UG PHYSICS SYLLABUS
(NEP2020)

Bachelor of Science
(Physics as major subject)

Department of Physics

DDU Gorakhpur UniversityGorakhpur - 273009

B.Sc. Programme Outline

According to the recommendation of the NEP 2020 and the Uttar Pradesh Government, the programme and course structures/syllabi format of the Major discipline Physics are modified. As per these recommendations for a student, admitted to the UG programme, to fulfill the degree requirements will have to opt for (i) three **Major** disciplines; (ii) **Minor/Elective courses**, in first four semesters (two years) completing minimum 8 credits; (iii) **Co-curricular courses**, in all six semesters (three years) completing minimum 12 credits and (iv) **Vocational Courses**, in first four semesters (two years) completing minimum 8 credits.

- *For the minor, vocational and co-curricular courses, a student may choose any course from the* ***central pool of courses*** *approved by the Academic Council and made available by any department of the university, with the approval of the Dean, Faculty of Science.*

- The Physics department is offering a course on '**Basics of Physics**', which is compulsory in the first semester for all students admitted to the B.Sc. programme with Physics as one of the major subjects. This course may also be made available in the even semester as Minor/Elective for students of other departments.

- *With the permission of the Dean, a student may also choose a regular 3 or 4 credit course of any other Major subject to complete his credit requirements of Minor/Elective.*

PROGRAMME SPECIFIC OUTCOMES (PSOs)

Science teaches the value of rational thought as well as importance of freedom of thought. Additionally, it has proved to be of practical value in technology development, productivity and raising the standard of living.
Our teaching is not only aimed at formal knowledge and understanding but also encourages training and application oriented learning. The emphasis is on training, application and fostering independent thinking and creativity.

Physics is a basic science; it attempts to explain the natural phenomenon in as simple a manner as possible. It is an intellectual activity aimed at interpreting the Multiverse. The starting point of all physics lies in experience. Experiment, whether done outside or in the laboratory, is an important ingredient of learning physics and hence the present programme integrates six experimental physics papers focusing on various aspects of modern technology based equipments. With all the limitations imposed (even the list of experiments as given in the syllabus) if the spirit of discovery by investigation is kept in mind, much of the thrill can be experienced.

1. The main aim of this programme is to help cultivate the love for Nature and its manifestations, to transmit the methods of science (the contents are only the means) to observe things around, to generalize, to do intelligent guessing, to formulate a theory & model, and at the same time, to hold an element of doubt and thereby to hope to modify it in terms of future experience and thus to practice a pragmatic outlook.

2. The programme intends to nurture the proficiency in functional areas of Physics, which is in line with the international standards, aimed at realizing the goals towards skilled India.

3. Keeping the application oriented training in mind; this programme aims to give students the competence in the methods and techniques of theoretical, experimental and computational aspects of Physics so as to achieve an overall understanding of the subject for holistic development. This will cultivate in specific application oriented training leading to their goals of employment.

4. The Bachelor's Project (Industrial Training / Survey / Dissertation) is intended to give an essence of research work for excellence in explicit areas. It integrates with specific job requirements / opportunities and provides a foundation for Bachelor (Research) Programmes.

Course Structure for B.Sc. PHYSICS Major

SEMESTER-WISE TITLES OF THE PAPERS IN UG PHYSICS COURSE			
YEAR	**COURSE CODE**	**PAPER TITLE**	**CREDIT**
First Year	**Semester-I**		
	PHY 101	Basics of Physics	2 + 0
	PHY 102 (B010101T)	Mathematical Physics & Newtonian Mechanics	4 + 0
	PHY 103 (B010102P)	Practical (Mechanical Properties of Matter)	0 + 2
	Semester-II		
	PHY 104 (B010201T)	Thermal Physics & Semiconductor Devices	4 + 0
	PHY 105 (B010202P)	Practical (Thermal Properties of Matter & Electronic Circuits)	0 + 2
Second Year	**Semester-III**		
	PHY 201 (B010301T)	Electromagnetic Theory & Optics	4 + 0
	PHY 202 (B010302P)	Practical (Demonstrative Aspects of Electricity & Magnetism)	0 + 2
	Semester-IV		
	PHY 203 (B010401T)	Modern Physics & Electronics	4 + 0
	PHY 204 (B010402P)	Practical (Basic Electronics Instrumentation)	0 + 2
Third Year	**Semester-V**		
	PHY 301 (B010501T)	Classical Mechanics & Statistical Mechanics	4 + 0
	PHY 302 (B010502T)	Quantum Mechanics & Spectroscopy	4 + 0
	PHY 303 (B010503P)	Practical (Demonstrative Aspects of Optics & Lasers)	0 + 2
	Semester-VI		
	PHY 304 (B010601T)	Solid State Physics & Nuclear Physics	4 + 0
	PHY 305 (B010602T)	Analog & Digital - Principles & Applications	4 + 0
	PHY 306 (B010603P)	Practical (Analog & Digital Circuits)	0 + 2

Basics of Physics

(Elementary appreciation of Physics)

PHY 101 **Credit 2+0**

Course Outcome:

CO1 Develop familiarity with various Physics terms and concepts.
CO2 Appreciate the role of Physics in diverse everyday phenomenon.
CO3 Learning to observe and analyze natural phenomenon.
CO4 Develop scientific temper.

Unit – I

Physical quantities, important units, dimensional analysis, error analysis. Mechanics: concepts of velocity, acceleration, momentum, force and energy. Gravity: Projectiles and satellites, orbits of planets, eclipses, solar system, stars and galaxies. Elementary idea of origin of the universe. Sound: oscillations, waves, concept of musical notes.

Indian Science organization and Premier Institutes.

Unit – II

Heat: Conservation of Energy, Temperature, heat capacities, thermal expansion and conductivity. Light: Mirrors, prism, lenses, human eye, microscope and telescope. Electromagnetic spectrum, Hydrogen spectral lines, Solar Fraunhofer lines. Electricity: Current, Potential, Resistance, Capacitance and Inductance. Household appliances. Conductors, Insulators and Semi-conductors.

References:

1. University Physics; Hugh Young and Roger Freedman (original edition by Mark Zemansky and Francis Sears); Pearson Publication.

2. NCERT Physics -I and -II; published by NCERT, New Delhi

Mathematical Physics & Newtonian Mechanics

PHY 102 **Credit 4+0**

Course Outcomes (COs)

CO1 Recognize the difference between scalars, vectors, pseudo-scalars and pseudo-vectors.
CO2 Understand the physical interpretation of gradient, divergence and curl.
CO3 Comprehend the difference and connection between Cartesian, spherical and cylindrical coordinate systems.
CO4 Know the meaning of 4-vectors, Kronecker delta and Epsilon (Levi Civita) tensors.
CO5 Study the origin of pseudo forces in rotating frame.
CO6 Study the response of the classical systems to external forces and their elastic deformation.
CO7 Understand the dynamics of planetary motion and the working of Global Positioning System (GPS).
CO8 Comprehend the different features of Simple Harmonic Motion (SHM) and wave propagation.

Part A

Unit 1 Vector Algebra

Coordinate rotation, reflection and inversion as the basis for defining scalars, vectors, pseudo-scalars and pseudo-vectors (include physical examples). Component form in 2D and 3D. Geometrical and physical interpretation of addition, subtraction, dot product, wedge product, cross product and triple product of vectors. Position, separation and displacement vectors.

Unit 2 Vector Calculus

Geometrical and physical interpretation of vector differentiation, Gradient, Divergence and Curl and their significance. Vector integration, Line, Surface (flux) and Volume integrals of vector fields. Gradient theorem, Gauss-divergence theorem, Stoke-curl theorem, Greens theorem and Helmholtz theorem (statement only). Introduction to Dirac delta function.

Unit 3 Coordinate Systems

2D & 3D Cartesian, Spherical and Cylindrical coordinate systems, basis vectors, transformation equations. Expressions for displacement vector, arc length, area element, volume element, gradient, divergence and curl in different coordinate systems. Components of velocity and acceleration in different coordinate systems. Examples of non-inertial coordinate system and pseudo-acceleration.

Unit 4 Introduction to Tensors

Principle of invariance of physical laws w.r.t. different coordinate systems as the basis for defining tensors. Coordinate transformations for general spaces of nD, contravariant, covariant & mixed tensors and their ranks, 4-vectors. Index notation and summation convention. Symmetric and skew-symmetric tensors. Invariant tensors, Kronecker delta and Epsilon (Levi Civita) tensors. Examples of tensors in physics.

Part B

Unit 1 Dynamics of a System of Particles

Review of historical development of mechanics up to Newton. Background, statement and critical analysis of Newton's axioms of motion. Dynamics of a system of particles, centre of mass motion, and conservation laws & their deductions. Rotating frames of reference, general derivation of origin of pseudo forces (Euler, Coriolis & centrifugal) in rotating frame, and effects of Coriolis force.

Unit 2 Dynamics of a Rigid Body

Angular momentum, Torque, Rotational energy and the inertia tensor. Rotational inertia for simple bodies (ring, disk, rod, solid and hollow sphere, solid and hollow cylinder, rectangular lamina). The combined translational and rotational motion of a rigid body on horizontal and inclined planes. Elasticity, relations between elastic constants, bending of beam and torsion of cylinder.

Unit 3 Motion of Planets & Satellites

Two particle central force problem, reduced mass, relative and centre of mass motion. Newton's law of gravitation, gravitational field and gravitational potential. Kepler's laws of planetary motion and their deductions. Motions of geo-synchronous & geo-stationary satellites and basic idea of Global Positioning System (GPS).

Unit 4 Wave Motion

Differential equation of simple harmonic motion and its solution, use of complex notation, damped and forced oscillations, Quality factor. Composition of simple harmonic motion, Lissajous figures. Differential equation of wave motion. Plane progressive waves in fluid media, reflection of waves and phase change, pressure and energy distribution. Principle of superposition of waves, stationary waves, phase and group velocity.

Suggested Readings

PART A

1. Murray Spiegel, Seymour Lipschutz, Dennis Spellman, "Schaum's Outline Series: Vector Analysis", McGraw Hill, 2017, 2e
2. A.W. Joshi, "Matrices and Tensors in Physics", New Age International Private Limited, 1995, 3e
3. D.S. Mathur, P.S. Hemne, "Mechanics", S. Chand Publishing, 1981, 3e

PART B

1. Charles Kittel, Walter D. Knight, Malvin A. Ruderman, Carl A. Helmholz, Burton J. Moyer, "Mechanics (In SI Units): Berkeley Physics Course Vol 1", McGraw Hill, 2017, 2e
2. Richard P. Feynman, Robert B. Leighton, Matthew Sands, "The Feynman Lectures on Physics - Vol. 1", Pearson Education Limited, 2012
3. Hugh D. Young and Roger A. Freedman, "Sears & Zemansky's University Physics with Modern Physics", Pearson Education Limited, 2017, 14e
4. D.S. Mathur, P.S. Hemne, "Mechanics", S. Chand Publishing, 1981, 3e

Practical (Mechanical Properties of Matter)

PHY 103 **Credit 0+2**

Course Outcomes (COs)

Experimental physics has the most striking impact on the industry wherever the instruments are used to study and determine the mechanical properties. Measurement precision and perfection is achieved through Lab Experiments.

Lab Experiment List

1. Moment of inertia of fly wheel.
2. Compound pendulum; Acceleration due to gravity and radius of gyration.
3. Modulus of rigidity by Maxwell’s needle.
4. Young’s modulus of rectangular bar by cathetometer or optical lever method
5. To determine the force constant of a spiral spring by statical and dynamical methods
6. To determine height of building and draw zero-error graph of sextant.
7. Elastic constants by Searle’s apparatus.
8. Surface tension of water by Jaeger’s method.
9. Coefficient of viscosity of water by Poiseuille’s method.
10. Frequency of electrically maintained tuning fork.
11. Frequency of A.C. mains using sonometer.

Thermal Physics & Semiconductor Devices

PHY 104 **Credit 4+0**

Course Outcomes (COs)

CO1 Recognize the difference between reversible and irreversible processes.
CO2 Understand the physical significance of thermodynamical potentials.
CO3 Comprehend the kinetic model of gases w.r.t. various gas laws.
CO4 Study the implementations and limitations of fundamental radiation laws.
CO5 Utility of AC bridges.
CO6 Recognize the basic components of electronic devices.
CO7 Design simple electronic circuits.
CO8 Understand the applications of various electronic instruments.

PART A

Unit 1 Zeroth & First Law of Thermodynamics

State functions and terminology of thermodynamics. Zeroth law and temperature. First law, internal energy, heat and work done. Work done in various thermodynamical processes. Enthalpy, relation between C P and C V . Carnot's engine, efficiency and Carnot's theorem. Efficiency of internal combustion engines (Otto and diesel).

Unit 2 Second & Third Law of Thermodynamics

Different statements of second law, Clausius inequality, entropy and its physical significance. Entropy changes in various thermodynamical processes. Third law of thermodynamics and unattainability of absolute zero. Thermodynamical potentials, Maxwell's relations, conditions for feasibility of a process and equilibrium of a system. Clausius- Clapeyron equation, Joule-Thompson effect.

Unit 3 Kinetic Theory of Gases

Kinetic model and deduction of gas laws. Derivation of Maxwell's law of distribution of velocities and its experimental verification. Degrees of freedom, law of equipartition of energy (no derivation) and its application to specific heat of gases (mono, di and poly atomic).

Unit 4 Theory of Radiation

Blackbody radiation, spectral distribution, concept of energy density and pressure of radiation. Derivation of Planck's law, deduction of Wien's distribution law, Rayleigh-Jeans law, Stefan-Boltzmann law and Wien's displacement law from Planck's law.

PART B

Unit 1 DC & AC Circuits

Growth and decay of currents in RL circuit. Charging and discharging of capacitor in RC, LC and V RCL circuits. Network Analysis - Superposition, Reciprocity, Thevenin's and Norton's theorems. AC Bridges - measurement of inductance (Maxwell's, Owen's and Anderson's bridges) and measurement of capacitance (Schering's, Wein's and de Sauty's bridges).

Unit 2 Semiconductors & Diodes

P and N type semiconductors, qualitative idea of Fermi level. Formation of depletion layer in PN junction diode, field & potential at the depletion layer. Qualitative idea of current flow mechanism in forward & reverse biased diode. Diode fabrication. PN junction diode and its characteristics, static and dynamic resistance. Principle, structure, characteristics and applications of Zener, Tunnel, Light Emitting, Point Contact and Photo diodes. Half and Full wave rectifiers, calculation of ripple factor, rectification efficiency and voltage regulation. Basic idea about filter circuits and voltage regulated power supply.

Unit 3 Transistors

Bipolar Junction PNP and NPN transistors. Study of CB, CE & CC configurations w.r.t. active, cutoff & saturation regions; characteristics; current, voltage & power gains; transistor currents & relations between them. Idea of base width modulation, base spreading resistance & transition time. DC Load Line analysis and Q-point stabilisation. Voltage Divider Bias circuit for CE amplifier. Qualitative discussion of RC coupled amplifier (frequency response not included).

Unit 4 Electronic Instrumentation

Multimeter: Principles of measurement of dc voltage, dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. Cathode Ray Oscilloscope: Block diagram of basic CRO. Construction of CRT, electron gun, electrostatic focusing and acceleration (no mathematical treatment). Front panel controls, special features of dual trace CRO, specifications of a CRO and their significance. Applications of CRO to study the waveform and measurement of voltage, current, frequency & phase difference.

Suggested Readings

PART A

1. M.W. Zemansky, R. Dittman, “Heat and Thermodynamics”, McGraw Hill, 1997, 7e
2. F.W. Sears, G.L. Salinger, “Thermodynamics, Kinetic theory & Statistical thermodynamics”, Narosa Publishing House, 1998
3. Enrico Fermi, “Thermodynamics”, Dover Publications, 1956
4. S. Garg, R. Bansal, C. Ghosh, “Thermal Physics”, McGraw Hill, 2012, 2e
5. Meghnad Saha, B.N. Srivastava, “A Treatise on Heat”, Indian Press, 1973, 5e

PART B

1. R.L. Boylestad, L. Nashelsky, “Electronic Devices and Circuit Theory”, Prentice-Hall of India Pvt. Ltd., 2015, 11e
2. J. Millman, C.C. Halkias, Satyabrata Jit, “Electronic Devices and Circuits”, McGraw Hill, 2015, 4e
3. B.G. Streetman, S.K. Banerjee, “Solid State Electronic Devices”, Pearson Education India, 2015, 7e
4. J.D. Ryder, “Electronic Fundamentals and Applications”, Prentice-Hall of India Private Limited, 1975, 5e
5. A. Sudhakar, S.S. Palli, “Circuits and Networks: Analysis and Synthesis”, McGraw Hill, 2015, 5e
6. S.L. Gupta, V. Kumar, “Hand Book of Electronics”, Pragati Prakashan, Meerut, 2016, 43e

Practical (Thermal Properties of Matter & Electronic Circuits)

PHY 105 **Credit 0+2**

Course Outcomes (COs)

Experimental physics has the most striking impact on the industry wherever the instruments are used to study and determine the thermal and electronic properties. Measurement precision and perfection is achieved through Lab Experiments.

Lab Experiment List

1. Mechanical Equivalent of Heat by Callender and Barne’s method
2. Value of Stefan’s constant
3. Verification of Stefan’s law
4. Characteristics of P-N junction.
5. Characteristics of Zener diode.
6. Measurement of inductance of a coil using Anderson’s bridge.
7. Measurement of capacity and power factor of a capacitor using Schering’s Bridge.
8. Study the behaviour of LCR circuit.
9. Characteristics of p-n-p transistor in common-emitter configuration.
10. Characteristics of p-n-p transistor in common-base configuration.
11. Study of resonance of digital display (LCR) in series and parallel circuit to find its resonance frequency.

Electromagnetic Theory & Optics

PHY 201 **Credit 4+0**

Course Outcomes (COs)

CO1 Better understanding of electrical and magnetic phenomenon in daily life.
CO2 To troubleshoot simple problems related to electrical devices.
CO3 Comprehend the powerful applications of ballistic galvanometer.
CO4 Study the fundamental physics behind reflection and refraction of light (electromagnetic waves).
CO5 Study the working and applications of Michelson and Fabry-Perot interferometers.
CO6 Recognize the difference between Fresnel’s and Fraunhofer’s class of diffraction.
CO7 Comprehend the use of polarimeters.
CO8 Study the characteristics and uses of lasers.

PART A

Unit 1 Electrostatics
Electric charge & charge densities, electric force between two charges. General expression for Electric field in terms of volume charge density (divergence & curl of Electric field), general expression for Electric potential in terms of volume charge density and Gauss law (applications included). Study of electric dipole. Electric fields in matter, polarization, auxiliary field D (Electric displacement), electric susceptibility and permittivity.

Unit 2 Magnetostatics
Electric current & current densities, magnetic force between two current elements. General expression for Magnetic field in terms of volume current density (divergence and curl of Magnetic field), General expression for Magnetic potential in terms of volume current density and Ampere’s circuital law (applications included). Study of magnetic dipole (Gilbert & Ampere model). Magnetic fields in matter, magnetisation, auxiliary field H, magnetic susceptibility and permeability.

Unit 3 Time Varying Electromagnetic Fields
Faraday's laws of electromagnetic induction and Lenz's law. Displacement current, equation of continuity and Maxwell-Ampere’s circuital law. Self and mutual induction (applications included). Derivation and physical significance of Maxwell’s equations. Theory and working of moving coil ballistic galvanometer (applications included).

Unit 4 Electromagnetic Waves
Electromagnetic energy density and Poynting vector. Plane electromagnetic waves in linear infinite dielectrics, homogeneous & inhomogeneous plane waves and dispersive & non-dispersive media. Reflection and refraction of homogeneous plane electromagnetic waves, law of reflection, Snell’s law, Fresnel’s formulae (only for normal incidence & optical frequencies) and Stoke’s law.

PART B

Unit 1 Interference

Conditions for interference and spatial & temporal coherence. Division of Wavefront - Fresnel's Biprism and Lloyd's Mirror. Division of Amplitude - Parallel thin film, wedge shaped film and Newton's Ring experiment. Interferometer - Michelson and Fabry-Perot.

Unit 2 Diffraction

Distinction between interference and diffraction. Fresnel's and Fraunhofer's class of diffraction. Fresnel's Half Period Zones and Zone plate. Fraunhofer diffraction at a single slit, n slits and Diffracting Grating. Resolving Power of Optical Instruments - Rayleigh's criterion and resolving power of telescope, microscope & grating.

Unit 3 Polarisation

Polarisation by dichronic crystals, birefringence, Nicol prism, retardation plates and Babinet's compensator. Analysis of polarized light. Optical Rotation - Fresnel's explanation of optical rotation and Half Shade & Biquartz polarimeters.

Unit 4 Lasers

Characteristics and uses of Lasers. Quantitative analysis of Spatial and Temporal coherence. Conditions for Laser action and Einstein's coefficients. Three and four level laser systems (qualitative discussion).

Suggested Readings

PART A

1. D.J. Griffiths, "Introduction to Electrodynamics", Prentice-Hall of India Private Limited, 2002, 3e
2. E.M. Purcell, "Electricity and Magnetism (In SI Units): Berkeley Physics Course Vol 2", McGraw Hill, 2017,2e
3. Richard P. Feynman, Robert B. Leighton, Matthew Sands, "The Feynman Lectures on Physics - Vol. 2", Pearson Education Limited, 2012
4. D.C. Tayal, "Electricity and Magnetism", Himalaya Publishing House Pvt. Ltd., 2019, 4e

PART B

1. Francis A. Jenkins, Harvey E. White, "Fundamentals of Optics", McGraw Hill, 2017, 4e
2. Samuel Tolansky, "An Introduction to Interferometry", John Wiley & Sons Inc., 1973, 2e
3. A. Ghatak, "Optics", McGraw Hill, 2017, 6e

Practical (Demonstrative Aspects of Electricity & Magnetism)

PHY 202 **Credit 0+2**

Course Outcomes (COs)

Experimental physics has the most striking impact on the industry wherever the instruments are used to study and determine the electric and magnetic properties. Measurement precision and perfection is achieved through Lab Experiments.

Lab Experiment List

1. Determine unknown resistance using Carey Foster's bridge.
2. Determination of high resistance by method of leakage.
3. Reduction factor of Helmholtz galvanometer.
4. Variation of magnetic field along the axis of Helmholtz coil
5. Verification of Child's law.
6. Current sensitivity of a dead-beat moving coil galvanometer.
7. Charge sensitivity of a ballistic galvanometer by capacity discharge method.
8. Calibration of energy meter using ammeter and voltmeter.
9. Time constant using charging discharging of capacitor.
10. Earth Inductor: Horizontal component of earth's magnetic field

Modern Physics & Electronics

PHY 203 **Credit 4+0**

Course Outcomes (COs)

CO1 Recognize the difference between the structure of space & time in Newtonian & Relativistic mechanics.
CO2 Understand the physical significance of consequences of Lorentz transformation equations.
CO3 Comprehend the wave-particle duality.
CO4 Develop an understanding of the foundational aspects of Quantum Mechanics.
CO5 Study the comparison between various biasing techniques.
CO6 Study the classification of amplifiers.
CO7 Comprehend the use of feedback and oscillators.
CO8 Comprehend the theory and working of optical fibers along with its applications.

PART A

Unit 1 Relativity-Experimental Background
Structure of space & time in Newtonian mechanics and inertial & non-inertial frames. Galilean transformations. Newtonian relativity. Galilean transformation and Electromagnetism. Attempts to locate the Absolute Frame: Michelson-Morley experiment and significance of the null result. Einstein's postulates of special theory of relativity.

Unit 2 Relativity-Relativistic Kinematics
Structure of space & time in Relativistic mechanics and derivation of Lorentz transformation equations (4-vector formulation included). Consequences of Lorentz Transformation Equations (derivations & examples included): Transformation of Simultaneity (Relativity of simultaneity); Transformation of Length (Length contraction); Transformation of Time (Time dilation); Transformation of Velocity (Relativistic velocity addition); Transformation of Acceleration; Transformation of Mass (Variation of mass with velocity). Relation between Energy & Mass (Einstein's mass & energy relation) and Energy & Momentum.

Unit 3 Inadequacies of Classical Mechanics
Particle Properties of Waves: Spectrum of Black Body radiation, Photoelectric effect, Compton effect and their explanations based on Max Planck's Quantum hypothesis. Wave Properties of Particles: Louis de Broglie's hypothesis of matter waves and their experimental verification by Davisson-Germer's experiment and Thomson's experiment.

Unit 4 Introduction to Quantum Mechanics
Matter Waves: Mathematical representation, Wavelength, Concept of Wave group, Group (particle) velocity, Phase (wave) velocity and relation between Group & Phase velocities. Wave Function: Functional form, Normalisation of wave function, Orthogonal & Orthonormal wave functions and Probabilistic interpretation of wave function based on Born Rule.

PART B

Unit 1 Transistor Biasing

Faithful amplification & need for biasing. Stability Factors and its calculation for transistor biasing V circuits for CE configuration: Fixed Bias (Base Resistor Method), Emitter Bias (Fixed Bias with Emitter Resistor), Collector to Base Bias (Base Bias with Collector Feedback) &, Voltage Divider Bias. Discussion of Emitter-Follower configuration.

Unit 2 Amplifiers

Classification of amplifiers based on Mode of operation (Class A, B, AB, C & D), Stages (single & multi stage, cascade & cascode connections), Coupling methods (RC, Transformer, Direct & LC couplings), Nature of amplification (Voltage & Power amplification) and Frequency capabilities (AF, IF, RF & VF). Theory & working of RC coupled voltage amplifier (Uses of various resistors & capacitors, and Frequency response) and Transformer coupled power amplifier (calculation of Power, Effect of temperature, Use of heat sink & Power dissipation). Calculation of Amplifier Efficiency (power efficiency) for Class A Series-Fed, Class A Transformer Coupled, Class B Series-Fed and Class B Transformer Coupled amplifiers.

Unit 3 Feedback & Oscillator Circuits

Feedback Circuits: Effects of positive and negative feedback. Voltage Series, Voltage Shunt, Current Series and Current Shunt feedback connection types and their uses for specific amplifiers. Estimation of Input Impedance, Output Impedance, Gain, Stability, Distortion, Noise and Band Width for Voltage Series negative feedback and their comparison between different negative feedback connection types. Oscillator Circuits: Use of positive feedback for oscillator operation. Barkhausen criterion for self-sustained oscillations. Feedback factor and frequency of oscillation for RC Phase Shift oscillator and Wein Bridge oscillator. Qualitative discussion of Reactive Network feedback oscillators (Tuned oscillator circuits): Hartley & Colpitt oscillators.

Unit 4 Introduction to Fiber Optics

Basics of Fiber Optics, step index fiber, graded index fiber, light propagation through an optical fiber, acceptance angle & numerical aperture, qualitative discussion of fiber losses and applications of optical fibers.

Suggested Readings

PART A

1. A. Beiser, Shobhit Mahajan, “Concepts of Modern Physics: Special Indian Edition”, McGraw Hill, 2009, 6e
2. John R. Taylor, Chris D. Zafiratos, Michael A.Dubson, “Modern Physics for Scientists and Engineers”, Prentice-Hall of India Private Limited, 2003, 2e
3. R.A. Serway, C.J. Moses, and C.A. Moyer, “Modern Physics”, Cengage Learning India Pvt. Ltd, 2004, 3e
4. R. Resnick, “Introduction to Special Relativity”, Wiley India Private Limited, 2007
5. R. Murugeshan, Kiruthiga Sivaprasath, “Modern Physics”, S. Chand Publishing, 2019, 18e

PART B

1. R.L. Boylestad, L. Nashelsky, “Electronic Devices and Circuit Theory”, Prentice-Hall of India Pvt. Ltd., 2015, 11e

2. J. Millman, C.C. Halkias, Satyabrata Jit, “Electronic Devices and Circuits”, McGraw Hill, 2015, 4e
3. B.G. Streetman, S.K. Banerjee, “Solid State Electronic Devices”, Pearson Education India, 2015, 7e
4. J.D. Ryder, “Electronic Fundamentals and Applications”, Prentice-Hall of India Private Limited, 1975, 5e
5. John M. Senior, “Optical Fiber Communications: Principles and Practice”, Pearson Education Limited, 2010, 3e
6. John Wilson, John Hawkes, “Optoelectronics: Principles and Practice”, Pearson Education Limited, 2018, 3e
7. S.L. Gupta, V. Kumar, “Hand Book of Electronics”, Pragati Prakashan, Meerut, 2016, 43e

Practical (Basic Electronics Instrumentation)

PHY 204 **Credit 0+2**

Course Outcomes (COs)

Basic Electronics instrumentation has the most striking impact on the industry wherever the components / instruments are used to study and determine the electronic properties. Measurement precision and perfection is achieved through Lab Experiments.

Lab Experiment List

1. Measurement of dc and ac voltages and frequency using cathod ray oscilloscope.
2. To study the characteristics of R-C network.
3. To study the characteristics of a rectifier circuit.
4. To study the characteristics of an unregulated power supply.
5. To study the characteristics of low/high pass filter.
6. To study the characteristics of interstage audio transformer.
7. To determine the dispersive power of the material of prism by spectrometer
8. Specific rotation of cane sugar using Polarimeter.
9. Resolving power of telescope
10. Resolving power of plane transmission grating
11. To determine the wavelength of sodium light by grating.

Classical Mechanics and Statistical Mechanics

PHY 301 **Credit 4+0**

Course Outcomes (COs)

CO1 Understand the concepts of generalized coordinates and D'Alembert's principle.
CO2 Understand the Lagrangian dynamics and the importance of cyclic coordinates.
CO3 Comprehend the difference between Lagrangian and Hamiltonian dynamics.
CO4 Study the important features of central force and its application in Kepler's problem.
CO5 Recognize the difference between macrostate and microstate.
CO6 Comprehend the concept of ensembles.
CO7 Understand the classical and quantum statistical distribution laws.
CO8 Study the applications of statistical distribution laws.

PART A

Unit 1 Constrained Motion
Constraints - Definition, Classification and Examples. Degrees of Freedom and Configuration space. Constrained system, Forces of constraint and Constrained motion. Generalised coordinates, Transformation equations and Generalised notations & relations. Principle of Virtual work and D'Alembert's principle.

Unit 2 Lagrangian Formalism
Lagrangian for conservative & non-conservative systems, Lagrange's equation of motion (no derivation), Comparison of Newtonian & Lagrangian formulations, Cyclic coordinates, and Conservation laws (with proofs and properties of kinetic energy function included). Simple examples based on Lagrangian formulation.

Unit 3 Hamiltonian Formalism
Phase space, Hamiltonian for conservative & non-conservative systems, Physical significance of Hamiltonian, Hamilton's equation of motion (no derivation), Comparison of Lagrangian & Hamiltonian formulations, Cyclic coordinates, and Construction of Hamiltonian from Lagrangian. Simple examples based on Hamiltonian formulation.

Unit 4 Central Force
Definition and properties (with prove) of central force. Equation of motion and differential equation of orbit. Bound & unbound orbits, stable & non-stable orbits, closed & open orbits and Bertrand's theorem. Motion under inverse square law of force and derivation of Kepler's laws. Laplace-Runge- Lenz vector (Runge-Lenz vector) and its applications.

PART B

Unit 1 Macrostate & Microstate

Macrostate, Microstate, Number of accessible microstates and Postulate of equal a priori. Phase space, Phase trajectory, Volume element in phase space, Quantisation of phase space and number of accessible microstates for free particle in 1D, free particle in 3D & harmonic oscillator in 1D.

Unit 2 Concept of Ensemble

Problem with time average, concept of ensemble, postulate of ensemble average and Liouville's theorem (proof included). Micro Canonical, Canonical & Grand Canonical ensembles. Thermodynamic Probability, Postulate of Equilibrium and Boltzmann Entropy relation.

Unit 3 Distribution Laws

Statistical Distribution Laws: Expressions for number of accessible microstates, probability & number of particles in ith state at equilibrium for Maxwell-Boltzmann, Bose-Einstein & Fermi-Dirac statistics. Comparison of statistical distribution laws and their physical significance. Canonical Distribution Law: Boltzmann's Canonical Distribution Law, Boltzmann's Partition Function, Proof of Equipartition Theorem (Law of Equipartition of energy) and relation between Partition function and Thermodynamic potentials.

Unit 4 Applications of Statistical Distribution Laws

Application of Bose-Einstein Distribution Law: Photons in a black body cavity and derivation of Planck's Distribution Law. Application of Fermi-Dirac Distribution Law: Free electrons in a metal, Definition of Fermi energy, Determination of Fermi energy at absolute zero, Kinetic energy of Fermi gas at absolute zero and concept of Density of States (Density of Orbitals).

Suggested Readings

PART A

1. Herbert Goldstein, Charles P. Poole, John L. Safko, "Classical Mechanics", Pearson Education, India, 2011, 3e
2. N.C. Rana, P.S. Joag, "Classical Mechanics", McGraw Hill, 2017
3. R.G. Takwale, P.S. Puranik, "Introduction to Classical Mechanics", McGraw Hill, 2017

PART B

1. F. Reif, "Statistical Physics (In SI Units): Berkeley Physics Course Vol 5", McGraw Hill, 2017, 1e
2. B.B. Laud, "Fundamentals of Statistical Mechanics", New Age International Private Limited, 2020, 2e
3. B.K. Agarwal, M. Eisner, "Statistical Mechanics", New Age International Private Limited, 2007, 2e

Quantum Mechanics & Spectroscopy

PHY 302 **Credit 4+0**

Course Outcomes (COs)

CO1 Understand the significance of operator formalism in Quantum mechanics.
CO2 Study the eigen and expectation value methods.
CO3 Understand the basis and interpretation of Uncertainty principle.
CO4 Develop the technique of solving Schrodinger equation for 1D and 3D problems.
CO5 Comprehend the success of Vector atomic model in the theory of Atomic spectra.
CO6 Study the different aspects of spectra of Group I & II elements.
CO7 Study the production and applications of X-rays.
CO8 Develop an understanding of the fundamental aspects of Molecular spectra.

PART A

Unit 1 Operator Formalism

Operators: Review of matrix algebra, definition of an operator, special operators, operator algebra and operators corresponding to various physical-dynamical variables. Commutators: Definition, commutator algebra and commutation relations among position, linear momentum & angular momentum and energy & time. Simple problems based on commutation relations.

Unit 2 Eigen & Expectation Values

Eigen & Expectation Values: Eigen equation for an operator, eigen state (value) and eigen functions. Linear superposition of eigen functions and Non-degenerate & Degenerate eigen states. Expectation value pertaining to an operator and its physical interpretation. Hermitian Operators: Definition, properties and applications. Prove of the hermitian nature of various physical-dynamical operators.

Unit 3 Uncertainty Principle & Schrodinger Equation

Uncertainty Principle: Commutativity & simultaneity (theorems with proofs). Non commutativity of operators as the basis for uncertainty principle and derivation of general form of uncertainty principle through Schwarz inequality. Uncertainty principle for various conjugate pairs of physical- dynamical parameters and its applications.

Schrodinger Equation: Derivation of time independent & time dependent forms, Schrodinger equation as an eigen equation, Deviation & interpretation of equation of continuity in Schrodinger representation, and Equation of motion of an operator in Schrodinger representation.

Unit 4 Applications of Schrodinger Equation

Application to 1D Problems: Infinite Square well potential (Particle in 1D box), Finite Square well potential, Potential step, Rectangular potential barrier and 1D Harmonic oscillator. Application to 3D Problems: Infinite Square well potential (Particle in a 3D box) and the Hydrogen atom (radial distribution function and radial probability included). (Direct solutions of Hermite, Associated Legendre and Associated Laguerre differential equations to be substituted).

PART B

Unit 1 Vector Atomic Model

Inadequacies of Bohr and Bohr-Sommerfeld atomic models w.r.t. spectrum of Hydrogen atom (fine structure of H-alpha line). Modification due to finite mass of nucleus and Deuteron spectrum. Vector atomic model (Stern-Gerlach experiment included) and physical & geometrical interpretations of various quantum numbers for single & many valence electron systems. LS & jj couplings, spectroscopic notation for energy states, selection rules for transition of electrons and intensity rules for spectral lines. Fine structure of H-alpha line on the basis of vector atomic model.

Unit 2 Spectra of Alkali & Alkaline Elements

Spectra of alkali elements: Screening constants for s, p, d & f orbitals; sharp, principle, diffuse & fundamental series; doublet structure of spectra and fine structure of Sodium D line. Spectra of alkaline elements: Singlet and triplet structure of spectra.

Unit 3 X-Rays & X-Ray Spectra

Nature & production, Continuous X-ray spectrum & Duane-Hunt's law, Characteristic X-ray spectrum & Mosley's law, Fine structure of Characteristic X-ray spectrum, and X-ray absorption spectrum.

Unit 4 Molecular Spectra

Discrete set of energies of a molecule, electronic, vibrational and rotational energies. Quantisation of vibrational energies, transition rules and pure vibrational spectra. Quantisation of rotational energies, transition rules, pure rotational spectra and determination of inter nuclear distance. Rotational-Vibrational spectra; transition rules; fundamental band & hot band; O, P, Q, R, S

Suggested Readings

PART A

1. D.J. Griffiths, "Introduction to Quantum Mechanics", Pearson Education, India, 2004, 2e
2. E. Wichmann, "Quantum Physics (In SI Units): Berkeley Physics Course Vol 4", McGraw Hill, 2017
3. Richard P. Feynman, Robert B. Leighton, Matthew Sands, "The Feynman Lectures on Physics - Vol. 3", Pearson Education Limited, 2012
4. R Murugeshan, Kiruthiga Sivaprasath, "Modern Physics", S. Chand Publishing, 2019, 18e

PART B

1. H.E. White, "Introduction to Atomic Spectra", McGraw Hill, 1934
2. C.N. Banwell, E.M. McCash, "Fundamentals of Molecular Spectroscopy", McGraw Hill, 2017, 4e
3. R Murugeshan, Kiruthiga Sivaprasath, "Modern Physics", S. Chand Publishing, 2019, 18e
4. S.L. Gupta, V. Kumar, R.C. Sharma, "Elements of Spectroscopy", Pragati Prakashan, Meerut, 2015, 27e

Practical (Demonstrative Aspects of Optics & Lasers)

PHY 303 **Credit 0+2**

Course Outcomes (COs)

Experimental physics has the most striking impact on the industry wherever the instruments are used to study and determine the optical properties. Measurement precision and perfection is achieved through Lab Experiments.

Lab Experiment List

1. Focal length of thin lenses and their combination by Nodal slide.
2. Wavelength of light using bi-prism.
3. Wavelength of light by Newton's rings method.
4. Breadth of single slit by diffraction of light using spectrometer.
5. Wavelength of light using double slit experiment (using spectrometer)
6. Refractive index using Brewster's law.
7. To determine the wavelength and separation between D1 and D2 line with the help of Michelson Interferometer.
8. To determine the Young's modulus by Cornue's Fringes or Newton's rings.
9. To determine the velocity of ultrasonic wave by diffraction method.
10. To determine the diameter of a thin wire by interference in a wedge shape air film.
11. To determine the wavelength of sodium light by interference due to three/ four slits.

Solid State Physics & Nuclear Physics

PHY 304 **Credit 4+0**

Course Outcomes (COs)

CO1 Understand the crystal geometry w.r.t. symmetry operations.
CO2 Comprehend the power of X-ray diffraction and the concept of reciprocal lattice.
CO3 Study various properties based on crystal bindings.
CO4 Recognize the importance of Free Electron & Band theories in understanding the crystal properties.
CO5 Study the salient features of nuclear forces & radioactive decays.
CO6 Understand the importance of nuclear models & nuclear reactions.
CO7 Comprehend the working and applications of nuclear accelerators and detectors.
CO8 Understand the classification and properties of basic building blocks of nature.

PART A

Unit 1 Crystal Structure
Lattice, Basis & Crystal structure. Lattice translation vectors, Primitive & non-primitive cells. Symmetry operations, Point group & Space group. 2D & 3D Bravais lattice. Parameters of cubic lattices. Lattice planes and Miller indices. Simple crystal structures - HCP & FCC, Diamond, Cubic Zinc Sulphide, Sodium Chloride, Cesium Chloride.

Unit 2 Crystal Diffraction
X-ray diffraction and Bragg's law. Experimental diffraction methods - Laue, Rotating crystal and Powder methods. Derivation of scattered wave amplitude. Reciprocal lattice, Reciprocal lattice vectors and relation between Direct & Reciprocal lattice. Diffraction conditions, Ewald's method and Brillouin zones. Reciprocal lattice to SC, BCC & FCC lattices.

Unit 3 Crystal Bindings
Classification of Crystals on the Basis of Bonding - Ionic, Covalent, Metallic, van der Waals (Molecular) and Hydrogen bonded. Crystals of inert gases, Attractive interaction (van der Waals- London) & Repulsive interaction, Equilibrium lattice constant, Cohesive energy and Compressibility & Bulk modulus. Ionic crystals, Cohesive energy, Madelung energy and evaluation of Madelung constant.

Unit 4 Lattice Vibrations
Lattice Vibrations: Lattice vibrations for linear mono & di atomic chains, Dispersion relations and Acoustical & Optical branches (qualitative treatment). Qualitative description of Phonons in solids. Lattice heat capacity, Dulong-Petit's law and Einstein's theory of lattice heat capacity.
Free Electron Theory: Fermi energy, Density of states, Heat capacity of conduction electrons, Paramagnetic susceptibility of conduction electrons and Hall effect in metals.
Band Theory: Origin of band theory, Qualitative idea of Bloch theorem, Kronig-Penney model, Effectice mass of an electron & Concept of Holes & Classification of solids on the basis of band theory.

PART B

Unit 1 Nuclear Forces & Radioactive Decays

General Properties of Nucleus: Mass, binding energy, radii, density, angular momentum, magnetic dipole moment vector and electric quadrupole moment tensor. Nuclear Forces: General characteristic of nuclear force and Deuteron ground state properties. Radioactive Decays: Nuclear stability, basic ideas about beta minus decay, beta plus decay, alpha decay, gamma decay & electron capture, fundamental laws of radioactive disintegration and radioactive series.

Unit 2 Nuclear Models & Nuclear Reactions

Nuclear Models: Liquid drop model and Bethe-Weizsacker mass formula. Single particle shell model (the level scheme in the context of reproduction of magic numbers included).
Nuclear Reactions: Bethe's notation, types of nuclear reaction, Conservation laws, Cross-section of nuclear reaction, Theory of nuclear fission (qualitative), Nuclear reactors and Nuclear fusion.

Unit 3 Accelerators & Detectors

Accelerators: Theory, working and applications of Van de Graaff accelerator, Cyclotron and Synchrotron. Detectors: Theory, working and applications of GM counter, Semiconductor detector, Scintillation counter and Wilson cloud chamber.

Unit 4 Elementary Particles

Fundamental interactions & their mediating quanta. Concept of antiparticles. Classification of elementary particles based on intrinsic-spin, mass, interaction & lifetime. Families of Leptons, Mesons, Baryons & Baryon Resonances. Conservation laws for mass-energy, linear momentum, angular momentum, electric charge, baryonic charge, leptonic charge, isospin & strangeness. Concept of Quark model.

Suggested Readings

PART A

1. Charles Kittel, "Introduction to Solid State Physics", Wiley India Private Limited, 2012, 8e
2. A.J. Dekker, "Solid State Physics", Macmillan India Limited, 1993
3. R.K. Puri, V.K. Babbar, "Solid State Physics", S. Chand Publishing, 2015

PART B

1. Kenneth S. Krane, "Introductory Nuclear Physics", Wiley India Private Limited, 2008
2. Bernard L. Cohen, "Concepts of Nuclear Physics", McGraw Hill, 2017
3. S.N. Ghoshal, "Nuclear Physics", S. Chand Publishing, 2019

Analog & Digital- Principles & Applications

PHY 305 **Credit 4+0**

Course Outcomes (COs)

CO1 Study the drift and diffusion of charge carriers in a semiconductor.
CO2 Understand the Two-Port model of a transistor.
CO3 Study the working, properties and uses of FETs.
CO4 Comprehend the design and operations of SCRs and UJTs.
CO5 Understand various number systems and binary codes.
CO6 Familiarize with binary arithmetic.
CO7 Study the working and properties of various logic gates.
CO8 Comprehend the design of combinational and sequential circuits.

PART A

Unit 1 Semiconductor Junction

Expressions for Fermi energy, Electron density in conduction band, Hole density in valence band, Drift of charge carriers (mobility & conductivity), Diffusion of charge carries and Life time of charge carries in a semiconductor. Work function in metals and semiconductors. Expressions for Barrier potential, Barrier width and Junction capacitance (diffusion & transition) for depletion layer in a PN junction. Expressions for Current (diode equation) and Dynamic resistance for PN junction.

Unit 2 Transistor Modeling

Transistor as Two-Port Network. Notation for dc & ac components of voltage & current. Quantitative discussion of Z, Y & h parameters and their equivalent two-generator model circuits. h-parameters for CB, CE & CC configurations. Analysis of transistor amplifier using the hybrid equivalent model and estimation of Input Impedance, Output Impedance and Gain (current, voltage & power).

Unit 3 Field Effect Transistors

JFET: Construction (N channel & P channel); Configuration (CS, CD & CG); Operation in different regions (Ohmic or Linear, Saturated or Active or Pinch off & Break down); Important Terms (Shorted Gate Drain Current, Pinch Off Voltage & Gate Source Cut-Off Voltage); Expression for Drain Current (Shockley equation); Characteristics (Drain & Transfer); Parameters (Drain III Resistance, Mutual Conductance or Transconductance & Amplification Factor); Biasing w.r.t. CS configuration (Self Bias & Voltage Divider Bias); Amplifiers (CS & CD or Source Follower); Comparison (N & P channels and BJTs & JFETs).
MOSFET: Construction and Working of DE-MOSFET (N channel & P channel) and E-MOSFET (N channel & P channel); Characteristics (Drain & Transfer) of DE-MOSFET and E-MOSFET; Comparison of JFFET and MOSFET.

Unit 4 Other Devices

SCR: Construction; Equivalent Circuits (Two Diodes, Two Transistors & One Diode-One Transistor); Working (Off state & On state); Characteristics; Applications (Static switch, Phase control system & Battery charger).
UJT: Construction; Equivalent Circuit; Working (Cutoff, Negative Resistance & Saturation

regions); Characteristics (Peak & Valley points); Applications (Trigger circuits, Relaxation oscillators & Sawtooth generators).

PART B

Unit 1 Number System
Number Systems: Binary, Octal, Decimal & Hexadecimal number systems and their inter conversion. Binary Codes: BCD, Excess-3 (XS3), Parity, Gray, ASCII & EBCDIC Codes and their advantages & disadvantages. Data representation.

Unit 2 Binary Arithmetic
Binary Addition, Decimal Subtraction using 9's & 10's complement, Binary Subtraction using 1's & 2's compliment, Multiplication and Division.

Unit 3 Logic Gates
Truth Table, Symbolic Representation and Properties of OR, AND, NOT, NOR, NAND, EX-OR & EX-NOR Gates. Implementation of OR, AND & NOT gates (realization using diodes & transistor). De Morgan's theorems. NOR & NAND gates as Universal Gates. Application of EX-OR & EX- NOR gates as pairty checker. Boolean Algebra. Karnaugh Map.

Unit 4 Combinational & Sequential Circuits
Combinational Circuits: Half Adder, Full Adder, Parallel Adder, Half Substractor, Full Substractor. Data Processing Circuits: Multiplexer, Demultiplexer, Decoders & Encoders. Sequential Circuits: SR, JK & D Flip-Flops, Shift Register (transfer operation of Flip-Flops), and Asynchronous & Synchronous counters.

Suggested Readings

PART A
1. R.L. Boylestad, L. Nashelsky, "Electronic Devices and Circuit Theory", Prentice-Hall of India Pvt. Ltd., 2015, 11e
2. J. Millman, C.C. Halkias, Satyabrata Jit, "Electronic Devices and Circuits", McGraw Hill, 2015, 4e
3. B.G. Streetman, S.K. Banerjee, "Solid State Electronic Devices", Pearson Education India, 2015, 7e
4. J.D. Ryder, "Electronic Fundamentals and Applications", Prentice-Hall of India Private Limited, 1975, 5e
5. S.L. Gupta, V. Kumar, "Hand Book of Electronics", Pragati Prakashan, Meerut, 2016, 43e

PART B
1. D. Leach, A. Malvino, Goutam Saha, "Digital Principles and Applications", McGraw Hill, 2010, 7e
2. William H. Gothmann, "Digital Electronics: An Introduction to Theory and Practice", Prentice-Hall of India Private Limited, 1982, 2e
3. R.P. Jain, "Modern Digital Electronics", McGraw Hill, 2009, 4e

Practical (Analog & Digital Circuits)

PHY 306 **Credit 0+2**

Course Outcomes (COs)

Analog & digital circuits have the most striking impact on the industry wherever the electronics instruments are used to study and determine the electronic properties. Measurement precision and perfection is achieved through Lab Experiments.

Lab Experiment List

1. Verification of Richardson-Dushman equation and evaluation of work function of cathode material.
2. To draw the characteristics and to determine the parameters of a field effect transistor (FET).
3. Characteristics of MOSFAT
4. Verification of truth table of OR, AND and NOT gates.
5. Study and Verification of AND gate using TTL IC 7408
6. Study and Verification of OR gate using TTL IC 7432
7. Study and Verification of NAND gate and use as Universal gate using TTL IC 7400
8. Study and Verification of NOR gate and use as Universal gate using TTL IC 7402
9. Study and Verification of NOT gate using TTL IC 7404
10. Study and Verification of Ex-OR gate using TTL IC 7486