

**School of Pure and Applied Sciences**

**Course Structure and Syllabi**

**B. Sc. (Physics Major)**

**Academic Programmes: 2018-2021**

**Total Credits for Batch Commencing in 2018: 153**

**Credit Scheme (Category wise): For Physics Major Only**

**Course(s) Foundation Core** **Specialized Interdisciplinary General** **Total**

**Credits**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Credits** | **18** | **13** | **32** | **-** | **-** | **63** |

**Credit Scheme (Total Credits Semester wise)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Semester** | **First** | **Second** | **Third** | **Fourth** | **Fifth** | **Sixth** | **Total** |
|  |  |  |  |  |  |  | **Credits** |
|  |  |  |  |  |  |  |  |
| **Credits** | **27** | **24** | **24** | **26** | **26** | **26** | **153** |
|  |  |  |  |  |  |  |  |

**Course Module-II**

**Semester I**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Lecture** | **Tutorials** | **Practical** | **Total** |  |
| **S. No.** | **Subject** | **(Hr.)** | **(Hrs.)** | **(Hrs.)** | **Credits** | **Category** |
| **BPH001A** | **Major- 1** | **4** | **-** |  | **4** | **F** |
|  |  |  |
| **BPH002A** | **Major- 2** | **4** | **-** |  | **4** | **F** |
|  |  |  |
| **BPH003A** | **Mechanical Workshop-I** |  |  | **2** | **1** | **F** |
|  |  |  |  |
| **BPH004A** | **Mechanical Workshop-II** |  |  | **2** | **1** | **F** |
|  |  |  |  |
|  | **Minor-1** | **4** |  | **2** | **5** |  |
|  | **Minor-2** | **4** |  | **2** | **5** |  |
| **BMC001A** | Computer Applications-I | **2** |  |  | **2** | **F** |
| **BMC002A** | Computer Lab-I |  |  | **2** | **1** | **F** |
| **BMC051A** | Environmental Studies | **3** |  | 1 | **4** | **C** |
|  | **Total Credits** |  |  |  | **27** |  |
| **Semester II** |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  | **Lecture** | **Tutorials** | **Practical** | **Total** |  |
| **S. No.** | **Subject** | **(Hr.)** | **(Hrs.)** | **(Hrs.)** | **Credits** | **Category** |
| **BPH005A** | **Major- 1** | **4** | **-** |  | **4** | **F** |
|  |  |  |  |
| **BPH006A** | **Major- 2** | **4** | **-** |  | **4** | **C** |
|  |  |  |  |
| **BPH007B** | **Thermodynamics Lab** |  |  | **2** | **1** | **C** |
|  |  |  |  |  |
| **BPH008B** | **Optics Lab** |  |  | **2** | **1** | **F** |
|  |  |  |  |  |
|  | **Minor-1** | **4** | **-** | **2** | **5** |  |
|  | **Minor-2** | **4** | **-** | **2** | **5** |  |
| **BMC 003A** | Computer Application-II |  |  | **2** | **1** | **G** |
|  | (Advanced MS-Excel) |  |  |  |
| **BMC 102A** | Communication Skills | **3** |  |  | **3** | **F** |
|  |  |  |  |  |  |  |
|  | **Total Credits** |  |  |  | **24** |  |

**Semester III**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Lecture** | **Tutorials** | **Practical** | **Total** |  |
| **S. No.** | **Subject** | **(Hr.)** | **(Hrs.)** | **(Hrs.)** | **Credits** | **Category** |
| **BPH009A** | **Major- 1** | **4** | **-** |  | **4** | **C** |
|  |  |  |  |
| **BPH010A** | **Major- 2** | **4** | **-** |  | **4** | **C** |
|  |  |  |  |
| **BPH011A** | **Mechanics Lab** |  |  | **2** | **1** | **S** |
|  |  |  |  |  |
| **BPH012A** | **Electricity and Magnetism** |  |  |  |  | **S** |
|  | **Lab** |  |  | **2** | **1** |  |
|  |  |  |  |  |
|  | **Minor-1** | **4** | **-** | **2** | **5** |  |
|  | **Minor-2** | **4** | **-** | **2** | **5** |  |
| **BMC 004A** | Computer Application-III(MS- |  |  | **2** | **1** | **G** |
|  | Projects) |  |  |  |
| **BMC105A** | Communication Skills | **3** |  |  | **3** | **F** |
|  |  |  |  |  |  |  |
|  | **Total Credits** |  |  |  | **24** |  |

**Semester IV**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | **Lecture** | **Tutorials** | **Practical** | **Total** |  |
| **S. No.** | **Subject** |  |  | **(Hr.)** | **(Hrs.)** | **(Hrs.)** | **Credits** | **Category** |
| **BPH013A** | **Major- 1** |  |  | **4** | **-** |  | **4** | **S** |
|  |  |  |  |  |  |
| **BPH014A** | **Major- 2** |  |  | **4** | **-** |  | **4** | **S** |
|  |  |  |  |  |  |
| **BPH015B** | **Computational** | **Lab:** |  |  |  |  | **S** |
|  | **Special** | **Theory** | **of** |  |  |  |  |  |
|  | **Relativity** |  |  |  | **2** | **1** |  |
|  |  |  |  |  |  |  |
| **BPH016B** | **Computational** | **Lab:** |  |  |  |  | **S** |
|  | **Quantum Mechanics** |  |  |  | **2** | **1** |  |
|  |  |  |  |  |  |  |
|  | **Minor-1** |  |  | **4** | **-** | **2** | **5** |  |
|  | **Minor-2** |  |  | **4** | **-** | **2** | **5** |  |
| **BMC 005A** | Computer Application-IV (Web | **2** |  |  | **2** | **S** |
|  |  | Designing) |  |  |  |  |
| **BMC 006A** | Computer Application-IV (Web |  |  | **2** | **1** | **S** |
|  | Designing Lab) |  |  |  |  |
| **BMC111A** | Communication Skills |  | **3** |  |  | **3** | **F** |
|  | **Total Credits** |  |  |  |  | **26** |  |

**Semester V**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Lecture** | **Tutorials** | **Practical** | **Total** |  |
| **S. No.** | **Subject** |  | **(Hr.)** | **(Hrs.)** | **(Hrs.)** | **Credits** | **Category** |
| **BPH017A** | **Major- 1** |  | **4** | **-** |  | **4** | **S** |
|  |  |  |  |  |
| **BPH018A** | **Major- 2** |  | **4** | **-** |  | **4** | **S** |
|  |  |  |  |  |
| **BPH019A** | **Solid State Electronics Lab** |  |  | **2** | **1** | **S** |
|  |  |  |  |  |  |
| **BPH020A** | **Electronics** | **and** |  |  |  |  | **S** |
|  | **Optoelectronics Lab** |  |  |  | **2** | **1** |  |
|  |  |  |  |  |  |
|  | **Minor-1** |  | **4** | **-** | **2** | **5** |  |
|  | **Minor-2** |  | **4** | **-** | **2** | **5** |  |
| **BMC109A** | Value Education |  | **3** |  |  | **3** | **G** |
| **BMC113A** | Communication Skills |  | **3** |  |  | **3** | **F** |
|  | **Total Credits** |  |  |  |  | **26** |  |

**Semester VI**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | **Lecture** | **Tutorials** | **Practical** | **Total** |  |
| **S. No.** | **Subject** |  |  | **(Hr.)** | **(Hrs.)** | **(Hrs.)** | **Credits** | **Category** |
| **BPH021A** | **Major- 1** |  |  | **4** | **-** |  | **4** | **S** |
|  |  |  |  |  |  |
|  | **Major- 2 (Elective Paper)** | **4** | **-** |  | **4** | **S** |
|  |  |  |  |  |  |
| **BPH030A** | **Basic** | **Electrical** | **and** |  |  |  |  | **S** |
|  | **Electronics Lab-I** |  |  |  | **2** | **1** |  |
|  |  |  |  |  |  |  |
| **BPH031A** | **Basic** | **Electrical** | **and** |  |  |  |  | **S** |
|  | **Electronics Lab-II** |  |  |  | **2** | **1** |  |
|  |  |  |  |  |  |  |
|  | **Minor-1** |  |  | **4** | **-** | **2** | **5** |  |
|  | **Minor-2** |  |  | **4** | **-** | **2** | **5** |  |
| **BCE026A** | Project (and Seminar) |  |  |  |  | **6** | **C** |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  | **Total Credits** |  |  |  |  | **26** |  |

**Credits for B.Sc. (Physics Major) Courses**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Course Code** | **Paper** |  | **Credits** | **Category** |
|  |  |  |  |  |
|  | **Semester-I** |  |  |  |
|  |  |  |  |  |
| **BPH001A** | **Mathematical Physics** |  | **4** | **F** |
|  |  |  |  |  |
| **BPH002A** | **Waves and Oscillations** |  | **4** | **F** |
|  |  |  |  |  |
| **BPH003A** | **Mechanical Workshop-I** |  | **1** | **F** |
|  |  |  |  |  |
| **BPH004A** | **Mechanical Workshop-II** |  | **1** | **F** |
|  |  |  |  |  |
|  | **Total Credits** |  | **10** |  |
|  |  |  |  |
|  |  |  |  |  |
|  | **Semester-II** |  |  |  |
|  |  |  |  |  |
| **BPH005A** | **Thermodynamics** |  | **4** | **F** |
|  |  |  |  |  |
| **BPH006A** | **Optics** |  | **4** | **C** |
|  |  |  |  |  |
| **BPH007B** | **Thermodynamics Lab** |  | **1** | **C** |
|  |  |  |  |  |
| **BPH008B** | **Optics Lab** |  | **1** | **F** |
|  |  |  |  |  |
|  | **Total Credits** |  | **10** |  |
|  |  |  |  |
|  |  |  |  |  |
|  | **Semester-III** |  |  |  |
|  |  |  |  |  |
| **BPH009A** | **Mechanics and Properties of Matter** |  | **4** | **C** |
|  |  |  |  |  |
| **BPH010A** | **Electricity and Magnetism** |  | **4** | **C** |
|  |  |  |  |  |
| **BPH011A** | **Mechanics Lab** |  | **1** | **S** |
|  |  |  |  |  |
| **BPH012A** | **Electricity and Magnetism Lab** |  | **1** | **S** |
|  |  |  |  |  |
|  | **Total Credits** |  | **10** |  |
|  |  |  |  |
|  |  |  |  |  |
|  | **Semester-IV** |  |  |  |
|  |  |  |  |  |
| **BPH013A** | **Special Theory of Relativity** |  | **4** | **S** |
|  |  |  |  |  |
| **BPH014A** | **Quantum Mechanics** |  | **4** | **S** |
|  |  |  |  |  |
| **BPH015B** | **Computational Lab: Special Theory** | **of** | **1** | **S** |
|  |  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Relativity** |  |  |
|  |  |  |  |
| **BPH016B** | **Computational Lab: Quantum Mechanics** | **1** | **S** |
|  |  |  |  |
|  | **Total Credits** | **10** |  |
|  |  |  |
|  |  |  |  |
|  | **Semester-V** |  |  |
|  |  |  |  |
| **BPH017A** | **Solid State Physics** | **4** | **S** |
|  |  |  |  |
| **BPH018A** | **Electronics (Solid State Electronic Devices)** | **4** | **S** |
|  |  |  |  |
| **BPH019A** | **Solid State Electronics Lab** | **1** | **S** |
|  |  |  |  |
| **BPH020A** | **Electronics and Optoelectronics Lab** | **1** | **S** |
|  |  |  |  |
|  | **Total Credits** | **10** |  |
|  |  |  |
|  |  |  |  |
|  | **Semester-VI** |  |  |
|  |  |  |  |
| **BPH021A** | **Nuclear and Particle Physics** | **4** | **S** |
|  |  |  |  |
|  | **Elective Paper\*** | **4** | **S** |
|  |  |  |  |
| **BPH030A** | **Basic Electrical and Electronics Lab-I** | **1** | **S** |
|  |  |  |  |
| **BPH031A** | **Basic Electrical and Electronics Lab-II** | **1** | **S** |
|  |  |  |  |
|  | **Total Credits** | **10** |  |
|  |  |  |
|  |  |  |  |
|  | **Elective Paper(s)** | **4** | **S** |
|  |  |  |  |
| **BPH022A** | **Computational Physics** | **4** | **S** |
|  |  |  |  |
| **BPH023A** | **Digital Electronics** | **4** | **S** |
|  |  |  |  |
| **BPH024A** | **Statistical Mechanics** | **4** | **S** |
|  |  |  |  |
| **BPH025A** | **Atomic & Molecular Spectroscopy** | **4** | **S** |
|  |  |  |  |
|  |  |  |  |
| **BPH026A** | **Project (and Seminar)** | **6** | **C** |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

**PEO-I**

Graduates will demonstrate proficiency in problem solving and analysis.

**PEO-II**

Graduates will demonstrate expertise with core physics concepts and their application. **PEO-III**

Graduates will demonstrate the ability to function effectively in a laboratory environment and to pursue independent research.

**PEO-IV**

Students will be provided with an educational foundation that prepares them for excellence, leadership roles along diverse career paths with encouragement to professional ethics and active participation needed for a successful career.

Program Outcome (PO’s)

**A graduate of the B.Sc. (Physics) Program will demonstrate:**

PO1.Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2.Effective Communication: Speak, read, write and listen clearly in person and through electronic media in English and in one Indian language, and make meaning of the world by connecting people, ideas, books, media and technology.

PO3. Social Interaction: Elicit views of others, mediate disagreements and help reach conclusions in group settings. Manual for Universities NAAC for Quality and Excellence in Higher Education 137

PO4. Effective Citizenship: Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

PO5. Ethics: Recognize different value systems including your own, understand the moral dimensions of your decisions, and accept responsibility for them.

PO6. Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

PO7. Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context sociotechnological changes

**Program Specific Outcome:**

PSO1. Understand the nature and basic concepts of optics, thermodynamics, waves and oscillations and mathematical physics.

PSO2. Analyse the relationships among principle and laws of physics with real world.

PSO3. Understand the applications of physical sciences in science and technology.

**Semester I**

**BPH001A: Mathematical Physics** **Credit(s): 4**

**Unit-I**

**Dirac Delta Function:** Definition. Representation and Properties of Dirac Delta Function.

**Theory of Errors:** Systematic and Random Errors. Propagation of Errors. Normal Law ofErrors. Standard and Probable Error

**Some Special Integrals:** Beta and Gamma Functions and Relation between them. Expression ofIntegrals in terms of Gamma Functions. Error Function (Probability Integral).

**Unit-II**

**Vector Calculus:** Vector Differentiation. Scalar and Vector Fields. Ordinary and PartialDerivative of a Vector w.r.t. coordinates. Space Curves. Unit Tangent Vector and Unit Normal Vector (without Frenet- Serret Formulae). Directional Derivatives and Normal Derivative. Gradient of a Scalar Field and its Geometrical Interpretation. Divergence and Curl of a Vector Field. Del and Laplacian Operators. Vector Identities. Vector Integration**:** Ordinary Integral of Vectors. Line, Surface and Volume Integrals. Flux of a Vector Field. Gauss’ Divergence Theorem, Green’s Theorem and Stokes Theorem.

**Unit-III**

**Orthogonal Curvilinear Coordinates:** Orthogonal Curvilinear Coordinates. Derivation of

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

**Unit-IV**

**Fourier Series:** Fourier Series. Dirichlet Conditions (Statement only). Kronecker’s Method for

Computation of Fourier Coefficients. Even and Odd Functions. Orthogonality of Sine and Cosine

functions. Sine and Cosine Series. Applications: Square Wave, Triangular Wave, Output of Full Wave Rectifier and other Simple Functions. Summing of Infinite Series Term-by-Term Differentiation and Integration of a Fourier Series.

**Unit-V**

**Calculus of Variations**

Variational Calculus: Variational Principle. Concept of Lagrangian. Generalized Coordinates. Definition of Canonical Momenta. Euler-Lagrange’s Equations of Motion and its Applications to Simple Problems: (e.g., simple pendulum and one dimensional harmonic oscillator).

**Suggested Books**

1. George Arfken: Mathematical Methods for Physicists, Academic Press.
2. L. A. Pipes: Applied Mathematics for Engineers & Physicists, McGraw Hill.
3. Merle C. Potter and Jack Goldberg: Mathematical Methods, PHI.
4. Fredrick W. Byron and Robert W. Fuller: Mathematics of Classical and Quantum Physics, Dover

Publications.

1. M. R. Spiegel: Vectors Analysis, Schaum’s Outline Series.

**Course Outcome (CO):**

Upon completion of this course, students should be able to:

*CO-1 apply special mathematical function appropriately in solving problems in physics CO-2 understand the Dirac Delta, Fourier series and other distributions and be able to derive their various properties*

*CO-3 apply techniques of vector calculus, to the study of special functions of mathematical*

*physics*

*CO-4 understand calculus of variation in different problems*

*CO-5have confidence in solving mathematical problems arising in physics by a variety of mathematical techniques*

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

***Course*** ***Program Outcome*** ***Program Specific***

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Outcome*** |  |  |  |  |  |  |  | ***Outcome*** |
|  |  |  |  |  |  |  |  |  |  |  |
|  | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PSO1 | PSO2 | PSO3 |
|  |  |  |  |  |  |  |  |  |  |  |
| CO1 |  |  | H | H |  | L |  | H |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| CO2 |  |  | L |  |  | M |  | H |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| CO3 |  | H |  |  |  |  | H |  | L |  |
|  |  |  |  |  |  |  |  |  |  |  |
| CO4 |  |  |  |  | M |  |  |  |  | M |
|  |  |  |  |  |  |  |  |  |  |  |
| CO5 |  | L |  |  | M |  | L |  | M |  |
|  |  |  |  |  |  |  |  |  |  |  |

H = Highly Related; M = Medium; L = Low

**BPH002A: Waves and Oscillations** **Credit(s): 4**

**Unit-I**

**Oscillations in Arbitrary Potential Well**: Simple Harmonic Oscillations. Differential Equationof SHM and its Solution. Amplitude, Frequency, Time Period and Phase. Velocity and Acceleration. Kinetic, Potential and Total Energy and their Time Average Values. Reference Circle. Rotating Vector Representation of SHM.

Free Oscillations of Systems with One Degree of Freedom: (1) Mass-Spring system, (2) Simple Pendulum, (3) Torsional Pendulum, (4) Oscillations in a U-Tube, (5) Compound pendulum: Centres of Percussion and Oscillation, and (6) Bar Pendulum.

**Unit-II**

**Driven Oscillations**: Damped Oscillations: Damping Coefficient, Log Decrement. ForcedOscillations: Transient and Steady States, Amplitude, Phase, Resonance, Sharpness of Resonance, Power Dissipation and Quality Factor. Helmholtz Resonator.

**Coupled Oscillators**: Normal Coordinates and Normal Modes. Energy Relation and EnergyTransfer. Normal Modes of N Coupled Oscillators.

**Unit-III**

**Wave Motion**: Plane and Spherical Waves. Longitudinal and Transverse Waves. PlaneProgressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave. Water Waves:

**Velocity of Waves**: Velocity of Transverse Vibrations of Stretched Strings. Velocity ofLongitudinal Waves in a Fluid in a Pipe. Newton’s Formula for Velocity of Sound. Laplace’s Correction.

**Unit-IV**

Elastic Waves in Solid Rod. Pressure Waves in Glass Columns. Transverse Waves in Strings. Waves in Three Dimensions. Spherical Waves. Plane Electromagnetic Waves. Energy and Momentum of Plane EM Waves. Radiation Pressure. Radiation Resistance of free space. EM Waves in dispersive Media. Spectrum of EM Waves.

**Unit-V**

**Ultrasonics:** Production of ultrasonic waves. Echo; Reverberation, reverberation time, Sabine‟sformula, remedies over reverberation; Absorption of sound, absorbent materials; Conditions for good acoustics of a building; Noise, its effects and remedies. **Piezoelectric effect**. Detection of ultrasonic waves: Piezoelectric detector. Kundt’s tube method. Sensitive flame method. Thermal detector method. Properties of ultrasonic waves. Cavitation. Acoustic grating. Velocity measurements.

Industrial Applications of Ultrasonics: Drilling. Welding. Soldering. Ultrasonic cleaning.

**SONAR**: Non-destructive testing. Pulse echo technique. Transmission technique. Resonance.

Medical Applications: Echocardiograms/Sonogram. Ultrasonic Imaging (Scandisplay).

***Suggested Books***

1. A. P. French: Vibrations and Waves, CBS Pub. & Dist., 1987.
2. K. Uno Ingard: Fundamentals of Waves & Oscillations, Cambridge University Press, 1988.
3. Daniel Kleppner and Robert J. Kolenkow: An Introduction to Mechanics, McGraw-Hill, 1973.
4. Franks Crawford, Waves: BERKELEY PHYSICS COURSE (SIE), Tata McGrawHill, 2007.
5. M. S. Seymour Lipschutz: Schaum's Outline of Vector Analysis, McGraw-Hill, 2009.
6. D. E. Bourne, P C Kendall: Vector Analysis and Cartesian Tensors, Chapman & Hall,

**COURSE OUTCOMES OF WAVE AND OSCILLATION**

CO-1 Oscillations, waves and wave equation to find out the relationship between the speed of propagation of waves and the physical properties of the string.

CO-2 To understand how stationary / standing waves are produced by the superposition of incident and reflected waves in string fixed at the both ends.

CO-3 Know the different modes of vibrating in the string and find out how different harmonics can be produced.

CO-4 Understand and be able to derive and solve the equations for a forced oscillator; understand the concept of resonance and the response of a system (amplitude and phase, power dissipation) as a function of driving frequency and the effects of transients.

CO-5Understand the basic concept of ultrasonic.

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO5* | *H* |  | *H* |  | *H* |  |  | *H* |  | *L* |
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H = Highly Related; M = Medium L = Low

**BPH003A: MECHANICAL WORKSHOP-I**

**BPH004A: MECHANICAL WORKSHOP-II**

**Credit(s): 1**

**Credit(s): 1**

**List of Exercises**

**Machine Shop Fitting Shop**

Study of lathe machine, drilling machine and shaper, their parts and

demonstration of operations performed on them.

1. Prepare a job on lathe machine by performing turning, facing and

chamfering as per given drawing.

2. Prepare a job on shaper as per given drawing.

Study of fitting tools, their uses and demonstration of operations by

using different tools.

1. Prepare a job including finishing of all four sides by filing and make a square notch.

4. Prepare a job by finishing its two sides and perform drilling and taping on it.

**Carpentry Shop** Study of wood and wood working, tools used in carpentry shop and their applications.

1. Prepare a T-lap/Cross lap joint.
2. Prepare a bridle joint.

**Welding Shop** Definition of welding and brazing process and their applications. Study of tools used in arc and gas welding shop.

1. Prepare a lap/butt joint in arc welding shop.
2. Demonstration of different types of flames in gas welding shop.
3. Study of common welding defects.

**Foundry Shop** Study of moulding and casting process, moulding sand, foundry tools and patterns used for moulding.

10 Prepare a mould by using a given pattern.

11 Making and baking of dry sand cores for placing in horizontal, vertical and hanging positions in the mould cavity.

**Tin Smithy Shop** Study of sheet metal workshop, tools used in smithy shop and soldering

|  |  |
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| 12 | Prepare a mechanical joint and perform soldering on it. |
| 13 | Prepare a funnel as per given drawing. |

***Suggested Books*:**

1. Hajra Choudhury Workshop Technology Vol 1 & 2, Media Promoters & Publishers P. Ltd,Bombay.
2. Chapman W. A. J., *Workshop* Technology Parts 1 & 2, Viva Books P. Ltd., New Delhi.

**COURSE OUTCOMES OF MECHANICAL WORKSHOP**

CO-1 Student will be able to make various joints in the given object with the available work material.

CO-2 Student will be able to know how much time a joint will take for the assessment of time

CO-3 Students will be able to learn welding.

CO-4 Students will be able to learn welding.

CO-5 Students will be able to learn molding and casting process

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO5* | *H* |  | *H* |  | *H* |  |  | *H* |  | *L* |
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H = Highly Related; M = Medium L = Low

**Semester II**

**BPH005A: Thermodynamics**

**Total Credit(s): 4**

**Unit-I**

**Second Law of Thermodynamics**: Reversible and Irreversible Changes. Conversion of Workinto Heat and Heat into Work. Heat Engines. Carnot Cycle. Carnot Engine and its Efficiency. Refrigerator and its Efficiency. Second Law of Thermodynamics : Kelvin-Planck and Clausius Statements and their Equivalence. Carnot Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

**Unit-II**

**Entropy**: Change in Entropy. Entropy of a State. Clausius Theorem. Clausius Inequality. SecondLaw of Thermodynamics in terms of Entropy. Entropy of a Perfect Gas. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Impossibility of Attainability of Absolute Zero: Third Law of Thermodynamics. Temperature-Entropy Diagrams. First and second order Phase Transitions.

**Unit-III**

**Thermodynamic Potentials**: Extensive and Intensive Thermodynamic Variables.Thermodynamic Potentials U, H, F and G: Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work. Cooling due to Adiabatic Memagnetization. Approach to Absolute Zero.

**Unit-IV**

**Kinetic Theory of Gases:** Distribution of Velocities: Maxwell-Boltzmann Law of Distributionof Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern’s Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom.

Law of Equipartition of Energy (No proof required). Specific Heats of Gases.

**Molecular Collisions**: Mean Free Path. Collision Probability. Estimates of Mean Free Path.Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.

**Unit-V**

**Real gases:** Behavior of Real Gases: Deviations from the Ideal Gas Equation. The VirialEquation. Andrew’s Experiments on CO2 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. Comparison with Experimental Curves. P-V Diagrams. Joule’s Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling.

**Phase Thransitions. Thermodynamic Potentials**.

***Suggested Books***

1. Enrico Fermi: Thermodynamics, Courier Dover Publications, 1956.
2. Meghnad Saha, B. N. Srivastava: A Treatise on Heat: Including Kinetic Theory of Gases,
	1. Thermodynamics and Recent Advances in Statistical Thermodynamics, Indian Press, 1958.

**COURSE OUTCOMES OF THERMODYNAMICS**

CO-1 Understand and correctly use thermodynamic terminology.

CO-2. Define the concepts of heat, work, and energy.

CO-3. Explain fundamental thermodynamic properties.

CO-4. Develop the General Energy Equation.

CO-5. Derive and discuss the first law of thermodynamics**.**

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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO5* | *H* |  | *H* |  | *H* |  |  | *H* |  | *L* |
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**BPH006A: Optics** **Total Credit(s): 4**

**Unit-I**

**Geometrical Optics**

Fermat’s Principle: Optical Path. Fermat’s Principle of Least Time or Extremum Path. Examples

of Fermat’s Principle: (1) Reflection and (2) Refraction.

**Wave Optics**

Nature of Light :- Theories of Light. Electromagnetic Nature of Light Definition of a Wave Front. Propagation of a Wave Front. Huygens Principle of Secondary Wavelets.

**Unit-II**

**Interference:** Interference: Division of Amplitude and Division of Wavefront. Young’s Double

Slit Experiment. Lloyd’s Mirror and Fresnel’s Biprism. Phase Change on Reflection: Stoke’s

treatment. Interference in Thin Films: Parallel and Wedge-shaped Films. Fringes of Equal Inclination (Haidinger Fringes) and Fringes of Equal Thickness (Fizeau Fringes). Newton’s Rings: Measurement of Wavelength and Refractive Index.

Michelson’s Interferometer: (1) Idea of form of fringes (No Theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, (5) Standardization of Meter and (6) Visibility of Fringes.

**Unit-III**

**Diffraction:** Fresnel diffraction: Fresnel’s Assumptions. Fresnel’s Half-Period Zones for PlaneWave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Comparison of a Zone plate with a Convex lens. Diffraction due to (1) a Straight Edge and (2) a Rectangular Aperture (Slit), (3) a Small Circular Aperture and (4) an Opaque Circular Disc. Fresnel’s Integrals, Cornu’s Spiral: Fresnel Diffraction Pattern due to a Straight Edge.

**Fraunhoffer diffraction:** Diffraction due to (1) a Single Slit, (2) a Double Slit and (3) a Plane

Transmission Grating. Rayleigh’s criterion of resolution. Resolving Power and Dispersive Power of a Plane Diffraction Grating.

**Unit-IV**

**Coherence**: Spatial and temporal coherence, Coherence length, Coherence time. Q- factor forLASER. Visibility as a Measure of Coherence. Spatial Coherence and Size of the Source. Temporal Coherence and Spectral Purity.

**LASER:** Theory of LASER action: Einstein’s coefficients, Threshold conditions for LASERAction. Method and Mechanism of production of He-Ne LASER. Semiconductor LASER. Elementary ideas of Q-switching and Mode Locking.

**Unit-V**

**Holography**: Holography versus photography. Basic theory of Holography. Applications ofHolography in Microscopy and Interferometry.

**Optical Communication**: Optical fiber as optical wave-guide. Numerical Aperture andMaximum Angle of Acceptance.

***Suggested Books***

1. F. A. Jenkins and Harvey Elliott White: Fundamentals of Optics, McGraw-Hill, 1976.
2. Ajoy Ghatak: Optics, Tata McGraw Hill, 2008.
3. Eugene Hecht and A R Ganesan: Optics, Pearson Education, 2002.
4. A. K. Ghatak & K. Thyagarajan: Contemporary Optics, Plenum Press, 1978.

**COURSE OUTCOMES OF OPTICS**

CO-1 Students will be able to explain the propagation of light in conducting and non-conducting media;

CO-2 Students will be able to define physics governing laser behaviour and light matter interaction;

CO-3 Students will be able to apply wave optics and diffraction theory to a range of problems;

CO-4 Students will be able to apply the principles of physics to materials used in optics and photonics;

CO-5 Students will be able to calculate the properties of propagation of laser beams

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

**Course** *Program Outcome* *Program Specific Outcome*

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| *CO2* |  | *M* |  |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO5* | *H* |  |  | *H* |  | *H* |  |  | *H* |  | *L* |
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| H = Highly Related; M = Medium L = Low |  |  |  |  |  |  |
| **BPH007B: Thermodynamics Lab** |  |  |  |  |  | **Credit(s): 1** |

**N.B.: Students are required to perform at least 12 experiments**

**List of Experiments**

1. To determine **thermal conductivity** of a given material by **Lee’s apparatus**.
2. To determine specific heat of the given material.
3. **To verify Stefan’s law of radiations by using an incandescent lamp.**
4. **To study Adiabatic changes using Clement and de Sorme experiment.**

**5. To determine Callendar and Barne’s constant flow method.**

1. **To determine the mechanical equivalent of heat (J) by Electrical method (Joule’s Calorimeter)**
2. To study conduction: Composite wall experiment
3. To study convection: Pool Boiling experiment
4. To study convection: Experiment on heat transfer from tube-natural convection.
5. To study convection: Heat Pipe experiment.
6. To study convection: Heat transfer through fin-natural convection .
7. To study convection: Heat transfer through tube/fin-forced convection.
8. Study of any experiment on Stefan's Law, on radiation determination of emissivity, etc.
9. To study heat exchange: Parallel flow experiment.
10. To study heat exchange: Counter flow experiment.

**COURSE OUTCOMES OF Thermodynamics Lab**

CO-1 Ability to understand the basic concepts of thermodynamic such as temperature, pressure, system, properties, process, state, cycles and equilibrium.

CO-2 Ability to conduct experiments regarding the measurement and calibration of temperatures and pressures in groups.

CO-3 Ability to identify the properties of substances on property diagrams and obtain the data from property tables.

CO-4 Ability to define energy transfer through mass, heat and work for closed and control volume systems.

CO-5 Ability to apply the first Law of Thermodynamics on closed and control volume systems.

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO5* | *H* |  | *H* |  | *H* |  |  | *H* |  | *L* |
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H = Highly Related; M = Medium L = Low

**BPH008B: Optics Lab** **Credit(s): 1**

**N.B.: Students are required to perform at least 12 experiments from the following list:**

1. To determine the Height of a Building using a Sextant.
2. To determine **Resolving power** of **Telescope**.
3. To determine the wavelength of prominent lines of Mercury by using plane **Diffraction Grating**.
4. To determine **Dispersive Power** of a Prism using Mercury light source and **Spectrometer**.
5. To determine the **Specific Rotation** of **Glucose/Sugar Solution** by **Polarimeter**.
6. To determine the **wavelength of Sodium light using diffraction grating** and spectrometer.
7. To determine **wavelength of sodium light using Fresnel Biprism**.
8. To determine **wavelength of Sodium light by** **Newton’s Rings’ experiment**.
9. To determine the **Dispersive Power of a Plane Diffraction Grating**.
10. To determine **transmission coefficient** of a semi-transparent glass plate using **LB Photometer**.
11. To determine the **wavelength of LASER using Diffraction** of Single Slit.
12. To determine Young’s Modulus of glass-plate by Cornu’s experiment.

**COURSE OUTCOMES OF OPTICS Lab**

CO-1 The wave optics part of the lab will give the student a thorough fundamental knowledge within interferometry, coherence, polarization and diffraction.

CO-2 The student will become able to analyze and understand interference between plane waves and spherical waves, reflection and transmission of plane waves.

CO-3 Student will learn optical wave guiding within thin plates and optical fibers.

CO-4 The student will get a thorough knowledge of the polarization of light and its changes upon reflection and transmission.

CO-5 The student will learn to analyze the polarization in optical systems using different polarimeters.

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO5* | *H* |  | *H* |  | *H* |  |  | *H* |  | *L* |
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H = Highly Related; M = Medium L = Low

**Semester III**

**BPH009A: Mechanics and Properties of Matter** **Credit(s): 4**

**Unit-I**

**Work and Energy Theorem**: Work and Kinetic Energy Theorem. Conservative and Non-Conservative Forces. Potential Energy. Energy Diagram. Stable and Unstable Equilibrium. Gravitational Potential Energy. Elastic Potential Energy. Force as Gradient of Potential Energy. Work and Potential energy. Work done by Non-conservative Forces. Law of Conservation of Energy. Elastic and Inelastic Collisions between particles. Centre of Mass and Laboratory Frames.

**Unit-II**

**Rotational Dynamics:** Angular Momentum of a Particle and System of Particles. Torque.Conservation of Angular Momentum. Rotation about a Fixed Axis. Moment of Inertia. Calculation of Moment of Inertia for Rectangular, Cylindrical, and Spherical Bodies. Kinetic Energy of Rotation. Motion involving both Translation and Rotation.

**Unit-III**

**Elasticity:** Relation Between Elastic Coefficients. Twisting Torque on a Cylinder or Wire.

**Fluid Motion:** Kinematics of Moving Fluids: Poiseuille’s Equation for Flow of a Liquid througha Capillary Tube.

**Unit-IV**

**Gravitation and Central Force Motion:** Law of gravitation. Inertial and Gravitational Mass.

Potential and Field due to Spherical Shell and Solid Sphere.

Motion of a Particle under Central Force Field. Two Body Problem and its Reduction to One Body Problem and its Solution. The Energy Equation and Energy Diagram. Kepler’s Laws (Ideas Only). Orbits of Artificial Satellites.

**Unit-V**

**Inertial and Non- Inertial Systems:** Reference Frames: Inertial Frames and GalileanTransformations. Galilean Invariance and Conservation Laws. Non-inertial Frames and Fictitious

Forces. Uniformly Rotating Frame. Physics Laws in Rotating Coordinate Systems. Centrifugal forces: Coriolis Force and its Applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems.

***Suggested Books***

1. Daniel Kleppner, Robert J. Kolenkow: An introduction to mechanics, McGraw-Hill, 1973.
2. Charles Kittel,Walter Knight: Malvin Ruderman,Carl Helmholz,Burton Moyer,Mechanics Berkeley physics course.

3.D. S. Mathur: Mechanics, S. Chand & Company Limited, 2000.

**COURSE OUTCOMES OF Mechanics and Properties of Matter**

**CO-1 Students will understand the vectorial and scalar representation of forces and moments.**

**CO-2 Student will describe static equilibrium of particles and rigid bodies both in two dimensions and also in three dimensions**

**CO-3 Students will analyse the properties of surfaces & solids in relation to moment of inertia.**

**CO-4. Students will illustrate the laws of motion, kinematics of motion and their interrelationship.**

**CO-5. Students will comprehend the effect of Friction on general plane motion.**

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO5* | *H* |  | *H* |  | *H* |  |  | *H* |  | *L* |
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H = Highly Related; M = Medium L = Low

**BPH010A**: **Electricity and Magnetism** **Credit(s): 4**

**Unit-I**

**Electric Field:** Electric Field: Electric Field and Lines. Electric Field **E** due to a Ring of Charge. Electric Flux. Gauss’s law. Gauss’s law in Differential form. Applications of Gauss’s Law: **E** due to (1) an Infinite Line of Charge, (2) a Charged Cylindrical Conductor, (3) an Infinite Sheet of Charge and Two Parallel Charged Sheets, (4) a Charged Spherical Shell, (5) a Charged Conducting Sphere, (6) a Uniformly Charged Sphere, (7) Two Charged Concentric Spherical Shells and (8) a Charged Conductor. Force on the Surface of a Charged Conductor and Electrostatic Energy in the Medium surrounding a Charged Conductor.

**Unit-II**

**Electric Potential**: Line Integral of Electric Field. Electric Potential Difference and ElectricPotential V (Line integral). Conservative Nature of Electrostatic Field. Relation between **E** and V. Electrostatic Potential Energy of a System of Charges. Potential and Electric Field of (1) a Dipole, (2) A Charged Wire and (3) A Charged Disc. Force and Torque on a Dipole. Conductors in an Electrostatic Field. Description of a System of Charged Conductors. An Isolated Conductor and Capacitance. Method of Images and its Application to: (1) Plane Infinite Sheet and (2) Sphere. **Electrostatic Energy** of (1) A Point Charge; (2) A System of Point Charges; (3) A Uniform Sphere; and (4) A Capacitor.

**Unit-III**

**Dielectric Properties of Matter:** Dielectrics: Electric Field in Matter. Dielectric Constant.Parallel Plate Capacitor with a Dielectric. Polarization, Polarization Charges and Polarization Vector. Electric Susceptibility. Gauss’s law in Dielectrics. Displacement vector **D**. Relations between the three Electric Vectors. Capacitors filled with Dielectrics.

**Unit-IV**

**Magnetic Field:** Magnetic Effect of Currents: Magnetic Field **B**. Magnetic Force betweenCurrent Elements and Definition of **B.** Magnetic Flux. Biot-Savart’s Law: **B** due to (1) a Straight Current Carrying Conductor and (2) Current Loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere’s Circuital law (Integral and Differential Forms): B due to (1) a Solenoid and (2) a Toroid. Properties of **B.**

Forces on an Isolated Moving Charge. Magnetic Force on a Current Carrying Wire. Torque on a Current Loop in a Uniform Magnetic Field.

**Unit-V**

**Electromagnetic induction:** Faraday’s law (Differential and Integral forms). Lenz’s Law. Selfand Mutual Induction. Energy stored in a Magnetic Field. Maxwell’s equations.

***Suggested Books***

1. Edward M. Purcell: Electricity and Magnetism, McGraw-Hill Education, 1986.

1. Arthur F. Kip: Fundamentals of Electricity and Magnetism, McGraw-Hill, 1968.
2. J. H. Fewkes & John Yarwood: Electricity & Magnetism, Oxford Univ. Press, 1991.
3. David J. Griffiths: Introduction to Electrodynamics, Benjamin Cummings, 1998 (Also, PHI).

**COURSE OUTCOMES OF Electricity and Magnetism**

CO-1 Apply knowledge of electricity and magnetism to explain natural physical processes and related technological advances.

CO-2 Use an understanding of calculus along with physical principles to effectively solve problems encountered in everyday life, further study in science, and in the professional world.

CO-3 Design experiments and acquire data in order to explore physical principles, effectively communicate results, and critically evaluate related scientific studies.

CO-4 Assess the contributions of physics to our evolving understanding of global change and sustainability while placing the development of physics in its historical and cultural context

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low

**BPH011A: Mechanics Lab** **Credit(s): 1**

**N.B.: Students are required to perform at least 12 experiments**

1. To determine the Young's Modulus.
2. To determine the Modulus of Rigidity of a Wire by Maxwell’s needle.

3**.** To determine the Elastic Constants of a Wire by Searle’s method.

1. To verify Law of Parallelogram of Forces.
2. To verify Polygon law of forces.
3. To determine Support Reactions of a Simply Supported Beam.
4. To measure coefficient of Static Friction.
5. To Verify Lami’s Theorem.
6. To determine moment of inertia of a flywheel about its own axis of rotation.
7. To determine the coefficient of discharge of venturimeter.
8. To determine the coefficient of discharge, contraction & velocity of an orifice.
9. To verify the Bernoullis Theorem.
10. Determination of velocity of sound in air by observing standing waves using speaker, microphone and CRO.
11. Study of the random decay and determination of decay constant using statistical board.

**COURSE OUTCOMES OF Mechanics Lab** CO-1 Apply knowledge of Elasticity to explain natural physical processes.

CO-2 Use an understanding of Modulus further study in science. CO-3 Design experiments and acquires data in order to explore physical principles, effectively communicate results, and critically evaluate related scientific studies. CO-4 Assess the contributions of physics using Parallelogram of Forces

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| H = Highly Related; M = Medium L = Low |  |  |  |  |  |  |  |

**BPH012A: Electricity and Magnetism Lab** **Credit(s): 1**

**N.B.: Students are required to perform at least 12 experiments**

1. To use a Multimeter for measuring (a) Resistances, (b) A/C and DC Voltages, (c) AC and DC Currents, (d) Capacitances, and (e) Frequencies.
2. To convert a **Galvanometer into an Ammeter** of given range and calibrate it.
3. To convert a **Galvanometer into a Voltmeter** of given range and calibrate it.
4. To determine **specific Resistance** of a wire by **Carrey-Foster’s Bridge**.
5. To determine radius of a current carrying coil using **Tangent Galvanometer**.
6. To study **LCR circuit** characteristics.
7. To study **L-C transmission Line** and determine **attenuation coefficient**.
8. To study **R-C transmission Line** and determine **attenuation coefficient**.
9. To determine an unknown resistance using ***de-Sauty Bridge***.
10. To determine an unknown resistance using ***Anderson Bridge***.
11. To study charging and discharging of a capacitor and determine time constant.
12. To determine characteristics of **Solar Cell**. (Complete Kit)
13. Determination of value of Earth’s magnetic field (B-H) using Tangent Galvanometer.
14. To determine the magnetic field along an axis passing through the centre of current carrying coil using Tangent Galvanometer.

***Suggested Books***

1. Geeta Sanon: B. Sc. Practical Physics, 1st Edn. (2007), R. Chand & Co.
2. B. L. Worsnop and H. T. Flint: Advanced Practical Physics, Asia Publishing House, New Delhi.
3. Indu Prakash and Ramakrishna: A Text Book of Practical Physics, Kitab Mahal, New Delhi.

1. D. P. Khandelwal: A Laboratory Manual of Physics for Undergraduate Classes, Vani Publication House, New Delhi.

**COURSE OUTCOMES OF Electricity and Magnetism lab**

CO-1 Apply knowledge of electricity and magnetism to explain natural physical processes .

CO-2 Use an understanding of transmission lines to effectively solve problems encountered in

everyday life.

CO-3 Design experiments using bridges in order to explore physical principles

CO-4 Assess the contributions of physics to our evolving understanding of global change and sustainability while placing the development of physics in its historical and cultural context

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
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H = Highly Related; M = Medium L = Low

**Semester IV**

**BPH013A: Special Theory of Relativity** **Credit(s): 4**

**Unit-I**

**Tensors:** Transformation of co-ordinates. Einstein’s Summation Convention. Relation betweenDirection Cosines. Tensors. Algebra of Tensors. Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Pseudotensors. Invariant Tensors: Kronecker Delta. Alternating Tensors. Association of Antisymmetric Tensor of Order Two and Vectors. Vector Algebra and Calculus using Cartesian Tensors: Scalar and Vector Products, Scalar and Vector Triple Products.

**Unit-II**

**Michelson-Morley Experiment and its Outcome**.

**Transformations**: Galilean Transformations. Postulates of Special Theory of Relativity. LorentzTransformations. Simultaneity and Order of Events.

**Unit-III**

Proper Time. Length Contraction. Time Dilation. Relativistic Transformation of Velocity, Relativistic Addition of Velocities. Frequency and Wave Number.

Mass-Energy equivalence principle. Variation of Mass with Velocity. Relativistic relation between energy and momentum. Relativistic Doppler effect. Relativistic Kinematics.

**Unit-IV**

**The idea of Space-Time and Minkowski Space**. Null-Cone representation. Metric Tensor.

**Four Vector Formalism**: Four Velocities, Four Momenta. Transformation of Energy andMomentum.

**Unit-V**

**Bucherer’s experiment. Segnac’s experiment.**

**Equivalence Principle. Mach’s Principle. Einstein’s Box Experiments.**

***Suggested Books***

1. David J. Griffiths: Introduction to Electrodynamics, Benjamin Cummings, 1998 (Also, PHI).
2. Arthur Beiser: Prospects in Modern Physics, McGraw-Hill Book Company (1998).
3. M. R. Spiegel: Vector Analysis, Schaum’s Outline Series.

**COURSE OUTCOMES OF Special Theory of Relativity** CO-1 Demonstrate and understanding of the basic principles of the special theory of relativity.

**CO-2** Perform basic calculations in relativistic kinematics.

**CO-3** Establish the non-existence of the hypothesised stationary ether through the null result ofMichelson-Morley experiments with interferometer.

**CO-4**. Explain the true nature of Newtonian mechanics and Lorentz Transformation equations.

**CO-5**. Understand the concept of constant relative motion of different bodies in different framesof references

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO-5* |  |  | *H* |  |  |  |  |  |  |  |
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| H = Highly Related; M = Medium L = Low |  |  |  |  |  |  |
| **BPH014A: Quantum Mechanics** |  |  |  |  |  | **Credit(s): 4** |

**Unit-I**

**Particles and Waves:** Inadequacies in Classical Physics. Blackbody Radiation: QuantumTheory of Light. Photoelectric Effect. Compton Effect. Franck-Hertz experiment. Wave Nature of Matter: De Broglie Hypothesis. Wave-Particle Duality. 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. Heisenberg’s Uncertainty Principle (Uncertainty Relations involving Canonical Pair of Variables): Derivation from Wave Packets. γ-ray Microscope.

**Unit-II**

Basic Postulates and Formalism: Energy, Momentum and Hamiltonian Operators. Time-independent Schrodinger Wave Equation for Stationary States. Properties of Wave Function. Interpretation of Wave Function. Probability Density and Probability. Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Expectation Values. Wave Function of a Free Particle.

**Unit-III**

**Applications of Schrödinger Wave Equation**

Eigen Functions and Eigenvalues for a Particle in a One Dimensional Box.

**Problems in One Dimension**: (1) Finite Potential Step: Reflection and Transmission. StationarySolutions. Probability Current. Attractive and Repulsive Potential Barriers. (2) Quantum Phenomenon of Tunneling: Tunnel Effect. Tunnel Diode (Qualitative Description). (3) Finite Potential Well (Square Well).

**Unit-IV**

**Bound State Problems**: General Features of a Bound Particle System, (1) One Dimensional

Simple Harmonic Oscillator: Energy Levels and Wave Functions. Zero Point Energy, (2) Quantum Theory of Hydrogen Atom: Particle in a Spherically Symmetric Potential. Schrodinger Equation. Separation of Variables. Radial Solutions and Principal Quantum. Number, Orbital and Magnetic Quantum Numbers.

**Unit-V**

**Sommerfeld’s Free Electron Gas Model and its Applications:** Density of energy states, Fermienergy levels. Determination of Specific Heats of solids. Band Theory of solids: Understanding Semiconductors. Band Gap in solids. Conductivity and Mobility due to electrons and Holes. Solar Cells.

***Suggested Books***

1. L. I. Schiff: Quantum Mechanics, 3rd edition, (McGraw Hill Book Co., New York 1968).
2. E. Merzbacher: Quantum Mechanics, 3rd edition, (John Wiley & Sons, Inc1997)
3. J. L. Powell & B. Crasemann: Quantum Mechanics, (Addison-Wesley Pubs.Co.,1965)
4. A. Ghatak & S. Lokanathan: Quantum Mechanics: Theory and Applications, 5th Edition, (Macmillan India , 2004)

**Course Outcomes**: On completion of the course the student shall be able to:

1. *Understand the fundamentals of Quantum Mechanics specifically the ‘Operator Mechanism in Quantum Mechanics’.*
2. *Understand the ‘Premise and Postulates of Quantum Mechanics’and make them understand Dirac’s ‘Bra and Ket representation’.*
3. *Understand the theory of ‘Quantum Linear Harmonic Oscillator’ and ‘The Idea of Creation and Annihilation Operators’.*
4. *Understand- ‘Theory of Angular Momentum in Quantum Mechanics’ and apply it to ‘Hydrogen-like Atom’ and ‘Spectroscopic Techniques’.*
5. *Understand and apply the mathematical techniques of ‘Total Angular Momentum’ including ‘selection rules’ and ‘Chlebsch-Gordon Coefficients’.*

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| *CO3* |  |  |  | *M* |  |  |  | *L* |  |  |
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| *CO4* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO5* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| H = Highly Related; M = Medium L = Low |  |  |  |  |  |  |
| **BPH015B: Computational Lab-I: Special Theory of Relativity** |  | **Credit(s): 1** |

1. To write programme to simulate motion of a projectile.
2. To write programme on length contraction formula and plot this expression.
3. To write programme on time-dialation formula and plot it geometrically.
4. To write programme on mass variation formula and plot this expression.
5. To write a program to simulate Doppler effect
6. To write the program to evaluate the expression for velocity addition theorem
7. To write programme to evaluate light-cone representation.

**In addition, students are advised to undergo the following virtual experience on Internet:**

V1-V11. Set of virtual experiments on ‘Special Theory of Relativity’:

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html>

V1. [**The Constancy of the Speed of Light**](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Constancy)

[The Michelson-Morley Experiment](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#MMExpt)

[http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/MichelsonMorley/Mich](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/MichelsonMorley/MichelsonMorley.html) [elsonMorley.html](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/MichelsonMorley/MichelsonMorley.html)

[Einstein "Explains" the Michelson-Morley Experiment](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Explains)

V2. [**Exploring the Consequences of Einstein's "Explanation"**](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Exploring)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/Flatland/Flatland.html>

**V3.** [**Spacetime:**](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Spacetime) [Spacetime Diagrams,](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Diagrams) **and** [The Dimensions of Spacetime](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Dimensions)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Surveyors>

[**Further Consequences of Einstein's Explanation**](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Further)

**V4.** [Time Dilation](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Time)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/TimeDilation.html>

V5. [Length Contraction](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Length)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/LengthContract.html>

V6. [Simultaneity](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Simultaneity)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/Simultaneity.html>

V7. [Relative Speeds](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#RelSpeeds)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#RelSpeeds>

V8. [Mass-Energy Equivalence](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#MassEnergy)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/MassEnergy.html>

V9. [The "Speed" of Objects](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#ObjectSpeed)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#RelSpeeds>

V10. [The Lorentz Contraction is Invisible](http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/SpecRel.html#Invisible)

<http://www.upscale.utoronto.ca/GeneralInterest/Harrison/SpecRel/Flash/ContractInvisible.html>

CO-1 Demonstrate and understanding of the basic principles of the special theory of relativity.

**CO-2** Perform basic calculations in relativistic kinematics.

**CO-3** Establish the non-existence of the hypothesised stationary ether through the null result ofMichelson-Morley experiments with interferometer.

**CO-4**. Explain the true nature of Newtonian mechanics and Lorentz Transformation equations.

**CO-5**. Understand the concept of constant relative motion of different bodies in different framesof references

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| *CO-5* |  |  | *H* |  |  |  |  |  |  |  |
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H = Highly Related; M = Medium L = Low

**BPH016B**: **Computational Lab-II: Quantum Mechanics** **Credit(s): 1**

1. To write programme to evaluate scalar potential due to electric charge.
2. To compute and plot electric potential due to two point charges.
3. To plot electric field vector due to electric charge(s).
4. To write programme to evaluate Schrӧdinger’s equation of motion.
5. To write a program to calculate the energy eigen values for harmonic oscillator (first 3energies)

6. To write programme to evaluate Heisenberg’s equation of motion.

7. To write a program to calculate probability of quantum mechanical tunneling.

**In addition, students are advised to undergo the following virtual experience on Internet:**

V1. [Quantifying the Uncertainty](http://www.saburchill.com/physics/chapters/0068.html)

<http://www.saburchill.com/physics/chapters/0068.html>

V2. For set of virtual experiments on electron diffraction

<http://www.uv.es/inecfis/QPhVL/index.html>

**Course Outcomes**: On completion of the course the student shall be able to:

1. *Understand the fundamentals of Quantum Mechanics specifically the ‘Operator Mechanism in Quantum Mechanics’.*
2. *Understand the ‘Premise and Postulates of Quantum Mechanics’and make them understand Dirac’s ‘Bra and Ket representation’.*
3. *Understand the theory of ‘Quantum Linear Harmonic Oscillator’ and ‘The Idea of Creation and Annihilation Operators’.*
4. *Understand- ‘Theory of Angular Momentum in Quantum Mechanics’ and apply it to ‘Hydrogen-like Atom’ and ‘Spectroscopic Techniques’.*
5. *Understand and apply the mathematical techniques of program for Schrödinger wave equation.*

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO1* | *L* |  | *H* |  | *M* |  |  | *H* |  | *M* |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  |  |  | *M* |  |  |  | *L* |  |  |
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| *CO4* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO5* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low

**Semester V**

**BPH017A: Solid State Physics** **Credit(s): 4**

**Unit-I**

**Crystal Structure:** Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors.Lattice with a Basis – Central and Non-Central Elements. Unit Cell. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Types of Bonds. Ionic Bond. Covalent Bond. Van der Waals Bond. Diffraction of x-rays by Crystals. Bragg’s Law.

**Unit-II**

**Elementary Lattice Dynamics:** Lattice Vibrations and Phonons: Linear Monoatomic andDiatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Einstein and Debye Theories of Specific Heat of Solids. *T3* Law.

**Unit-III**

**Dielectric Properties of Materials:** Dielectric Polarization. Local Electric Field at an Atom.Depolarization Field. Dielectric Constant. Electric Susceptibility. Polarizability. Classical Theory of Electric Polarizability. Clausius- Mosotti Equation. Normal and Anomalous Dispersion. Complex Dielectric Constant.

**Unit-IV**

**Electrical Properties of Materials:** Elementary Band Theory of Solids. Bloch Theorm. Kronig-Penney Model. Effective Mass of Electron. Concept of Holes. Band Gaps. Energy Band Diagram and Classification of Solids. Law of Mass Action. Insulators, and Semiconductors. Direct and Indirect Band Gap. Intrinsic and Extrinsic Semiconductors. p- and n- Type Semiconductors. Conductivity in Semiconductors. Hall Effect in Semiconductors (Qualitative Discussion Only).

**Unit-V**

**Superconductivity:** 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): Cooper Pair and Coherence length. Variation of Superconducting Energy Gap with Temperature. Experimental Evidence of Phonons. Josephson Effect.

***Suggested Books***

1. Charles Kittel: Introduction to Solid State Physics, 7th Edition, John Wiley and Sons, Inc.
2. A. J. Dekkar: Solid State Physics, Macmillan India Limited, 2000.
3. J. S. Blackmore: Solid State Physics, Cambridge University Press, Cambridge.
4. N. W. Ascroft and N. D. Mermin: Solid State Physics, (Harcourt Asia, Singapore 2003).

**Course outcomes**:- Upon successful completion of the course, students should:

CO1. have an understanding of the elastic properties of solids and lattice vibrations.

CO2. have an understanding of the properties of metals on the basis of the free electron gas models.

CO3. have an understanding of the essence of dielectric properties of materials.

CO4. have an understanding of the superconductivity of condensed matter.

CO5. have an understanding of the structural properties of solids and the relation to their electronic properties.

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| ***Course*** |  |  | ***Program Outcome*** |  |  | ***Program Specific*** |
| ***Outcome*** |  |  |  |  |  |  |  | ***Outcome*** |
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| CO2 |  |  | L |  |  | M |  | H |  |  |
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| CO3 |  | H |  |  |  |  | H |  | L |  |
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| CO4 | M |  |  |  |  |  |  |  |  | M |
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| CO5 |  | L |  |  | M |  | L |  | M |  |
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H = Highly Related; M = Medium; L = Low

**BPH018A: Electronics (Solid State Electronic Devices)** **Credit(s): 4**

**Unit-I**

**Circuit Analysis**: Kirchhoff’s Laws, Mesh and Node Analysisof dc and ac Circuits, Duality inNetworks. Network Theorems. Norton’s Theorem. Thevenin’s Theorem. Equivalent Star (T) and delta (π) Networks of a Given Network. Wheatstone Bridge and its Applications to Wien Bridge and Anderson Bridge.

**Unit-II**

**Semiconductor Diodes**: p and n Type Semiconductors. Energy Level Diagram. Conductivityand Mobility. pn Junction Fabrication (Simple Idea). Barrier Formation in pn Junction Diode. Current Flow Mechanism in Forward and Reverse Biased Diode (Recombination, Drift and Saturation of Drift Velocity). Derivation of Mathematical Equations for Barrier Potential, Barrier

Width and Current for Step Junction. pn junction and its characteristics. Static and Dynamic Resistance. Diode Equivalent Circuit. Ideal Diode. Load Line Analysis of Diodes. Load Line and Q-point.

**Unit-III**

**Two-terminal Devices and their Applications**: (1) Rectifier Diode. Half-wave Rectifiers.

Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification

Efficiency. Qualitative idea of C, L and π - Filters. (2) Zener Diode and Voltage Regulation. (3)

Photo Diode, (4) Tunnel Diode, (5) LED (6) Varactor Diode.

**Bipolar Junction transistors**: NPN and PNP Transistors. Characteristics of CB, CE and CCConfigurations. Current gains α, β and γ and Relations between them. Load Line Analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff, and Saturation Regions. Transistor in Active Region and Equivalent Circuit.

**Unit-IV**

**Amplifiers**: Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias.Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Resistance, Voltage and Power Gains. Class A, B, and C Amplifiers.

Coupled Amplifiers: RC-Coupled Amplifier and its Frequency Response of Voltage Gain.

**Unit-V**

Feedback in Amplifiers, Effects of Positive and Negative Feedback on Input Impedance, Output Impedance and Gain, Stability, Distortion and Noise.

**Sinusoidal Oscillators**: Barkhauson’s Criterion for Self-sustained Oscillations. RC Phase ShiftOscillator, Determination of Frequency. Hartley Oscillator. Colpitts Oscillator.

***Suggested Books***

1. Robert Boylestad and Louis Nashelsky: Electronic Devices and Circuit Theory, 8Th Edition, Pearson Education, India, 2004.
2. A. P. Malvino: Electronic Principals, Glencoe, 1993.
3. Allen Motorshead: Electronic Circuits and Devices, PHI, 1997.

**COURSE OUTCOMES OF SOLID STATE ELECTRONIC DEVICES**

CO-1 Students develop a fundamental understanding of the static and dynamic behavior of P-N Junction and Metal Oxide Semiconductor structures.

CO-2. Students develop fundamental understanding of the impact of material parameters and device design on performance of selected solid-state devices.

CO-3. Students collaborate in developing technical approaches leading to solutions to complex

problems.

CO-4. Students understand the factors that influence the flow of charge in semiconductors.

CO-5. Students able to describe the operation of semiconductor devices.

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**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO3* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO4* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO5* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low

**BPH019A: Solid State Electronics Devices Lab** **Credit(s): 1**

**N.B.: Students are required to perform at least 12 experiments from the following list:**

1. To test a Diode and Transistor using (a) a Multimeter and (b) a CRO.
2. To measure (a) Voltage, (b) Frequency and (c) Phase Difference using a CRO.
3. To study **Diode/Zener Diode** characteristics.
4. To study **Transistor** characteristics.
5. Determine static resistance and dynamic resistance of p-n junction diode and plot the V-I characteristics
6. Plot the V-I characteristics of zener diode and hence determine the dynamic resistance from the characteristics.

1. Observe output waveform of half wave rectifier with and without filter capacitor and measure DC voltage, DC current, ripple factor with and without filter capacitor.
2. Observe output waveform of full wave rectifier with and without filter capacitor and measure DC voltage, DC current, ripple factor with and without filter capacitor.
3. Observe waveform at the output of Bridge rectifier with and without filter capacitor and measure DC voltage, DC current, ripple factor with and without filter capacitor.
4. Design a full wave rectifier using discrete components on a breadboard and measure DC voltage, DC current, ripple factor with and without filter capacitor.
5. Obtain the input and output characteristics of common emitter transistor
6. Obtain the input and output characteristics of common base transistor.
7. Draw DC load line of transistor working as a switch.
8. Obtain V-I characteristics of field effect transistor (FET).

**COURSE OUTCOMES OF SOLID STATE ELECTRONIC DEVICES lab**

CO-1 Students develop a fundamental understanding of the static and dynamic behavior of P-N Junction and Metal Oxide Semiconductor structures.

CO-2. Students develop fundamental understanding of the impact of material parameters and device design on performance of selected solid-state devices.

CO-3. Students collaborate in developing technical approaches leading to solutions to complex

problems.

CO-4. Students understand the factors that influence the flow of charge in semiconductors.

CO-5. Students able to describe the operation of semiconductor devices.

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**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO3* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO4* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO5* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| H = Highly Related; M = Medium L = Low |  |  |  |  |  |  |  |
| **BPH020A: Electronics and Opto-Electronics Lab** |  |  |  | **Credit(s): 1** |

1. To measure **Numerical Aperture of an Optical Fiber**.
2. To determine the Coherent Length and Coherent Time of **LASER** using Semiconductor **LASER**.
3. To determine the profile of **He-Ne LASER** beam.
4. To determine the value of Planck’s Constant using a Photoelectric Cell.
5. To determine the value of e/m by using Bar Magnet method.
6. To determine the Wavelength and the Angular Spread of a He-Ne Laser.
7. To determine resistance of the given material by **Four Probe method**.
8. To study the variation in resistance of semiconductor with temperature and determine **Band-Gap**.
9. To study **Logic Gates** and verify their **truth tables.**
10. To determine the value of Planck’s Constant using LEDs of at least 4 different

wavelengths.

**COURSE OUTCOMES OF Electronics and Opto-Electronics Lab**

CO-1 Apply knowledge of laser to explain natural physical processes and related technological advances.

CO-2 Use an understanding of Logic gates along with physical principles to effectively solve

problems.

CO-3 Design experiments and acquire data in order to determine Band-Gap.

CO-4 Assess the contributions of physics to our evolving understanding of truth tables.

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low

**Semester VI**

**BPH021A: Nuclear and Particle Physics** **Credit(s): 4**

**Unit-I**

**Structure of nuclei**: Basic Properties of Nuclei: (1) Mass, (2) Radii, (3) Charge, (4) AngularMomentum, (5) Spin, (5) Magnetic Moment (μ), (6) Stability and (7) Binding Energy.

**Radioactivity**: Law of Radioactive Decay. Half-life, Theory of Successive RadioactiveTransformations. Radioactive Series, Binding Energy, Mass Formula.

**Unit-II**

**α-decay**: Range of α-particles, Geiger-Nuttal law and α-particle Spectra. Gamow Theory ofAlpha Decay.

**β-decay**: Energy Spectra and Neutrino Hypothesis.

**γ-decay**: Origin of γ-rays, Nuclear Isomerism and Internal Conversion.

**Nuclear Models**: Liquid Drop Model. Mass formula. Shell Model. Meson Theory of NuclearForces and Discovery of Pion.

**Unit-III**

**Nuclear Reactions**: Types of Reactions and Conservation Laws. Concept of Compound andDirect Reaction. Compound Nucleus. Scattering Problem in One Dimension: Reflection and Transmission by a Finite Potential Step. Stationary Solutions, Attractive and Repulsive Potential Barriers. Scattering Cross-section. Reaction Rate. Q-value of Reaction. Fission and Fusion.

**Unit-IV**

**Accelerators**: Van de Graff Generator, Linear Accelerator, Cyclotron, Betatron and Light andHeavy Ion Synchro-Cyclotron. Idea of Large Hadron Collider.

**Detectors of Nuclear Radiations**: Interaction of Energetic particles with matter. Ionizationchamber. GM Counter. Cloud Chambers. Wilson Cloud Chamber. Bubble Chamber. Scintillation

Detectors. Semiconductor Detectors (Qualitative Discussion Only). An Idea about Detectors used in Large Hadron Collider.

**Unit-V**

**Elementary Particles (Qualitative Discussion Only)**: Fundamental Interactions. Classificationof Elementary Particles. Particles and Antiparticles. Baryons, Hyperons, Leptons, and Mesons. Elementary Particle Quantum Numbers : Baryon Number, Lepton Number, Strangeness, Electric Charge, Hypercharge and Isospin.

***Suggested Books***

1. Arthur Beiser: Concepts of Modern Physics, McGraw-Hill Book Company, 1987.
2. Bernard L. Cohen: Concepts of Nuclear Physics, Tata Mcgraw Hill (1998).
3. R.A. Dunlap: Introduction to the Physics of Nuclei and Particles, Singapore: Thomson Asia (2004).
4. Irving Kaplan: Nuclear physics, Oxford & IBH, 1962.
5. Kenneth S. Krane: Introductory Nuclear Physics, John Wiley & Sons, 1988.

**COURSE OUTCOMES OF Nuclear and Particle Physics**

CO-1 Apply knowledge of properties of nuclei to explain natural physical processes and related technological advances.

CO-2 Use an understanding of nuclear model with physical principles to effectively solve problems encountered in everyday life, further study in science, and in the professional world.

CO-3 Design experiments and acquires data in order to explore nuclear reactions and critically evaluate

related scientific studies.

CO-4 Assess the contributions of physics to our evolving understanding of detectors.

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low

**Elective Papers**

**One has to choose one of the following four elective papers**

**BPH022A: (Elective 1) Computational Physics** **Credit(s): 4**

**Exercises to understand any five of the following problems:**

1. Solving [differential equations](http://en.wikipedia.org/wiki/Differential_equation)
2. Evaluating [integrals](http://en.wikipedia.org/wiki/Integral)
3. Stochastic methods, especially [Monte Carlo methods](http://en.wikipedia.org/wiki/Monte_Carlo_method)
4. Specialized [partial differential equation](http://en.wikipedia.org/wiki/Partial_differential_equation) methods, for example the [finite difference](http://en.wikipedia.org/wiki/Finite_difference) method and the [finite element method](http://en.wikipedia.org/wiki/Finite_element_method)
5. The [matrix eigen value problem](http://en.wikipedia.org/wiki/Matrix_eigenvalue_problem) – the problem of finding [eigen values](http://en.wikipedia.org/wiki/Eigenvalue) of very large matrices, and their corresponding [eigenvectors](http://en.wikipedia.org/wiki/Eigenvectors) [(eigen states](http://en.wikipedia.org/wiki/Eigenstates) in [quantum physics)](http://en.wikipedia.org/wiki/Quantum_physics).
6. Understanding [Molecular dynamics](http://en.wikipedia.org/wiki/Molecular_dynamics) by computational means.
7. Understanding [Computational fluid dynamics](http://en.wikipedia.org/wiki/Computational_fluid_dynamics)
8. Understanding [Computational Magneto-hydrodynamics](http://en.wikipedia.org/wiki/Computational_Magnetohydrodynamics)

***Suggested Books***

1. **Andi Klein and Alexander Godunov,** Introductory Computational Physics **(2006)**
2. [**Rubin H. Landau,**](http://www.amazon.com/Rubin-H.-Landau/e/B001IYTPVM/ref%3Dntt_athr_dp_pel_1) [**José Páez**](http://www.amazon.com/s/ref%3Dntt_athr_dp_sr_2?_encoding=UTF8&sort=relevancerank&search-alias=books&ie=UTF8&field-author=Jos%C3%A9%20P%C3%A1ez) **and** [**Cristian C. Bordeianu**](http://www.amazon.com/Cristian-C.-Bordeianu/e/B002F31WWA/ref%3Dntt_athr_dp_pel_3) **and** A Survey of ComputationalPhysics: Introductory Computational Science.

**COURSE OUTCOMES OF Computational Physics**

CO-1 Apply knowledge of differential equations to explain natural physical processes and related technological advances.

CO-2 Use an understanding of calculus along with physical principles to effectively solve problems encountered in everyday life, further study in science, and in the professional world.

CO-3 Design experiments and acquire data in order to explore physical principles, effectively communicate results, and critically evaluate related scientific studies.

CO-4 Assess the contributions of physics to our evolving understanding of global change and sustainability while placing the development of physics in its historical and cultural context

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low

**BPH023A: (Elective 2) Digital Electronics** **Credit(s): 4**

**Unit-I**

**Analog Circuits:** Integrated Circuits (Qualitative Treatment only): Active and Passivecomponents. Discrete Circuit Component. Wafer. Chip. Advantages and Drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (Basic Idea and Definitions Only). Classification of ICs. Fabrication of Components on Monolithic ICs. Examples of Linear and Digital ICs.

**Unit-II**

**Operational Amplifiers** (Use Black Box approach): Basic Characteristics of Op-Amps.

Characteristics of an Ideal Op-Amp. Feedback in Amplifiers . Open-loop and Closed-loop Gain.

Frequency Response. CMRR. Virtual ground.

**Unit-III**

**Applications of Op-Amps**: (1) Inverting and Non-inverting Amplifiers, (2) Adder, (3)Subtractor, (4) Unity follower, (5) Differentiator, (6) Integrator, (7) Zero Crossing Detector.

**Unit-IV**

**Digital Circuits:** Difference Between Analog and Digital Circuits. Binary Numbers. Decimal toBinary and Binary to Decimal Conversion. AND, OR and NOT Gates (Realization using Diodes and Transistor). NAND AND NOR Gates. Exclusive OR and Exclusive NOR Gates.

**Boolean algebra**: De Morgan’s Theorems. Boolean Laws. Simplification of Logic Circuit usingBoolean Algebra. Fundamental Products. Minterms and Maxterms. Conversion of a Truth Table into an Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

**Unit-V**

**Data processing circuits**: Basic Idea of Multiplexers, De-multiplexers, Decoders, Encoders,Parity Checkers.

**Memories**: Read-only memories (ROM), PROM, EPROM.

***Suggested Books***

1. D. P. Leach & A. P. Malvino: Digital principles and applications, Glencoe, 1995.
2. Thomas L. Floyd, Digital Fundamentals: 3rd Edition, Universal Book Stall, India, 1998.
3. Robert F Coughlin and Frederick F Driscoll: Operational Amplifiers and Linear Integrated Circuits, 4th Edition, PHI, 1992.

4.R. A. Gayakwad: Op-Amps and Linear Integrated Circuits, Pearson, 2000.

**COURSE OUTCOMES OF Digital Electronics**

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| --- | --- | --- | --- |
| CO-1 | Apply knowledge of analog circuits to explain natural physical | processes and | related |
| technological |  |  |  |  |  | advances. |
| CO-2 | Use an understanding of calculus along with physical principles to effectively solve problems |
| encountered in | everyday | life, further study in science, | and in the | professional | world. |
| CO-3 | Design experiments and acquire data in order to explore physical principles, effectively |
| communicate | results, | and | critically | evaluate | related | scientific | studies. |
| CO-4 | Assess the contributions of physics to our evolving understanding of global change and |
| sustainability while placing the development of physics in its historical and cultural context |  |

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO1* | *L* |  | *H* |  | *M* |  |  | *H* |  | *M* |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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| H = Highly Related; M = Medium L = Low |  |  |  |  |  |  |  |

**BPH024A: (Elective 3) Statistical Mechanics** **Credit(s): 4**

**Unit-I**

**Classical Statistics:** Entropy and Thermodynamic Probability. Maxwell-Boltzmann DistributionLaw. Ensemble Concept. Partition Function. Thermodynamic Functions of Finite Number of Energy Levels. Negative Temperature. Thermodynamic Functions of an Ideal Gas. Classical Entropy Expression, Gibbs Paradox. Law of Equipartition of Energy – Applications to Specific Heat and its Limitations.

**Unit-II**

**Classical Theory of Radiation:** Properties of Thermal Radiation. Blackbody Radiation. PureTemperature Dependence. Kirchhoff’s Law. Stefan-Boltzmann Law and Wien’s Displacement law. Saha’s Ionization Formula.

**Unit-III**

**Quantum Theory of Radiation:** Radiation: Stefan-Boltzmann Law: Thermodynamic Proof.Radiation Pressure. Spectral Distribution of Black Body Radiation. Wien’s Distribution Law and Displacement Law. Rayleigh-Jean’s Law. Ultraviolet Catastrophe. 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 and (4) Wien’s Displacement Law from Planck’s Law.

**Unit-IV**

**Bose-Einstein Statistics:** B-E distribution law. Thermodynamic functions of a Completely

Degenerate Bose Gas. Properties of liquid He (qualitative description). Radiation as photon gas.

Bose’s derivation of Planck’s law.

**Unit-V**

**Fermi-Dirac Statistics:** Fermi-Dirac Distribution Law. Thermodynamic functions of an ideal

Completely Degenerate Fermi Gas. Fermi Energy. Electron gas in a Metal. Specific Heat of

Metals.

***Suggested Books***

1. F. Reif, Statistical Physics: Berkeley Physics Course, McGraw-Hill, Company Ltd, 2008.

1. S. Lokanathan and R. S. Gambhir: Statistical and Thermal Physics: An introduction PHI.
2. K. Huang: Statistical Mechanics, Wiley, 1987.

**COURSE OUTCOMES OF Statistical Mechanics**

CO-1 Apply knowledge of classical statistics to explain natural physical processes and related technological advances.

CO-2 Use an understanding of calculus along with physical principles to effectively solve problems encountered in everyday life, further study in science, and in the professional world.

CO-3 Design experiments and acquire data in order to explore physical principles, effectively communicate results, and critically evaluate related scientific studies.

CO-4 Assess the contributions of physics to our evolving understanding of global change and sustainability while placing the development of physics in its historical and cultural context

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO1* | *L* |  | *H* |  | *M* |  |  | *H* |  | *M* |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low

**BPH025A: (Elective 4) Atomic and Molecular Spectroscopy** **Credit(s): 4**

**Unit-I** Determination of e/m of the Electron. Thermionic Emission. Isotopes and Isobars.

**Introduction to Spectroscopy**: X-rays: Ionizing Power, X-ray Diffraction, Bragg’s Law. Bohr

Atomic Model, Critical Potentials, X-rays-Spectra: Continuous and Characteristic X-rays, Moseley Law.

**Unit-II**

**Atoms in Electric and Magnetic Fields**: Electron Angular Momentum. Space Quantization.Electron Spin and Spin Angular Momentum. Larmor’s Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton.

**Atoms in External Magnetic Fields**: Normal and Anomalous Zeeman Effect. Paschen Back andStark Effect (Qualitative Discussion only).

**Unit-III**

**Many electron atoms**: Pauli’s Exclusion Principle. Symmetric and Antisymmetric WaveFunctions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total Angular Momentum. Vector Model. L-S and J-J couplings. Hund’s Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.).

**Unit-IV**

**Molecular Spectra**: Rotational Energy levels, Selection Rules and Pure Rotational Spectra of aMolecule. Vibrational Energy Levels, Selection Rules and Vibration Spectra. Rotation-Vibration Energy Levels, Selection Rules and Rotation-Vibration Spectra. Determination of Internuclear Distance.

**Raman Effect**: Quantum Theory of Raman Effect. Characteristics of Raman Lines. Stoke’s andAnti-Stoke’s Lines. Complimentary Character of Raman and infrared Spectra.

**Unit-V**

**LASER**: Einstein’s A and B coefficients. Metastable states. Spontaneous and Stimulatedemissions. Optical Pumping and Population Inversion. Three-Level and Four-Level Lasers. Ruby Laser and He-Ne Laser.

***Suggested Books***

1. Arthur Beiser: Concepts of Modern Physics, McGraw-Hill Book Company, 1987.
2. J. B. Rajam: (with foreword by Louis de Broglie) Atomic physics, S. Chand & Co., 2007.
3. Ghatak and Thyagarajan: Optoelectronics, Oxford University Press.

**COURSE OUTCOMES OF Atomic and Molecular Spectroscopy**

CO-1 Apply knowledge of spectroscopy to explain natural physical processes and related technological advances.

CO-2 Use an understanding of calculus along with physical principles to effectively solve problems encountered in everyday life, further study in science, and in the professional world.

CO-3 Design experiments and acquire data in order to explore physical principles, effectively communicate results, and critically evaluate related scientific studies.

CO-4 Assess the contributions of physics to our evolving understanding of global change and sustainability while placing the development of physics in its historical and cultural context

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO1* | *L* |  | *H* |  | *M* |  |  | *H* |  | *M* |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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**BPH030A: Basic Electrical and Electronics Lab-I**

**BPH031A: Basic Electrical and Electronics Lab-II**

**Credits: 1**

**Credits: 1**

**List of Exercises**

**A. ELECTRICAL LAB**

1. To study Graphical Symbols used to indicate electrical equipment and components. Single line diagram of an Electrical power distribution system.

2(i) To study the functions of components used in house wiring. Connections of house wiring including earthing with 1-phase energy meter, MCB, ceiling fan, tube light, three pin socket and a lamp operated from two different positions.

1. To study the construction, working of the different types of lamps.

3(i) To study the construction and working of ceiling fan, single phase induction motor and three phase squirrel cage induction motor.

1. To connect ceiling fan along with regulator. To also connect a single phase induction motor through an auto-transformer and to run it at varying speeds.

4(i) To study moving coil & moving iron ammeters and voltmeters, wattmeters and energy meters.

1. To run a 3-phase squirrel cage induction motor on no load and measure its voltage, current, power and power factor. Reverse the direction of rotation.

5(i) To study the construction and connect single phase transformer and auto-transformer.

Measure input and output voltage and find turn ratio of transformer.

1. To study the construction of a core type three phase transformer. Connect star and delta connection of a 3-phase transformer and find relation between line and phase voltage.

**ELECTRONICS LAB**

6(i) Identification, testing of resistors, inductors, capacitors, PN-diode, Zener diode, LED, LCD, BJT, FET, UJT, SCR, Photo diode and Photo transistor.

* 1. Introduction to Printed Circuit Boards (PCBs) and mount components on PCB.
1. To study the functions of CRO, analog & digital multi-meters and function / signal generator.
2. To observe output waveform of half wave and full wave rectifier (centre tap and bridge).
3. To design circuits using *Bread Board* (introductory lessons).

**COURSE OUTCOMES OF ELECTRICAL LAB & ELECTRONICS LAB**

CO-1 Apply knowledge of rectifiers to explain natural physical processes and related technological advances.

CO-2 Use an understanding of calculus along with physical principles to effectively solve problems encountered in everyday life, further study in science, and in the professional world.

CO-3 Design experiments and acquire data in order to explore physical principles, effectively communicate results, and critically evaluate related scientific studies.

CO-4 Assess the contributions of physics to our evolving understanding of global change and sustainability while placing the development of physics in its historical and cultural context

**MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:**

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| **Course** |  |  | *Program Outcome* |  |  |  | *Program Specific Outcome* |
| **Outcome** |  |  |  |  |  |  |  |  |  |  |
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| *CO2* |  | *M* |  |  | *H* |  | *M* | *H* | *M* |  |
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| *CO3* |  | *L* |  |  |  | *L* |  | *H* |  | *L* |
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| *CO4* |  |  |  | *L* | *H* |  |  |  | *M* |  |
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H = Highly Related; M = Medium L = Low