices Rules for combination of tensors addition, subtraction, outer multiplication, contraction and inner multiplications. Transformation of coordinates: Galilean and Lorentz transformations. Tangent vectors and gradients. Metric tensor in different curved spaces.

Section IV : Group theory *(Lectures 11)*

Group axioms, permutation groups (S2 and S3) and symmetry operations of equilateral triangle, multiplication table, subgroup, classes, finite groups (Zn), direct and semi-direct products, block diagonalisation – reducible and irreducible representation. Infinite group, generators and their algebra, spin/ isospin invariance and SU(2) group, SO(3) group and its generators, Isomorphism..

Reference Books

1) Mathematical methods for physicists : Arfken and Weber

2) Mathematical Physics : P K Chattopadhyay

3) Mathematical Physics : B S Rajput

4) Matrices and tensors in Physics : A W Joshi

5) Mathematics for physicists : P Dennery and A Krzywick

6) Partial differential equations of Mathematical Physics : A G Webster

7) Differential equations and their applications : Zafar Ahsan

8) Mathematical Physics : A G Ghatak, I C Goyal and S J Chua

Lab Part

1) Python program for Gram-Schmidt orthonormalization process

2) Python program for finding eigen value, inverse of a matrix.

3) Python program for solution of linear equation.

4) Python program for Laplace transform and its property

5) Python program for Fourier transform and its property

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY7204C : Astronomy & Astrophysics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course has been designed with the aim to have a solid grounding in the underlying principles and important conceptual models from core subject areas of astronomy and physics and demonstrate their ability to correctly draw logical conclusions from these principles and models, enabling them to make accurate quantitative predictions in astronomical contexts.

Course Outcome: This part of the course contains introduction to the Basic concepts of Astronomy and techniques related to the observational astronomy. This forms the basic foundation, leading to the understanding of the basic physical principles of stars and stellar systems. This will help the students to realise the underlying principles of physics and their application in Astronomy & Astrophysics.

Theory Part

Section I : Astrophysical Co-ordinate *(Lectures 11)*

Celestial coordinate systems, The right Ascension, Declination and Altitude-Azimuth coordinate systems. The ecliptic and annual motion of the Sun across the sky the Signs of Zodiac. Identifications of the Constellations and bright stars.

Section II : Basics of Astronomy *(Lectures 12)*

Stellar Magnitude system and Distance measurement: The Stellar magnitude system and its relation with luminosity. Apparent and absolute magnitude and their relations with distances. Trigonometric and spectroscopic parallax to determine the distances. Difference magnitude systems. Spectral classification, color index, HD classification. The HR Diagram.

Section III : Stellar Evolution *(Lectures 11)*

Pre main sequence steller evolution and the evolutionary track of a star, Physics of Main Sequence stars, Low and high mass stars' post main sequence steller evolution and the evolutionary tracks, White Dwarf stars, Neutron stars and Black Holes (qualitative discussions only)

Section IV : Asteroids, Meteors, Comets & Galaxies *(Lectures 11)*

Asteroids: Discovery and designation, Origin, Nature and Orbits of Asteroids. Meteors : Meteor showers and sporadic meteors. Comets : Periodic comets, Brightness variation in Comets. Gas production rates, dust and ion tails. The Milky way, Hubble's morphological classification of galaxies, The tuning fork diagram -Spiral galaxies, Elliptical galaxies, Irregular galaxies, Dwarf galaxies, and their observational properties

Reference Books

1) Introduction to Astrophysics - H.L. Duorah & Kalpana Duorah

2) ASTRONOMY – a Self Teaching Guide - Dinah L. Moche

3) Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.

4) Astrophysics – Stars and Galaxies, K. D. Abhyankar, University Press, 2001.

5) Introduction to Stellar Astrophysics, Vol. 3 : Stellar structure and evolution -Erika Bohm-Vitense

6) Introduction to Astronomy & Cosmology by I. Morrison (Wiley, 2008)

Lab Part

1) Construction of a Galilean telescope.

2) Construction of a Newtonian telescope.

3) Measuring the size of the Sun

4) Measuring the size of the Moon

5) To study the azimuth of Sun by theodolite

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY7304C : Advanced Quantum Mechanics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: In this course you will learn about basic concepts and methods in non-relativistic quantum mechanics, such as Dirac notation, Hermitian operators, Hilbert spaces and the position and momentum representation which is an excellent base for further studies in physics on advanced level.

Course Outcome: The students will be able to calculate the probability of finding a particle at different locations. They will be able to solve the Schrdinger equation by approximate methods.

Theory Part

Section I : Basic principles of quantum mechanics *(Lectures 12)*

Essence of wave mechanics, physical interpretation of wave function, central potential, spherical harmonics and complete wave function (H-atom), angular momentum, matrix formulation of quantum mechanics, Bra and Ket vectors, their algebra and applications, orthonormality, completeness and closure, simultaneous eigenstates, expectation values, linear harmonic oscillator in operator method, Heisenberg's uncertainty principle using wave and matrix mechanics, Heisenberg's equation of motion and its physical equivalence with Schrdinger equation.

Section II : Indistinguishable and identical particles in quantum mechanics *(Lectures 10)*

Combinations of wave functions for a system of particles, symmetric and antisymmetric wave functions, spin- statistics connection, evolution of quantum statistics, exchange interaction and exchange energy.

Section III : Symmetry, invariance principle, and conservation *(Lectures 11)*

Space and time translations, rotational invariance under infinitesimal and finite rotations. Angular momentum operators, ladder operators, addition of angular momentum - Clebsch-Gordan coefficients.

Section IV : Approximation methods in quantum mechanics *(Lectures 12)*

Time independent perturbation theory, Stark and Zeeman effects, variational method and its applications, WKB approximation, time dependent perturbation theory, transition to continuum states, Fermi's Golden rule, adiabatic and sudden approximation.

Reference Books

1) Quantum mechanics - L. I. Schiff

2) Quantum Mechanics - S. N. Biswas

3) Quantum Mechanics - A. K. Ghatak and S. Lokanathan

4) Principles of Quantum Mechanics - R. Shankar

5) Quantum Mechanics: concepts and applications - N. Zettili

6) Quantum Mechanics by Mathew and Venkatasan

Lab Part

1) Solve the s-wave Schrödinger equation for the ground state and the first excited state of the hydrogen atom $\frac{d^2\psi}{dr^2} = \frac{2m}{\hbar^2}[V(r) - E]\psi$ for (a) Coulomb Potential, $V(r) = -\frac{e^2}{r}$ and $m = 0.5$ MeV/c^2, (b) screened Coulomb potential $V(r) = -\frac{e^2}{r}e^{\frac{-r}{a}}$ where $a = 3\mathring{A}$, $5\mathring{A}$ & $7\mathring{A}$ and (c) anharmonic potential $V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$ where $m = 940$ MeV/c^2 $k = 100$ MeV fm^{-2} , $b = 0$, 10, 30 MeV fm^{-3}. Obtain the energy eigenvalues and plot the corresponding wave functions. Take $e = 3.795$ (eV$\mathring{A}$), $\hbar c = 1973$ (eV$\mathring{A}$)

2) Study of electron spin resonance – determine magnetic field as a function of the resonance frequency.

3) Study of Zeeman effect – with external magnetic field; hyperfine splitting.

4) To show the tunneling effect in tunnel diode using I-V characteristics.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY7404C : Electrodynamics

Total lectures : 60(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: This course aims to bridge the gap between the fundamental principles taught in electromagnetism and its practical application to specific fields such as materials, physics, and chemistry related to energy storage and harvesting.

Course Outcome: The students will acquire advanced knowledge of electromagnetic fields. They will be able to investigate the collective behaviour of charged particles and their dynamics, which provides the basic working model of plasma.

Theory Part

Section I : Maxwell's equations - Potential formulation *(Lectures 15)*

Potential formulation of electrodynamics: electromagnetic potentials, gauge transformation, Lorentz and Coulomb gauge, gauge invariance, four-potential and four-current in Minkowski's formalism, covariant formulation of Maxwell's equations. Electrodynamics in tensorial notations: Transformation properties of electric and magnetic fields, electromagnetic field tensor and Maxwell's equations.

Section II : Lagrangian Formalism of Electrodynamics *(Lectures 15)*

Lagrangian Formulation of Electrodynamics: Lagrangian for a relativistic charged particle in an E.M. field, interaction between charged particles and fields. Energy-momentum tensor, conservation of energy- momentum.

Section III : Retarded Potentials and Radiation field *(Lectures 15)*

Retarded potential, radiation from oscillatory dipole, radiation fields, radiation from a point charge in motion, Lienard - Wiechart potential, fields of a point charge in motion, power radiated by a point charge, Larmor formula, Bremsstrahlung. Synchrotron radiation, Cherenkov radiation

Section IV : Scattering of EM waves *(Lectures 15)*

Scattering of e. m. waves due to free electrons, Thomson scattering, scattering from bound electrons, Rayleigh scattering and resonance fluorescence, dispersion- normal and anomalous.

Reference Books

1) Introduction to Electrodynamics - David J Griffiths
2) Foundation of Electromagnetic Theory - J R Reitz, F J Milford and R W Christy
3) Electricity and Magnetism - M H Nayfeh and M K Brussel
4) Classical Electrodynamics - J D Jackson
5) The Feynman Lectures on Physics Vol II

PHY8104C : Laser & Spectroscopy

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course has been designed to give the basic knowledge on spectroscopic techniques that use lasers and theoretical background on lasers and the interaction between laser radiation and matter. The course also provides knowledge of the techniques and instrumentation for laser spectroscopy.

Course Outcome: Student will be able to understand the physics behind electronic spectra and other associated phenomenon and also also come to know various principles along with types of Lasers which will in turn lead to laser spectroscopy.

Theory Part

Section I : Molecular spectra *(Lectures 12)*

IR spectra - Rotation, vibration and rotation-vibration spectra of diatomic molecules, selection rules, determi- nation of rotational constants. Electronic spectra: Born-Oppenheimer approximation, vibrational structure of electronic transition, progressions and sequences of vibrational bands, Intensity distribution, Franck Condon principle. Raman spectra: Classical theory of Raman effect, Vibrational Raman spectrum, selection rules, Stokes and anti-Stokes lines, Rotational Raman spectrum, selection rule.

Section II : Fluorescence spectra *(Lectures 10)*

Luminescence: fluorescence and phosphorescence, Jablonski diagram, Characteristics of fluorescence emission, Fluorescence lifetimes and Quantum Yields, Fluorescence anisotropy, Resonance energy transfer, Steady state and Time-resolved fluorescence, Molecular information from fluorescence.

Section III : Laser *(Lectures 12)*

Basic elements of a laser, properties of laser light; spontaneous and stimulated emission: Einstein coefficients, light amplification, population inversion and threshold condition for laser oscillations, optical resonator modes of a rectangular cavity, rate equations: two-level, three-level and four-level systems; ammonia maser, ruby laser, He-Ne laser

Section IV : Nonlinear optics *(Lectures 11)*

Nonlinear Optical Materials, Organic Nonlinear Optical Materials, Nonlinear susceptibilities from anharmonic oscillator. Kramers-Kronig relations. second harmonic generation, phase matching, parametric oscillation, intensity-dependent refractive index: self-focusing, phase conjugation: four wave mixing.

Reference Books

1) Laser Fundamentals - W T Silfvast.
2) Principles of fluorescence spectroscopy - J R Lakowicz.
3) Essentials of Laser and Nonlinear Optics - G D Baruah.
4) Molecular Spectra and Molecular Structure (Vol. 2) - G Herzberg.

Lab Part

1) Analysis of vibrational spectra of PN molecule.
2) Analysis of rotational Raman spectrum.
2) Rydberg constant using Hydrogen emission lines.
3) Rydberg constant using Hydrogen absorption lines.
4) Verification of Hartmann formula for prism spectrogram

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY8204C : Experimental Techniques

Total lectures : 60(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: This course is not a "lab course", but rather seeks to introduce students to basic experimental techniques, measurement theory and experiment design. The primary goal is to develop an appreciation of the role and significance of experimentation in the field of science. Students will be exposed to some widely employed experimental techniques and be introduced to some of the instrumentation that is used in experimental physics research.

Course Outcome: Students will learn the systematic procedure for performing an experiment along with the various conditions generally performed under. They will also learn the various tools which will help them in future studies

Theory Part

Section I : Measurement fundamentals & Uncertainty in measurements *(Lectures 15)*

Measurement, Calibration, Errors, Accuracy, Precision, Uncertainty, Repeatability, Reproducibility. Mean, median and mode of discrete and grouped data, geometric mean, harmonic mean and weighted mean. Dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis. Kinds of errors - Gross, Systematic and random errors. Types of Uncertainty: Type A and B, Measurement of Uncertainty, Propagation of errors.

Section II : Correlation, Regression & Goodness of Fit test *(Lectures 15)*

Positive and negative correlation, scatter plot, Karl Pearson coefficient of correlation. Regression - line of regression. least square method, chi-squared test

Section III : Low pressure & Temperature *(Lectures 15)*

Gas flow at low pressures, Principles of pumping, parameters and classifications of vacuum pumps, Mechanical pumps, Vapour pumps, Ion pumps, Sorption pumps, Cryopumps, Classification and selection of vacuum gauges, Gauges using liquids, Thermal conductivity gauges, Ionization gauges, Calibration of vacuum gauges. Properties of cryoliquids, Helium-4 cryostats, Helium-3 cryostats, Refrigeration by adiabatic demagnetization, Low temperature thermometry

Section IV : Measuring equipments *(Lectures 15)*

XRD, XRF, SEM, TEM, AFM, STM, VSM, Absorption spectrophotometer, Spectrofluorometer, Raman Spectrometer, FTIR, ESR, NMR.

Data acquisition system (CRO/DSO, Particle Detectors, Signal Detection).

Reference Books

1) A. Roth, Vacuum Technology, 3rd edition, Elsevier Science B.V., 1996.

2) F. Pobell, Matter and Methods at Low Temperatures, Springer-Verlag, 1992.

3) B. D. Cullity and S. R. Stock, Elements of X-ray Diffraction, Prentice Hall, 2001

4) Les Kirkup and Bob Frenkel. An Introduction to Uncertainity in Measurement, Cambridge University Press.

5) Techniques & Measurement of Radiation, G. F. Knoll

6) Techniques for Nuclear and Particle Physics Experiments, W. R. Leo,

PHY8304C : Plasma Physics

Total lectures : 60(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: The purpose of the course is to familiarize the students with the tools used in theoretical plasma physics. The course builds upon the foundation of the introductory plasma physics course. Subjects of fundamental importance are considered, such as kinetic theory, space and solar plasma

Course Outcome: After completing the course the student will have an overall view of charged particle dynamics in electromagnetic fields, behaviour of plasma as a fluid and basic elements of kinetic theory. The student understands the hierarchy of plasma theories from kinetic theory to magnetohydrodynamics.

Theory Part

Section I : Basics of plasma physics & EM wave propagation *(Lectures 15)*

Concept of Plasma Temperature, Plasma frequency, Debye Shielding, plasma parameters, motion of charged paticle in constant and slowly varying E and B fields, curvature, gradient and external force drift, Adiabatic Invariants. Plasma confinement schemes (linear pinch, mirror, Tokamak),

Section II : Linear Theory of Plasma Waves and Instability with MHD *(Lectures 15)*

Development of Ideal MHD theory. Plasma as a Fluid. Linear theory of Plasma Waves with MHD description-Electron and Ion Waves. Concept of Plasma Resistivity. Single Fluid MHD equations and MHD Waves. Two- stream Instability.

Section III : Kinetic Theory of Plasma and its Application *(Lectures 15)*

Need for kinetic theory, Boltzmann-Vlasov equation, Application of Kinetic Theory to Electron Plasma Waves, Landau Damping, Collision Damping.

Section IV : Solar & Space Plasma *(Lectures 15)*

Significance of plasma astrophysics, Neutral and ionized gas, gaseous nebulae, H II regions, supernova remnants, photodissociation regions Accretion disks: magnetorotational instability, winds and jets. Properties, solar wind formations, Interaction of Solar Wind with Magnetized and Unmagnetized Planets. Magnetophere: Magnetopause, Magnetotail, Magnetic reconnection, Ionosphere: Structure, Irregularities, Magnetosphere- Ionosphere coupling.

Reference Books

1) Introduction to Plasma Physics and Controlled Fusion- F F Chen
2) Fundamentals of Plasma Physics- J A Bittencourt
3) Plasma Physics via Computer Simulation, C.K. Birdsall, A.B Langdon
4) Plasma Physics and Engineering, A. Fried and L.A. Kennedy
5) Magnetohydrodynamics of the Sun- Eric Priest
6) Basic Space Plasma Physics: W.Baumjohauand R.A.Treumann.
7) Space Plasma Physics: A. C .Das.

PHY8404C : Nano Physics

Total lectures : 60(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: To make the students acquire an understanding the influence of dimensionality of the object at nanoscale on their properties; size and shape controlled synthesis of nanomaterials and their future applications in industrial applications.

Course Outcome: Students will learn about the background on Nanoscience along with the understanding of synthesis of nanomaterials and their application and the impact of nanomaterials on modern day life. They can then will be able to apply their learned knowledge to develop Nanomaterial.

Theory Part

Section I : Introduction to nanotechnology and nanomaterials *(Lectures 15)*

Synthesis of carbon buckyballs, list of stable carbon allotropes extended, fullerenes, metallofullerenes, solid C60, bucky onions, nanotubes, nanocones, properties of individual nanoparticles, methods of synthesis for carbon nanostructures, carbon nanofilaments.

Section II : Synthesis techniques *(Lectures 15)*

Top-down vs. bottom-up techniques, sol-gel method, solution growth and hydrothermal routes, mechanical milling and solid state reaction techniques, chemical and photochemical reduction routes, thermal evaporation and e-beam evaporation methods, molecular beam epitaxy.

Section III : Surface properties *(Lectures 15)*

Phonons in nanostructured systems, surface optic phonons, surface plasmons, interfacial charge transfer, grain growth, surface defects, Langmuir relation, Ostwald ripening, Hall-Petch relation, grain correlated properties.

Section IV : Analytical tools *(Lectures 15)*

X-ray diffraction, AFM Studies, optical absorption and emission spectroscopy, Raman spectroscopy, scanning and transmission electron microscopy.

Reference Books

1) Cao, G. and Wang, Y., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, 2nd edition, (World Scientific, 2011).

2) Rao, C. N. R., Thomas, P. J. and Kulkarni, G. U., Nanocrystals: Synthesis, Properties and Applications, (Springer-Verlag, 2007).

3) Poole, Jr. C. P. and Owens, F. J., Introduction to Nanotechnology, (Wiley, 2003).

4) Deb, P., Kinetics of Heterogeneous Solid State Processes, (Springer, 2013).

5) Nouailhat, A., An Introduction to Nanosciences and Nanotechnology, (Wiley 2007).

6) K. K. Chattopadhyay, A. N. Banerjee, Introduction to Nanoscience and Nanotechnology, Prentice Hall, 2009.

PHY8404C : Research Project (In lieu of PHY8204C, PHY8304C, PHY8404C)

Duration : Entire Semester **Credits : 12**

Course Objective: This course is focused to facilitate student to carry out extensive research and development project or technical project at place of work through problem and gap identification, development of methodology for problem solving, interpretation of findings, presentation of results and discussion of findings in context of national and international research.

Course Outcome: The student will be able to gain in-depth knowledge and use adequate methods in the major subject/field of study along with the ability to create, analyze and critically evaluate different technical/research solutions

What is expected from the research ?

Research is an essential component of graduate education. The thesis is often seen as the culmination of graduate work, and it is the formal product. The crucial component of this work is the Advisor or the Advisory Committee. Either of these components, interacting with a Master's student, create a significant professional experience and shape the degree work and resulting thesis. **Ultimately it is the student's responsibility for making adequate progress toward completion of his or her thesis and for producing high quality work.**

Master's projects should be the result of work that is independently conducted, and that represents original research and critical analysis. The work should demonstrate the following from the student concerning the field of study:

- Awareness and understanding of important current work in the field
- Ability to plan a research activity
- Knowledge and motivation to carry out the planned research activity
- Ability to analyze the results of the research
- Ability to draw reasonable conclusions from the research
- Ability to complete a written description of the work in the form of a well-written, properly organized thesis
- Ability to complete a thesis with potential for presentation at and/or participation in professional meetings and/or publication in scholarly journals

Phases of the MSc Research

Phase	Activity	Product
Proposal writing	Orientation, Problem analysis, Literature search, Work plan	Written proposal
Performing the research	Experiment, Field work, Modeling, Data gathering, analysis & interpretation	Preliminary results
Thesis writing & Evaluation	Putting the pieces together, Writing report, Presentation	Thesis report & Viva (In Presence of External)

Contents for the MSc Research Proposal

Phase	Activity
Project title	As concise as possible formulated
Introduction	Including background of problem, state of the art according scientific literature, scientific & social relevance, Formulation of scientific research questions and hypotheses
Methods	Description of available data, fieldsites & models that will be used, design of field inventory, design of experiments, modelling activities, Description of statistical methods to analyze data

Contents for MSc Research Thesis Report

Contents	Description
Cover page	Should contain Title, name & designation, Roll No., Supervisor/Guide's name etc
Abstract	A brief write up of the method/results
Introduction	problem definition, state-of-the-art, theory/concepts, objectives, research questions
Material & Methods	Description of how the problem was studied, which materials were used, statistical analysis
Results	What are the findings
Discussion	Discuss your findings with those from literature, what are good/weaker points in your study
Conclusions	Answer your research questions and formulate recommendations
References	All the literature from where help has been taken
Annexures	Detailed presentations of the obtained results in tabular form

SE :: SKILL ENHANCEMENT Courses/Papers

PHY1103SE : Digital Photography & Editing Skills

Total lectures : 30(L+T) & 30 (P) **Credits : 3 (Theory: 02, Lab: 01)**

Course Objective: This course is designed from a photographic viewpoint. To become proficient at the technical aspect of photographing with a digital camera. Students will be working with those images in capturing & processing including digital editing, saving, sizing, and posting of those images

Course Outcome: After completion of the course students will be able to learn the basic technology necessary for the production of their art work, as well as learning about the visual arts, how to look at and critique photography, photographic vocabulary, using tools such as framing, composition, "rule of thirds", light, texture, pattern, lines, symmetry, depth of field, distance, perspective, culture, space, balance, color and black and white photography, and be introduced to many works by well known photographers.

Theory Part

Section I : Theory of Basic Photography & Camera- Components *(Lectures 08)*

History of Photography, Introduction to Digital Photography, Digital Camera, dSLR, Advantages and Disadvantages of Digital Photography, Lens, Focal Length, Lens type, Aperture, Depth of Field, Shutter, Shutter Speed, Image sensor, Memory cards, External Flash, File types

Section II : Conditions in Digital Photography *(Lectures 08)*

Lighting, Importance of Natural Light, Best Time of Day to Take Photos, Disable Flash Indoors, Disable Flash in Low Light, Use Flash to Balance Bright Light, Get Closer to the Subject, Crop Your Photo, Choose Better Backgrounds, Pick Proper Orientation, Use Point of View, Frame your Subject, Experiment with Abstract Photography, Holding your DSLR

Section III : Exposure Modes *(Lectures 08)*

Automatic mode, Manual mode, aperture mode, shutter mode, Scene mode, Portrait mode, landscape mode, close up mode, sports mode, Twilight mode, Night Mode, Black and white, sepia, Panoramic mode.

Section IV : Capturing an Image, Hands-on Basics *(Lectures 06)*

Elements of Composition: Pattern, Symmetry, Texture, Depth of Field, Lines; Law of Thirds, Camera Shake, Red eye, Lighting, Digital Noise

Reference Books

1. Beginner's Guide to Digital Photography
2. Complete Idiot's Guide to Digital Photography – Steve Greenberg
3. Complete Digital Photography Third Edition – Ben Long
4. The Textbook of Digital Photography Second Edition – Dennis P. Curtin

Lab Part

1) To differentiate the same image captured using different ISO, shutter speed and f numbers.
2) Implement the rule of thirds and golden ratio on the same scenery.
3) Visualise the colour histogram, noise profile, white balance and other exif data of a captured raw and jpeg format.
4) Observed the depth of field variation of an object by changing the F stop no.
5) Creating HDR image by capturing a landscape image with different exif data using double exposure or manually in photoshop.

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY2103SE : Graphic Design Skills for Digital Advertising

Total lectures : 30(L+T) & 30 (P) **Credits : 3 (Theory: 02, Lab: 01)**

Course Objective: To thrive in today's competitive and thriving digital world one needs a multitude of skills in order to give a true competitive advantage in the current career, sustainability, diversity and in the business environment, the graphic design is a perfect opportunity to do what one loves while doing some good in the world, which is the objective of the course.

Course Outcome: Students who successfully complete a degree in Graphic Design will be able to Analyze, synthesize, and utilize design processes and strategy from concept to delivery to creatively solve communication problems. They will be able to utilize relevant applications of tools and technology in the creation, reproduction, and distribution of visual messages and apply graphic design principles in the ideation, development, and production of visual messages.

Theory Part

Section I : Getting Started & Importance of Adobe Photoshop CC *(Lectures 08)*

Overview of Adobe Photoshop CC, Features of Adobe Photoshop CC , Tools Used in Adobe Photoshop CC, Importance of Adobe Photoshop CC

Section II : Working with Typography, Layers & Filters *(Lectures 08)*

Typography, Creating Typographies, Choosing the Right Font and Color, Basics of Layers, Creating Layers for Print and Digital Media, Aligning, Images within Multiple Layers, Merging Layer Techniques Photoshop Filters, Smart Filters, Common Features of Photoshop Filter

Section III : Digital Painting of images *(Lectures 06)*

Cropping a Photo, Resizing Images, Working with Brush Tool, Importance of Using Colors

Section IV : Masking and File Formats in Adobe Photoshop CC *(Lectures 08)*

Introduction to Mask, Creating Vector and Layer Masks, Essential File Formats, Choosing the Right Format for Print and Digital Media

Reference Books

1. The Non-Designer's Design Book by Robin Williams

2. Photoshop : Learn Color Grading Photoshop Actions To Enhance Your Photos NOW! By Edward Bailey

3. Powered by Design : An Introduction to Problem Solving with Graphic Design by Renee Stevens

4. The Language of Graphic Design Revised and Updated : An illustrated handbook for understanding fundamental design principles by Richard Poulin

5. A Beginners Guide for Adobe Photoshop, Adobe Illustrator , Adobe In-Design Basics by Robert Pattinson

Lab Part

1) Design something for an imaginary client
2) Redesign an existing brand
3) Create a logo for yourself
4) Offer graphic design work to your instructor and friends
5) Kern Type design

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY3103SE : Video Editing Skills

Total lectures : 30(L+T) & 30 (P) **Credits : 3 (Theory: 02, Lab: 01)**

Course Objective: This course is intended to introduce and/or strengthen the student's knowledge in the aesthetics and technical skills of editing for film and video. These skills will be attained during lectures and class discussions, scene analysis and through exercises and projects conducted in a nonlinear editing environment.

Course Outcome: Students will be able to identify and describe key terms and concepts and major trends and periods related to various modes of production (narrative, documentary, experimental, and/or animation), film history, and theory. They will also develope the skills necessary to effectively collaborate and communicate on video project productions, including working in groups, and engaging with peers and professors.

Theory Part

Section I : Adobe Premier Pro CC 7.0 *(Lectures 06)*

New Features: Summary, Workspace Basic Workflow, Preferences

Section II : Importing, Working, Editing & Tilting *(Lectures 10)*

Transferring and Importing Files, Supported File Format, Importing Sequences, Clip Lists, Compositions, Still Images, and Digital Videos, Creating and Changing Sequences, Adding, Rearranging, and Working with Clips in a Sequences, Rendering and Previewing Sequences, Overview of Audio and Audio Track Mixer, Working with Clips, Channels, and Tracks, Editing Audio in a Timeline Panel, Adjusting Volume Levels, Creating and Editing Titles, Creating and Formatting Text in Titles, Working with Text and Objects in Titles

Section III : Effects *(Lectures 06)*

About Effects - Applying, Removing, Finding, and Organizing Effects, Viewing and Adjusting Effects, Keyframes, and Effects Presets, Masking and Tracking, Applying Transitions, Adjustment Layers, Color Correction and Adjustments, Three-way Color Corrector Effect, Audio Effects and Transitions

Section IV : Compositing and Exporting *(Lectures 08)*

Compositing, Alpha Channels, and Adjusting Clip Opacity, Blending Modes, Workflow and Overview for Exporting, Exporting Projects for Other Applications, Exporting Still Images Working with Rough Cut, Editing Rough Cuts, The Prelude Workspace, Exporting Still Images

Reference Books

1. In the Blink of an Eye: A Perspective on Film Editing by Walter Murch

2. Editing Techniques with Final Cut Pro by Micheal Wohl

3. Editing Digital Video: The Complete Creative and Technical Guide (Digital Video and Audio) by Robert M Goodman.

Lab Part

1) Assembling all raw footage, with camera shots either recorded or transferred onto video tape in preparation for inputting into the computer.

2) Organize and string together raw footage into a continuous whole according to scripts.

3) Select and combine the most effective shots of each scene to form a logical and smoothly running story.

4) Trim film segments to specified lengths and reassemble segments in sequences that present stories.

5) Edit films and videotapes to insert music, dialogue, and sound effects, to arrange films into sequences, and to correct errors, using editing equipment.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

ID :: INTERDISCIPLINARY Courses/Papers

PHY1104ID : Renewable Energy & Energy Harvesting

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: The aim of the course is to let the students to know the skill set in the field of research in renewable energy sectors using blended interdisciplinary knowledge required to establish as an entrepreneur and industry centric in renewable energy for their adherence to professional, social and ethical responsibilities in implementing sustainable energy solutions.

Course Outcome: After completion students are expected to gain an ability to independently carry out research /investigation and development work to solve practical problems in contemporary and futuristic renewable energy research towards industry and society for sustainable energy solutions.

Theory Part

Section I : Fossil fuels and Alternate Sources of energy *(Lectures 12)*

Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of 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, Hydro-electricity.

Section II : Solar energy *(Lectures 12)*

Solar energy, its importance, storage of solar energy, solar pond, non convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems.

Section III : Ocean Energy *(Lectures 10)*

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 Biomass.

Section IV : Wind & Piezoelectric Energy harvesting *(Lectures 11)*

Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies. Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric energy harvesting applications, Human power

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

Lab Part

1. Demonstration of Training modules on Solar energy, wind energy, etc.
2. Conversion of vibration to voltage using piezoelectric materials
3. Conversion of thermal energy into voltage using thermoelectric modules.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY2104ID : Weather Forecasting

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course is designed to impart theoretical knowledge to the students and enable them to develop awareness and understanding regarding the causes and effects of different weather phenomenon.

Course Outcome: After completion students will acquire the knowledge of the atmosphere, its composition variation of pressure and temperature with height, cyclones and anti-cyclones and many other atmospheric parameters along with the science of cloud formation and other related aspects.

Theory Part

Section I : Introduction to atmosphere *(Lectures 13)*

Elementary idea of atmosphere: physical structure and composition; compositional layering of the atmosphere; variation of pressure and temperature with height; air temperature; requirements to measure air temperature; temperature sensors: types; atmospheric pressure: its measurement; cyclones and anticyclones: its characteristics.

Section II : Measuring the weather *(Lectures 10)*

Wind; forces acting to produce wind; wind speed direction: units, its direction; measuring wind speed and direction; humidity, clouds and rainfall, radiation: absorption, emission and scattering in atmosphere; radiation laws.

Section III : Climate and Climate Change *(Lectures 10)*

Climate & its classification; causes of climate change; global warming and its outcomes; air pollution; aerosols, ozone depletion, acid rain, environmental issues related to climate.

Section IV : Basics of weather forecasting *(Lectures 12)*

Weather forecasting: analysis and its historical background; need of measuring weather; types of weather forecasting; weather forecasting methods; criteria of choosing weather station; basics of choosing site and exposure; satellites observations in weather forecasting; weather maps; uncertainty and predictability; probability forecasts.

Reference Books

1) Aviation Meteorology, I.C. Joshi, 3rd edition 2014, Himalayan Books

2) The weather Observers Hand book, Stephen Burt, 2012, Cambridge University Press.

3) Meteorology, S.R. Ghadekar, 2001, Agromet Publishers, Nagpur.

4) Text Book of Agro meteorology, S.R. Ghadekar, 2005, Agromet Publishers, Nagpur

5) Atmosphere and Ocean, John G. Harvey, 1995, The Artemis Press.

Lab Part

1. Processing and analysis of weather data: To study the variation of rainfall amount over a place in a particular year using GrADS .

2. Processing and analysis of weather data: To study the variation of relative humidity over a place in a particular year using GrADS

3. Processing and analysis of weather data: To study the variation of precipitation month-wise over a place in a particular year using GrADS

4. Exercises in chart reading: Plotting of constant pressure charts, surfaces charts, upper wind charts and its analysis.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY3104ID : Ancient Astronomy

Total lectures : 60(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: This course aims to achieve two purposes: (1) to increase the awareness of the scientific process and its role in our world and (2) to give an academic and professional skills that will benefit in shaping the career.

Course Outcome: By the end of this course, students will be able to read technical articles efficiently for key concepts, acquire critical thinking skills by learning to evaluate the evidence behind a scientific theory along with the basic ideas of numerology gemmology etc.

Theory Part

Section I : Naked Eye Astronomy *(Lectures 15)*

The constellations and their identification, Identification of some individual stars, A historical perspective and Copernican revolution, Earth's rotation and other motions, Age calculation from the movement of planets. Eclipses: Lunar & Solar eclipse and its prediction

Section II : The Way the Sky Looks *(Lectures 15)*

An Introduction Daily & Annual Motions of the Sun, Moon, Planets & Stars Lunar Phases, the Sun at all Seasons & the Development of Calendars Setting the Calendar with Monument Alignments: e.g., Stonehenge & the Sundagger Maya sites & the Maya Calendars

Section III : Ancient Astronomical Cultures *(Lectures 15)*

Indian Astronomy and Vedas, Indian Astronomy and the Siddhantic Era, Contribution of Aryabhata, Bhaskara, Varahamihira to Indian astronomy, Astronomy During Shunga Empire Constellations and Star-lore of several Cultures, e.g. Greek, Egyptian Islamic Chinese etc

Section IV : Astrology & Astronomy Cultures *(Lectures 15)*

Basics of Astrology, Significance, Effects, the behaviour of planets, Zodiac Signs Understanding of *Dashas*, Reading of Horoscope, Comparisons and Predictions, Study of Constellations, *Dashas* and Defects on Horoscope Solutions for *Dashas*

Reference Books

1) The History and Practice of Ancient Astronomy by James Evans
2) Surya Siddhanta: The oldest book known to Man on Astronomy
3) The Story of Astronomy in India by Chander Mohan
4) Echoes of the Ancient Skies: The Astronomy of Lost Civilizations by E C Krupp
5) Hindu Astronomy W. Brennand
6) Architecture, Astronomy And Sacred Landscape In Ancient Egypt by Guilio Magli

MC :: Minor Courses/Papers

PHY1104M : Introduction to Mechanics & Properties of Matter

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: The objective of this course is to introduce the students to the world of mechanics and properties of matter that exists in different phases ie solid liquid and gas. Laws of motion and its application to various systems studied in this paper is of fundamental in nature and will enable the students to handle different types problems which prerequisites for many advances courses in physics and chemistry.

Course Outcome: Learner will be able to apply the equation of motion to one or two dimensions of the system in order to understand kinematics of the body under the various conditions of applied force along with ability to apply knowledge in understanding the various properties of solids and flow of liquids.

Theory Part

Section I : Laws of Motion *(Lectures 12)*

Frames of reference. Newton's Laws of motion. Dynamics of a system of particles. Centre of Mass. Conservation of momentum. Work and energy. Conservation of energy. Angular velocity and angular momentum. Torque. Conservation of angular momentum. Moment of inertia, Parallel and Perpendicular axis theorem (no proof required).

Section II : Gravitation *(Lectures 11)*

Newton's Law of Gravitation. Gravitational Field and Potential due to a spherical shell, Motion of a particle in a central force field (motion is in a plane, angular momentum is conserved, areal velocity is constant). Kepler's Laws (statement only).

Section III : Elasticity *(Lectures 12)*

Hooke's law - Stress-strain diagram - Elastic moduli-Relation between elastic constants - Poisson's Ratio Expression for Poisson's ratio in terms of elastic constants – Work done in stretching and work done in twisting a wire

Section IV : Fluid Mechanics *(Lectures 10)*

Viscosity, Streamline, Turbulent motion of fluids, Bernoulli's theorem, Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.

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) Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.

4) Analytical Mechanics, G. R. Fowles and G. L. Cassiday. 2005, Cengage Learning.

5) University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

7) Mechanics, D. S. Mathur, S. Chand and Company Limited, 2000

Lab Part

1. Measurements of length (or diameter) using vernier caliper, screw gauge and Spherometer.
2. To determine the Young's Modulus of the material of a wire by Searle's apparatus.
3. To determine the elastic Constants of a wire by Searle's method.
4. To determine the value of g using Bar Pendulum.
5. To determine the value of g using Kater's Pendulum.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY2104M : Introduction to Waves & Optics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course builds on the ideas of harmonic motion to cover in depth the concept of waves in physics with particular emphasis on light waves as an example. This will help the students to acquire skills to identify and apply formulas of optics, understand the properties of light like interference, diffraction and polarization and then to apply the skills to understand the resolving power of different optical instruments.

Course Outcome: Upon successful completion, students will have the knowledge and skills to Understand the role of the wave equation and appreciate the universal nature of wave motion in a range of physical systems by different phenomena like interferrence difraction & polarisation etc

Theory Part

Section I : Wave Motion and its superposition *(Lectures 13)*

General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity. Linearity & Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats).

Section II : Interference *(Lectures 11)*

Electromagnetic nature of light. Definition and Properties of wave front. Huygens Principle. Division of amplitude and division of wavefront. Young's Double Slit experiment. Lloyd's Mirror and Fresnel's Biprism. Newton's Rings: measurement of wavelength

Section III : Diffraction *(Lectures 11)*

Fresnel and Fraunhofer diffraction. Fresnel diffraction at a straight edge. Fraunhofer diffraction due to a Single slit, Diffraction grating . Resolving power of a grating.

Section IV : Polarization *(Lectures 10)*

Transverse nature of light waves. Double Refraction, Plane, circular and elliptically polarized light

Reference Books

1) Fundamentals of Optics, F. A. Jenkins and H.E. White, 1981, McGraw-Hill

2) Optics, Ajoy Ghatak, 2008, Tata McGraw Hill

3) The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

4) The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.

5) Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.

Lab Part

1. To determine the Frequency of an Electrically Maintained Tuning Fork by Melde's Experiment and to verify λ^2 -T Law.
2. To determine the focal length of a convex mirror with the help of convex lens .
3. To determine the refractive index of a liquid by using plane mirror and convex lens.
4. Familiarization with Schuster's focussing; determination of angle of prism.
5. To determine wavelength of sodium light using Newton's Rings.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY3104M : Mathematical Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This part of the course builds on the Essential Mathematics module to develop further mathematical skills as an aid to understanding and exploring physics concepts. The computational part of the course consists of a series of assessed exercises, with classroom support, with an intend to develop their logical understanding problem solving skills.

Course Outcome: The students will have the understanding of basic and advanced mathematical tools required for Physics Problems and will also develop computational problem solving skills, and link in with the mathematics covered elsewhere.

Theory Part

Section I : Vector Differentiation *(Lectures 12)*

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

Section II : Vector Intergration *(Lectures 12)*

Ordinary Integrals of Vectors. 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).

Section III : First and Second order Differential Equations *(Lectures 11)*

First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration.

Section IV : Orthogonal Curvilinear Coordinates *(Lectures 10)*

Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. Transformation matrix between cartesian & spherical coordinate, cartesian & cylindrical coordinate

Reference Books

1) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, and F. E.. Harris, 2013, 7th Edn., Elsevier.

2) An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI

3) Learning Differential Equations, George F. Simmons, 2007, McGraw Hill.

4) Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book

5) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge University Press

Lab Part

1) Review of Python Programming Introduction to Python Language, Python Language Syntax, Python Keywords and Identifiers, Python Variables, Data Types, Operators, Variables, Basic Operators, Boolean Values, Conditional Execution, Loops, Lists etc

2) Programs Sum & average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order

3) Random number generation Area of circle, area of square, volume of sphere, value of pi (π)

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY3204M : Thermal Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course aims to provide a good platform to the physics students to understand, model and appreciate concept of dynamics involved in thermal energy transformation along with the understanding of thermodynamic fundamentals before applying them to other allied fields.

Course Outcome: To appreciate concepts learnt in fundamentals laws of thermodynamics from which learning ideas how to sustain in energy crisis and think beyond curriculum in the field of alternative and renewable sources of energy.

Theory Part

Section I :Distribution of Velocities *(Lectures 10)*

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds, Maxwell's mean free path

Section II : Real Gases *(Lectures 11)*

Behaviour of Real Gases, Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants.

Section III : Laws of Thermodynamics *(Lectures 12)*

Zeroth Law of Thermodynamics & Concept of Temperature, First Law of Thermodynamics, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence.

Section IV :Entropy *(Lectures 12)*

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of En- tropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero.

Reference Books

1) Heat and Thermodynamics, M. W. Zemansky, Richard Dittman, 1981, McGraw-Hill.

2) A Treatise on Heat, Meghnad Saha, and B. N.Srivastava, 1958, Indian Press

3) Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill

4) Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa. 5) Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

Lab Part

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY4104M : Electricity & Magnetism

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: To develop the knowledge about Fundamental laws and concepts in electricity and magnetism along with a conception of space and time adequate for understanding electrodynamics along with the training for problem-solving skills.

Course Outcome: The candidate should among other things will have especially with regard to Maxwells laws- Electrical circuits with the most common components with the abilty to perform quantitative calculations in situations involving electric and magnetic fields, and demonstrate knowledge of the relevant basic units, vector addition, and application of basic calculus. Students will be able to assess answers to questions for plausibility.

Theory Part

Section I :Electric Field and Electric Potential *(Lectures 12)*

Electric field: Electric field lines. Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor.

Section II : Dielectric Properties of Matter *(Lectures 10)*

Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor(parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss' Law in dielectrics.

Section III : Magnetic Field *(Lectures 11)*

Magnetic Force on a point charge, definition and properties of magnetic field B. Biot-Savart's law and its simple application: straight wire and circular loop. Magnetic Force on a current carrying wire. Torque on a current loop in a uniform magnetic field. Ballistic Galvanometer. Curl and Divergence of magnetic field. Ampere's circuital law and its application to Solenoid and Torus. Vector potential A. Current loop as a magnetic dipole and its dipole moment.

Section IV : Electromagnetism and AC Circuits *(Lectures 12)*

Faraday's Law. Lenz's Law. Self-Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge conservation and Displacement current. AC Circuits: Complex Reactance and Impedance. Series LCR Circuit: Resonance, Power Dissipation, Quality Factor, and Band Width. Parallel LCR Circuit.

Reference Books

1) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw

2) Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education

3) Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.

4) Elements of Electromagnetics, M. N. O. Sadiku, 2010, Oxford University Press.

5) Electricity and Magnetism, J. H. Fewkes & J. Yarwood. Vol. I, 1991, Oxford Univ. Press.

Lab Part

1) Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.

2) To study the characteristics of a series RC Circuit.

3) To determine an unknown Low Resistance using Potentiometer.

4) To determine an unknown Low Resistance using Carey Foster's Bridge.

5) To compare capacitances using DeSauty's bridge.

6) To determine self inductance of a coil by Anderson's bridge.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY4204M : Fundamentals of Quantum Mechanics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: The main objective of this course is to make students aware about the basic formulations in quantum mechanics how the evolution of the microscopic physical systems occurs and its connection to actual observables.

Course Outcome: After taking this course students will be able to appreciate the beauty of quantum mechanics which plays an important role in the microscopic world while measuring the observables with a statistical interpretation.

Theory Part

Section I :Quantum Theory and Blackbody Radiation *(Lectures 12)*

Quantum theory of light; photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. group and phase velocities and relation between them. Two-slit experiment with electrons. Probability. wave amplitude and wave functions.

Section II : Uncertainty and Wave-Particle Duality *(Lectures 10)*

Position measurement : gamma ray microscope thought experiment; wave-particle duality, Uncertainty principle (Uncertainty relations involving Canonical pair of variables): Derivation from wave packets, impossibility of a particle following a trajectory; estimating minimum energy of a confined particle using uncertainty principle

Section III : Schrödinger Equation *(Lectures 12)*

Two slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Schrödinger equation for non- relativistic particles; momentum and energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; probability and probability current densities in one dimension.

Section IV : Hydrogen-like Atoms *(Lectures 11)*

Time independent Schrödinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wave functions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers l and m, s, p, d, . . . shells.

Reference Books

1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.

2) Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill

3) Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.

4) Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.

5) Modern Physics, G. Kaur and G. R. Pickrell, 2014, McGraw Hill

6) Quantum Mechanics: Theory & Applications, A. K. Ghatak & S. Lokanathan, 2004, Macmillan

Lab Part

1) Measurement of Planck's constant using black body radiation and photo-detector.

2) Photo-electric effect Photo current versus intensity and wavelength of light; maximum energy of photo- electrons versus frequency of light.

3) To determine work function of material of filament of directly heated vacuum diode.

4) To determine the Planck's constant using LEDs of at least 4 different colours.

5) To determine the wavelength of H-α emission line of hydrogen atom.

6) To determine the wavelength He-Ne laser using plane diffraction grating.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY5104M : Elements of Electronics & Network Analysis

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course provides the student with the fundamental skills to understand the basic of semiconductor and components like diodes, transistors and operational amplifiers, logic gates and their usage in digital circuits. It will build mathematical and numerical background for design of electronics circuit & component value.

Course Outcome: Students equipped with the knowledge and training provided in the course will be able to participate in design , development and operation in the different area of electronics system .

Theory Part

Section I :Network Theorems and Transistor and Amplifiers *(Lectures 12)*

Ideal voltage and current Sources. Thevenin theorem, Norton theorem, Maximum Power Transfer theorem. CB, CE and CC Configurations of Transistors. Current gains α and β. Transistor Biasing Circuits - Base Bias, Fixed Bias, Emitter Bias, Voltage Divider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of RC-coupled amplifier and its frequency response.

Section II : Oscillators and OPAMPS *(Lectures 11)*

Positive and Negative Feedback. Advantages of Negative Feedback (Qualitative). Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator. Differential Amplifier and OPAMP. Characteristics of an Ideal OPAMP. Offset Voltage and Current. CMRR. Applications of OPAMP as (1) Inverting amplifier, (2) Non-inverting amplifier, (3) Adder, (4) Differentiator, (5) Integrator.

Section III : Introduction to Digital Algebra *(Lectures 12)*

Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD. Binary Addition. Binary Subtraction using 2's Complement. Digital Logic Gates (AND, OR, NOT, NAND. NOR, XOR, XNOR). Laws of Boolean Algebra. De Morgan's Theorems. Idea of Minterms and Maxterms. Minimization with Karnaugh Map Method (up to four variables).

Section IV : Data Processing Circuits *(Lectures 10)*

Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders. SR, JK, D and T Flip-Flops. SISO, SIPO, PISO and PIPO Shift Registers (up to 4-bit). Asynchronous counter

Reference Books

1) Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, Tata McGraw
2) Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
3) Digital Electronics G. K. Kharate ,2010, Oxford University Press
4) Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer, 2001, PHI Learning
5) Logic circuit design, Shimon P. Vingron, 2012, Springer.
6) Microprocessor Architecture Programming & applications with 8085, 2002, R. S. Goankar, Prentice Hall.

Lab Part

1) To design a switch (NOT gate) using a transistor.
2) To verify and design AND, OR, NOT and XOR gates using NAND gates.
3) Half Adder, Full Adder and 4-bit binary Adder.
4) Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder IC.
7) To design inverting amplifier using Op-amp (741/351) and study its frequency response.
8) To design non-inverting amplifier using Op-amp (741/351) & study its frequency response.

Reference

1) Lab manuals.
2) Practical notes/ Books suggested by the Lab Instructor.

PHY5204M : Classical & Relativistic Mechanics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This part of the course is introduced to understand the Lagrangian & Hamiltonian Approach formulation of Newtonian mechanics. Then to realize the reduction of a two-body problem to a one-body problem in a central force system and to study the behaviour of systems under extremely high speed.

Course Outcome: Upon successful completion of this course it is intended that a student will be able to understand about the alternate approach to the Newtonian mechanics and the fascinating facts derived from special theory of relativity.

Theory Part

Section I :Central Force Problem & Newtonian Mechanics *(Lectures 12)*

Central force motion, two body central force motion, two body motion as a one body problem, general properties of central force motion, Application of central force problem to motion under inverse square force field (e.g. Keplerian motion). Differential equation of orbit, nature of the orbits as parabolic, elliptic and circular. Energy equation involving only the radial motion, energy diagram and nature of orbits.

Section II : Lagrangian Mechanics *(Lectures 11)*

Constraints, generalized co-ordinates, generalised force, principle of virtual work, D' Alembert's principle, Lagrange equations from D' Alembert's principle, cyclic coordinates and conservation theorem. Applications of Lagrangian formulation in (i) simple pendulum (ii) compound pendulum

Section III : Hamiltonian Mechanics *(Lectures 12)*

Hamilton's principle as a fundamental principle, Lagrange equations from Hamilton's principle, significance of Hamilton's principle. Hamiltonian of a system, Physical meaning of Hamiltonian, Hamilton's canonical equations of motion, Applications of Hamiltonian formulation in (i) simple pendulum (ii) compound pendulum

Section IV : Special theory of Relativity *(Lectures 10)*

Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Relativistic Kinematics, Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Twin paradox, Relativistic force law, Relativistic transformation of velocity. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect.. Transformation of Energy and Momentum.

Reference Books

1) Classical Mechanics, S.N. Biswas (Books and Allied (P) Ltd).

2) Classical Mechanics, H. Goldstein (Narosa Publishing House).

3) An Introduction to Mechanics, Kleppner and Kolenkow (Tata McGraw- Hill).

4) Introduction to Classical Mechanics, Takwale and Puranik (Tata McGraw-Hill).

5) Classical Mechanics A modern Perspective, Barger & Olsson (McGraw Hill International).

6) Elementary fluid dynamics. Acheson, D. J. (1990) New York, USA: Oxford UniversityPress. 532 ACH

Lab Part

1) Python Program to Model a simple pendulum using (a) Lagrangian mechanics, (b) Hamiltonian mechanics

2) Python Program to Model a compound pendulum using (a) Lagrangian mechanics, (b) Hamiltonian mechanics

3) Python Program to Model a double pendulum using (a) Lagrangian mechanics, (b) Hamiltonian mechanics

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY5304M : Atomic & Nuclear Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: Students completing this module should be able to describe the structure of the atom, the constituents of the nucleus, some basic terms. It has been the intend also, to familirize the behaviour of atoms under fundamental forces & nuclear decay schemes. Also to give the basic idea about particle accelerators & detectors.

Course Outcome: Upon successful completion of this course the atomic physics part of this course is to provide a comprehensive introduction to atomic structure allowing one to understand atomic spectra, the behaviour of angular momentum in quantum mechanical systems, understanding of the period table of elements and many-electron atoms along with nuclear unstabilities, models and nuclear instruments.

Theory Part

Section I : Atomic Models *(Lectures 11)*

Rutherford's nuclear atom model, α- scattering expt; deduction of the scattering formula. Atomic spectra: Bohr's theory of hydrogen spectra; energy level diagram; Pauli's exclusion principle, Ritz combination principle; resonance, excitation, critical and ionization potentials; fine structures of the spectral lines; Hund's rule of maximum multiplicity, Aufbau Principle, Electronic configuration, Sommerfeld's extension of the Bohr's theory.

Section II : Atoms in Electric & Magnetic Fields *(Lectures 11)*

Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. Zeeman Effect: Normal and Anomalous Zeeman Effect. Paschen-Back Effect and Stark Effect (Qualitative Discussion only).

Section III : Nuclear Structure, Models & Radioactivity *(Lectures 12)*

Brief review of Size and structure of atomic nucleus, nature of nuclear force, N-Z graph, liquid drop model: semi-empirical mass formula and binding energy, nuclear shell model (qualitative discussions) and magic numbers. Alpha decay, impossibility of an electron being in the nucleus, β decay energy released, spectrum and Pauli's prediction of neutrino. Gamma ray emission, Cause of alpha decay, basic α-decay process, range and energy of α-decay, Geiger Nuttle rules

Section IV : Nuclear Accelerators & Detectors *(Lectures 11)*

Necessity of charge particle acceleration - construction and working principle of linear accelerator (LINAC). Construction and working principle of a Cyclotron Detectors: Principles of detection of charge particles. Construction and working principle of gas filled detectors. Ionization chamber – its construction & working principle.

Reference Books

1) Atomic Physics - John Yarwood

2) Concept of Modern Physics - A. Beiser

3) Atomic and Nuclear Physics - S. N. Ghosal

4) Atomic Physics- J. B. Rajam

Lab Part

1) To determine the Planck's constant using LEDs of at least 4 different colours.

2) To determine the wavelength of H- α emission line of hydrogen atom.

3) To determine the ionization potential of mercury.

4) To determine the absorption lines in the rotational spectrum of iodine vapour

5) To determine the value of $\frac{e}{m}$ by bar magnet.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY6104M : Condensed Matter Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: Students completing this course should have the theoretical concepts of the condensed matter physics with the various aspects of the interactions effects. It's also aim to bridge the gap between basic solid state physics and quantum theory of solids along with the ability to solve the problems related to metal-insulator transition and superconductivity.

Course Outcome: Upon successful completion of this course students will be able to differentiate between different Lattice types and explain the concepts of reciprocal lattice and crystal diffraction. They will also be able to understand & explain various types of magnetic phenomenon, physics behind them, along with the properties, important parameters related to superconductivity, its possible applications.

Theory Part

Section I : Crystal Structure & Lattice Dynamics *(Lectures 12)*

Amorphous and Crystalline Materials. Lattice Translation Vectors. Symmetry operations, Lattice with a Basis Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor. Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons.

Section II : Magnetic, Dielectric & Ferroelectric Properties of Matter *(Lectures 12)*

Dia, Para, Ferri, and Ferromagnetic Materials. Classical Langevin Theory of Dia and Paramagnetic Domains. Local Electric Field at an Atom. Electric Susceptibility. Polarizability. Clausius-Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

Section III : Free Electron Theory of Metals *(Lectures 11)*

Electrical and thermal conductivity of metals, Wiedemann-Franz law. Elementary band theory: Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect.

Section IV : Superconductivity *(Lectures 10)*

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation required).

Reference Books

1) Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.

2) Elements of Solid State Physics, J. P. Srivastava, 4th Edition, 2015, Prentice-Hall of India

3) Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning

4) Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India

5) Solid State Physics, M. A. Wahab, 2011, Narosa Publications

Lab Part

1) Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method).

2) To determine the Coupling Coefficient of a Piezoelectric crystal.

3) To study the PE Hysteresis loop of a Ferroelectric Crystal.

4) To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.

5) To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150^o C) and to determine its band gap.

6) To determine the Hall coefficient of a semiconductor sample.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY6204M : Statistical Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course extends the undergraduate thermal physics to a more advanced level so as to prepare the graduate students for the research literature on the subjects of modern statistical physics.

Course Outcome: By the end of the course, students will be able to converse with correct concepts of thermodynamics and statistical mechanics, understand statistics of particles and statistics of fields, perform mean field calculations, understand various (classical & quantum) models in statistical mechanics.

Theory Part

Section I : Classical Theory of Radiation *(Lectures 10)*

Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula. Rayleigh-Jean's Law. Ultraviolet Catastrophe.

Section II : Classical Statistics *(Lectures 12)*

Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur-Tetrode equation, Law of Equipartition of Energy (with proof)

Section III : Quantum Theory of Radiation *(Lectures 11)*

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.

Section IV : Quantum Statistics *(Lectures 12)*

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. Fermi-Dirac Distribution Law

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) Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer

Lab Part

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

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

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

4) Plot Planck's law for Black Body radiation and compare it with Rayleigh-Jeans Law at high temperature and low temperature.

5) 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.

6) Plot the following functions with energy at different temperatures (a) Maxwell-Boltzmann distribution (b) Fermi-Dirac distribution (c) Bose-Einstein distribution

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY6304M : Electromagnetic Theory

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course is designed to review the fundamentals and application of electromagnetic field theory. This course also enables the students to understand all Maxwell's equation in time varying field. In this course the students will also learn about Transmission line and reflection and refraction on plane as well oblique plane. The students will also be able to understand to solve real life problem related to electromagnetics

Course Outcome: At the end of the course the student should be able to illustrate the physical concepts of static electric & magnetic fields, Apply the maxwell equations to solve problems in electromagnetic field theory, Analyze the propagation of wave in different media and features of fibre optics.

Theory Part

Section I : Maxwell Equations *(Lectures 10)*

Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density.

Section II : EM Wave Propagation in Bounded & Unbounded Media *(Lectures 13)*

Boundary conditions 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 cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth.

Section III : Polarization of Electromagnetic Waves *(Lectures 10)*

Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Analysis of Polarized Light.

Section IV : Wave guides & Optical Fibres *(Lectures 12)*

Wave Guides: Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibres (Concept and Definition Only).

Reference Books

1) Introduction to Electrodynamics, D. J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.

2) Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.

3) Introduction to Electromagnetic Theory, T. L. Chow, 2006, Jones & Bartlett Learning

4) Electromagnetic field Theory, R. S. Kshetrimayun, 2012, Cengage Learning

Lab Part

1) To verify the law of Malus for plane polarized light.
2) To determine the specific rotation of sugar solution using Polarimeter.
3) To analyze elliptically polarized Light by using a Babinet's compensator.
4) To study Polarization and double slit interference in microwaves.
5) To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY7104M : Higher Level Mathematical Physics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This part of the course builds on the Essential Mathematics module to develop further mathematical skills as an aid to understanding and exploring physics concepts. The computational part of the course consists of a series of assessed exercises, with classroom support, with an intend to develop their logical understanding problem solving skills.

Course Outcome: The students will have the understanding of basic and advanced mathematical tools required for Physics Problems and will also develop computational problem solving skills, and link in with the mathematics covered elsewhere.

Theory Part

Section I :Frobenius Method and Special Functions *(Lectures 12)*

Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Hermite Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials.

Section II : Partial Differential Equations *(Lectures 10)*

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation.

Section III : Delta Function & Some Special Integrals *(Lectures 11)*

Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function. Beta and Gamma Functions and Relationship between them. Expression of Integrals in terms of Gamma Functions.

Section IV : Matrix *(Lectures 12)*

Properties of matrices, Special type of matrices with their properties: Transpose matrix, complex conjugate matrix, Hermitian matrix, Anti-Hermitian matrix, special square matrix, unit matrix, diagonal matrix, symmetric matrix, antisymmetric matrix, unitary matrix, orthogonal matrix, trace of a matrix, inverse matrix. Determinant, Eigen value, Eigen vector and diagonalisation of matrix. Cayley-Hamilton's theorem

Reference Books

1) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, and F. E.. Harris, 2013, 7th Edn., Elsevier.

2) An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI

3) Learning Differential Equations, George F. Simmons, 2007, McGraw Hill.

4) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

5) Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book

6) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge University Press

Lab Part

1) First order ODE Solution of first order Differential equation Euler, modified Euler and Runge-Kutta second order methods. First order differential equation (a) Current in RC, LC circuits with DC source (b) Classical equations of motion.

2) Second order ODE Second order differential equation. Fixed difference method. Second order Differential Equation (a) Harmonic oscillator (no friction) (b) Damped Harmonic oscillator (c) Over damped (d) Critical damped.

3) Partial Differential Equation (PDE) Solution of Partial Differential Equation: (a) Wave equation (b) Heat equation.

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY7204M : Astronomy & Astrophysics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course has been designed with the aim to have a solid grounding in the underlying principles and important conceptual models from core subject areas of astronomy and physics and demonstrate their ability to correctly draw logical conclusions from these principles and models, enabling them to make accurate quantitative predictions in astronomical contexts.

Course Outcome: This part of the course contains introduction to the Basic concepts of Astronomy and techniques related to the observational astronomy. This forms the basic foundation, leading to the understanding of the basic physical principles of stars and stellar systems. This will help the students to realise the underlying principles of physics and their application in Astronomy & Astrophysics.

Theory Part

Section I : Astrophysical Co-ordinate *(Lectures 10)*

Celestial coordinate systems, The right Ascension, Declination and Altitude-Azimuth coordinate systems. The ecliptic and annual motion of the Sun across the sky the Signs of Zodiac. Identifications of the Constellations and bright stars.

Section II : Basics of Astronomy *(Lectures 13)*

Stellar Magnitude system and Distance measurement: The Stellar magnitude system and its relation with luminosity. Apparent and absolute magnitude and their relations with distances. Trigonometric and spectroscopic parallax to determine the distances. Difference magnitude systems. Spectral classification, color index, HD classification. The HR Diagram.

Section III : Stellar Evolution *(Lectures 11)*

Pre main sequence steller evolution and the evolutionary track of a star, Physics of Main Sequence stars, Low and high mass stars' post main sequence steller evolution and the evolutionary tracks, White Dwarf stars, Neutron stars and Black Holes (qualitative discussions only)

Section IV : Asteroids, Meteors, Comets & Galaxies *(Lectures 11)*

Asteroids: Discovery and designation, Origin, Nature and Orbits of Asteroids. Meteors : Meteor showers and sporadic meteors. Comets : Periodic comets, Brightness variation in Comets. Gas production rates, dust and ion tails. The Milky way, Hubble's morphological classification of galaxies, The tuning fork diagram -Spiral galaxies, Elliptical galaxies, Irregular galaxies, Dwarf galaxies, and their observational properties

Reference Books

1) Introduction to Astrophysics - H.L. Duorah & Kalpana Duorah

2) ASTRONOMY - a Self Teaching Guide - Dinah L. Moche

3) Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.

4) Astrophysics - Stars and Galaxies, K. D. Abhyankar, University Press, 2001.

5) Introduction to Stellar Astrophysics, Vol. 3 : Stellar structure and evolution -Erika Bohm-Vitense

6) Introduction to Astronomy & Cosmology by I. Morrison (Wiley, 2008)

Lab Part

1) Construction of a Galilean telescope.

2) Construction of a Newtonian telescope.

3) Measuring the size of the Sun

4) Measuring the size of the Moon

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY8104M : Modern Optics

Total lectures : 45(L+T) & 30 (P) **Credits : 4 (Theory: 03, Lab: 01)**

Course Objective: This course has been designed to give the basic knowledge on spectroscopic techniques that use lasers and theoretical background on lasers and the interaction between laser radiation and matter. The course also provides knowledge of the techniques and instrumentation for laser physics.

Course Outcome: Student will be able to understand the physics behind electronic spectra and other associated phenomenon and also also come to know various principles along with types of Lasers which will in turn lead to laser spectroscopy.

Theory Part

Section I : Molecular spectra *(Lectures 12)*

IR spectra - Rotation, vibration and rotation-vibration spectra of diatomic molecules, selection rules, determi- nation of rotational constants. Electronic spectra: Born-Oppenheimer approximation, vibrational structure of electronic transition, progressions and sequences of vibrational bands, Intensity distribution, Franck Condon principle. Raman spectra: Classical theory of Raman effect, Vibrational Raman spectrum, selection rules, Stokes and anti-Stokes lines, Rotational Raman spectrum, selection rule.

Section II : Fluorescence spectra *(Lectures 10)*

Luminescence: fluorescence and phosphorescence, Jablonski diagram, Characteristics of fluorescence emission, Fluorescence lifetimes and Quantum Yields, Fluorescence anisotropy, Resonance energy transfer, Steady state and Time-resolved fluorescence, Molecular information from fluorescence.

Section III : Laser *(Lectures 12)*

Resonators : Modes of a resonant cavity: Longitudinal & transverse laser modes; stability condition; properties of Gaussian beams; single and multimode oscillations; Q switching: requirements, techniques, pulse duration and width; mode locking: intensity, pulse separation, techniques. Types of lasers: 2, 3 and 4-level lasers: rate equations; Ruby, CO2, semiconductor, Nd:YAG and dye lasers: excitation mechanisms.

Section IV : Nonlinear optics *(Lectures 11)*

Nonlinear susceptibility, second harmonic generation, phase matching, parametric oscillation, intensity- dependent refractive index: self-focusing, phase conjugation: four wave mixing.

Reference Books

1) Laser Fundamentals - W T Silfvast.

2) Principles of fluorescence spectroscopy - J R Lakowicz.

3) Essentials of Laser and Nonlinear Optics - G D Baruah.

4) Molecular Spectra and Molecular Structure (Vol. 2) - G Herzberg.

Lab Part

1) Analysis of vibrational spectra of PN molecule.

2) Analysis of rotational Raman spectrum.

2) Rydberg constant using Hydrogen emission lines.

3) Rydberg constant using Hydrogen absorption lines.

4) Verification of Hartmann formula for prism spectrogram

Reference

1) Lab manuals.

2) Practical notes/ Books suggested by the Lab Instructor.

PHY8204M : Experimental Techniques

Total lectures : 60(L+T) **Credits : 4 (Theory: 04, Lab: 00)**

Course Objective: This course is not a "lab course", but rather seeks to introduce students to basic experimental techniques, measurement theory and experiment design. The primary goal is to develop an appreciation of the role and significance of experimentation in the field of science. Students will be exposed to some widely employed experimental techniques and be introduced to some of the instrumentation that is used in experimental physics research.

Course Outcome: Students will learn the systematic procedure for performing an experiments along with the various conditions generally performed under. They will also learn the various tools which will help them in future studies

Theory Part

Section I : Measurement fundamentals & Uncertainty in measurements *(Lectures 15)*

Measurement, Calibration, Errors, Accuracy, Precision, Uncertainty, Repeatability, Reproducibility. Mean, median and mode of discrete and grouped data, geometric mean, harmonic mean and weighted mean. Dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis. Kinds of errors - Gross, Systematic and random errors. Types of Uncertainty: Type A and B, Measurement of Uncertainty, Propagation of errors.

Section II : Correlation, Regression & Goodness of Fit test *(Lectures 15)*

Positive and negative correlation, scatter plot, Karl Pearson coefficient of correlation. Regression - line of regression. least square method, chi-squared test

Section III : Low pressure & Temperature *(Lectures 15)*

Gas flow at low pressures, Principles of pumping, parameters and classifications of vacuum pumps, Mechanical pumps, Vapour pumps, Ion pumps, Sorption pumps, Cryopumps, Classification and selection of vacuum gauges, Gauges using liquids, Thermal conductivity gauges, Ionization gauges, Calibration of vacuum gauges.

Section IV : Measuring equipments *(Lectures 15)*

XRD, XRF, SEM, TEM, Absorption spectrophotometer, Spectrofluorometer, Raman Spectrometer, ESR, NMR.

Reference Books

1) A. Roth, Vacuum Technology, 3rd edition, Elsevier Science B.V., 1996.

2) F. Pobell, Matter and Methods at Low Temperatures, Springer-Verlag, 1992.

3) B. D. Cullity and S. R. Stock, Elements of X-ray Diffraction, Prentice Hall, 2001

4) Les Kirkup and Bob Frenkel. An Introduction to Uncertainity in Measurement, Cambridge University Press.