U.G. 6th Semester Examination-2025

PHYSICS

[PROGRAMME]

Discipline Specific Elective (DSE)

Course Code : PHY-G-DSE-T-02(A-E)

[Old Syllabus]

Full Marks : 40/60 Time : $2\frac{1}{2}$ Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

Answers must be precise and to the point to earn credit.

All symbols are of usual significance.

Answer all the questions from Selected Option.

OPTION-A

PHY-G-DSE-T-02

(Digital, Analog Circuits and Instrumentation)

[Marks : 40]

GROUP–A

1. Answer any **five** questions: 2×5=10

a) What is the cut-in voltage in p-n junction diode? Explain.

b) Convert $(75.812)_{10}$ into binary.

c) Minimise the Boolean expression: CA+CAB+CAB+CAB

d) Define half adder with a circuit diagram.

e) Perform binary addition of $(1011)_2$ and $(1101)_2$.

f) What is the difference between a photo diode and solar cell?

g) What are the practical values of input and output resistances of 741 OP AMP?

h) What are the functions of CRO?

GROUP–B

2. Answer any **two** questions: 5×2=10

a) i) What are De Morgan's theorems? Prove that:

$$\overline{\left(\left(A.\overline{(A\,.\,B)}\right).\left(B.\overline{(A\,.\,B)}\right)\right)} = \bar{A}.B + A.\bar{B}$$

ii) Simplify the Boolean expression by Karnaugh Map

$$Y = \bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + A\bar{B}\bar{C}\bar{D} + \bar{A}BCD$$

2+1+2

b) How does an LED produce light? What are its major advantages over conventional light sources? Discuss the working principle of a LED with suitable diagrams. 1+1+3

c) Explain the terms α and β in transistor operation and derive their relation. Compare CB, CE & CC configuration of transistor in terms of input impedance, output impedance & current gain. 3+2

d) What are the Barkhausens criterion for self-sustained oscillations in a linear electronic circuit? Explain with diagram. If A is the amplifier gain and β is the feedback gain of an oscillator, write down the conditions when (i) the output signal will die out. (ii) the output signal will build up. (iii) the output signal will be steady. 3+2

GROUP–C

3. Answer any **two** questions: 10×2=20

a) Construct a NAND gate using diodes and transistors. Why is the NAND gate considered a universal gate? Explain. 4+6

b) State the important characteristics of an ideal OP-AMP? What is inverting OP-AMP? Draw the circuit diagram of an inverting OP-AMP with inputs v_1, v_2, v_3 for gain 100 and derive the expression of the output voltage, V_0 and values of resistances. What will be the V_0 when inputs are applied at the non-inverting input. 3+2+2+1+1+1

c) What is XOR gate? Draw a block diagram of a Full-Subtractor using Half-subtractors & also design its logic gate diagram. Describe the digital circuit which can perform both addition and subtraction of two 4-bit binary numbers. 2+2+2+4

d) i) With the help of V-I characteristics of a zener diode explain the operation of zener as a voltage regulator. Define zener voltage for variable input voltage. What is the manufacturing tricks that makes it different from ordinary diode? 4+1+1

ii) Draw the circuit diagram & wave form of monostable multivibrator using IC-555. 4

OPTION-B

PHY-G-DSE-T-02

(Solid State Physics)

[Marks : 40]

GROUP–A

1. Answer any **five** questions: 2×5=10

a) What is a Bravais Lattice?

b) Describe how Bragg's Law explains formation of X-ray Diffraction peaks from crystals.

c) Distinguish between acoustical and optical phonons in connection with a diatomic linear chain.

d) What is the main difference between Debye theory and Einstein theory of specific heat? What do you mean by Debye temperature?

e) What is the difference between paramagnetism and diamagnetism?

f) Explain piezoelectric effect.

g) Explain hall coefficient.

h) What do you mean by type I and type II superconductor?

GROUP-B

2. Answer any **two** questions : 5×2=10

a) Define an unit cell of a crystal lattice. Find the number of atoms per unit cell for a f.c.c lattice. Define reciprocal lattice. 1+2+2

b) Explain the main features of Einstein's theory of lattice heat capacity. Write down the expression of heat capacity calculated using Einstein's theory and explain the high and low temperature behavior. 1+4

c) State and explain Curie Law. Derive an expression for paramagnetic susceptibility at ordinary temperature and magnetic field according to quantum theory of magnetism. 1+4

d) Show that diamagnetic susceptibility of a material of temperature independent. 5

GROUP-C

3. Answer any **two** questions : 10×2=20

a) What is Bloch theorem? Find the energy bands of electrons for a one dimensional periodic potential of period $(a+b)$ defined as $V=0$ *for* $0 \le x \le a$ and $V=V_0$ *for* $a \le x \le b$, where $V_0 \to \infty$, $b \to 0$ and $V_0 b$ finite. Show that an energy band of a crystal comprising of N primitive unit cell can accommodate 2N electrons. 2+5+3

b) Explain Hall effect. Consider a metal having electron as only charge carriers. Calculate the Hall-coefficient. Define mobility of a charge

carriers. Establish the relation between electrical conductivity and mobility for a metal. 2+3+2+3

c) Define the terms electric displacement **D**, electric field **E**, and polarization **P**, Establish the relationship between **D**, **E** and **P**. Define atomic polarizability. Deduce the Clausias-Mossotti relation between atomic polarizability and dielectric constant. 3+2+5

d) Distinguish between conductor and semiconductor in terms of Band theory. Explain what is effective mass of electron in a band. Explain how the conductivity of semiconductor varies with temperature. What is ferroelectricity? Explain '*polarization catastrophe*'. 2+2+3+1+2

OPTION-C

PHY-G-DSE-T-02

(Nuclear & Particle Physics)

[Marks : 60]

GROUP–A

1. Answer any **ten** questions: 2×10=20

a) Write down the quark content of Anti Proton and Neutron.

b) Write down the classification of elementary particles with examples.

c) What is s- process path?

d) What is Cyclotron Accelerator? Name one such Cyclotron facility in India.

e) What are the principal processes by which γ rays interact with matter?

f) Calculate the wave length and frequencies of γ rays of energies 1.0 and 8.0 MeV.

g) The radius of $^{64}_{29}Cu$ nucleus is measured to be 4.8×10^{-13}cm. Estimate the radius of a $^{49}_{25}Mg$ nucleus?

h) The $^{238}_{92}U$ nucleus decays to stable $^{206}_{82}Pb$ nucleus by emitting how many α and β disintegrations?

i) What do you mean by Q-value of a nuclear reaction?

j) The best possible detector for γ - rays detection is (a) Proportional Counter (b) Gas detector (c) NaI(Tl) scintillation detector (d) High purity Germanium detector.

k) What do you mean by Impact parameter in case of Rutherford Scattering of α -particles?

l) What are the basic β - decay process in a nucleus like ${}^{A}_{Z}X_{N}$?

m) If the half-life of ${}^{90}_{30}Sr$ is 28.8 years, then find out its decay constant?

n) Show that the lepton number is conserved for the following decay process $\mu^- \rightarrow e^- + \overline{\nu}_e + \nu_\mu$.

o) The relativistic mass of an electron is twice that of its rest mass What should be its velocity and kinetic energy?

GROUP–B

2. Answer any **four** questions : 5×4=20

a) Write down the advantages of Semiconductor detectors over other type of radiation detectors? Calculate the minimum kinetic energy of proton at which Cherenkov radiation will produce in a medium of refractive index 1.5 (for Protons Mc^2 = 938.3 MeV). 2+3

b) Describe briefly the principle of operation of Cyclotron accelerator. Assuming a magnetic

field of 1.4 T, compute the maximum energy of protons that can be obtained from a cyclotron of radius 75 cm? 3+2

c) What are the magic numbers of nuclear shell model? Explain. What are the evidences of shell structure in the nuclei? 2+3

d) What do you mean by conservation laws of nuclear reactions? What is compound nucleus model of nuclear reactions? 3+2

e) What do you mean by Baryon number conservation? Give an example where baryon number is conserved? In which interaction strangeness must be conserved? 2+2+1

f) What is neutrino hypothesis in the context of β - decay of a nucleus? Write down the expression of the Q values for the following β - decay processes:

${}^{A}_{Z}X_{N} \rightarrow {}^{A}_{Z+1}X'_{N-1} + \beta^-$ and ${}^{A}_{Z}X_{N} \rightarrow {}^{A}_{Z-1}X'_{N+1} + \beta^+$

2+3

GROUP–C

3. Answer any **two** questions : 10×2=20

a) Discuss briefly the theory of α -emission. The radioactive ${}^{212}_{84}Po$ nucleus decays to the ground state ${}^{208}_{82}Pb$ by α - emission. Calculate the Q value

of the decay process in Mev? Given the mass of $^{212}_{84}Po$ is 211.988874 amu, $^{208}_{82}Pb$ is 207.976658 amu and $^{4}_{2}He$ is 4.002603 amu. Discuss briefly about the principal processes by which γ-rays interact with matter? 4+3+3

b) Define (i) nuclear binding energy, (ii) mass defect, (iii) packing fraction and (iv) binding fraction of a nucleus? "The nature of binding fraction curve is complementary to the nature of the packing fraction curve"- explain. Discuss about the similarities between the nucleus of an atom and a liquid drop. Let E_s denote the contribution of the surface energy per nucleon in the semiempirical mass formula. Calculate the ratio $E_S\left(^{27}_{13}Al\right) : E_S\left(^{64}_{30}Zn\right)$. 4+3+2+1

c) Discuss briefly the basic principle of the action of the scintillation detector. Write down the use of photo multiplier tube. Write a short note on basic operation of Van de Graaff generator. 4+2+4

d) What do you mean by quark model of particle physics? What are colour quantum numbers? What does the roles play by gluons in strong interactions? What is the basic difference between photons and gluons? 4+2+2+2

OPTION-D

PHY-G-DSE-T-02

(Quantum Mechanics)

[Marks : 40]

GROUP–A

1. Answer any **five** questions: 2×5=10

a) An eigen function of the operator $\frac{d^2}{dx^2}$ is $\psi = \sin(2x)$. Find the corresponding eigen value.

b) What do you mean by a potential well?

c) What is Bohr magneton? What is its value?

d) Show that for commuting observables the operators have same eigenvalue.

e) Write down the Hamiltonian operator for one dimensional Linear Harmonic Oscillator.

f) Determine the de Broglie wavelength of an electron that has been accelerated through a potential difference of 100V.

g) What is J-J coupling in quantum mechanics?

h) What is meant by probability current densities of Wave Function in three dimensions?

GROUP–B

2. Answer any **two** questions: 5×2=10

a) Define expectation value of a dynamical variable in quantum mechanics. Prove that the expectation value of energy in the eigenstate $\psi_n = u_n(r) \exp\left(-\frac{iE_n t}{h}\right)$ is certainly E_n, where $u_n(r)$ is normalized. 2+3

b) Derive time independent Schrodinger equation in three dimension.

c) Write down time independent Schrodinger equation for hydrogen atom in spherical polar coordinates. Prove that the operators $\hat{x}$ *and* $\widehat{p_x}$ do not commute. Find the value of the commutator $[\hat{x}, \widehat{p_x}]$. 2+2+1

d) Discuss the physical significance of Orbital angular momentum quantum numbers l and m.

GROUP–C

3. Answer any **two** questions: 10×2=20

a) i) What is zero point energy of a linear Harmonic oscillator in one dimension?

ii) The uncertainty in the location of a particle is equal to its de Broglie wavelength. Show that the uncertainty in its velocity is equal to its velocity.

iii) What do you mean by stationary state? Show that the position probability density corresponding to the stationary states are constant in time. 2+3+(2+3)

b) What is the physical interpretation of a wave function? Write its orthogonality conditions. Define stationary state. Show that probability density is constant for stationary states. What do you understand by Normalization of wave function? Explain. 2+2+1+2+3

c) i) Briefly discuss the Stern-Gerlach experiment and the outcome of this experiment.

ii) What is the total angular momentum in the vector-atom model of atom?

iii) Find the possible values of the total angular momentum J under LS coupling of two electrons atom whose orbital quantum numbers are $l_1 = 1$ and $l_2 = 1$. 4+3+3

d) Explain normal Zeeman effect with energy level diagram. State Pauli's Exclusion Principle. Which particles do not follow Pauli's Exclusion Principle? 5+3+2

OPTION-E

PHY-G-DSE-T-02

(Elements of Modern Physics)

[Marks : 40]

GROUP–A

1. Answer any **five** questions: 2×5=10

a) Explain the need for neutrino hypothesis in beta decay.

b) What do you understand by the wave function ψ of a moving particle?

c) What is meant by mean life and half life of a radioactive substance?

d) What do you mean by quantum mechanical tunneling effect of particles?

e) Write down Heisenberg's uncertainty principle in terms of energy and time.

f) Write down the problems with Rutherford model to describe the stability of an atom.

g) Write down the operators for momentum and energy in quantum mechanics.

h) Define the terms 'threshold frequency' and 'work function' related to photoelectric effect.

GROUP–B

2. Answer any **two** questions: 5×2=10

a) Derive the expression for the total energy of an electron in the n^{th} Bohr orbit and show that $E_n \propto \frac{1}{n^2}$. 5

b) Write down the Schrödinger equation for non-relativistic particles. State the physical interpretation of wave function. What do you mean by stationary states? Define probability current density of a wave function in one dimension. 1+2+1+1

c) Write down the semi empirical mass formula. Give an explanation of the various terms in the formula. 5

d) Write down the salient features of photoelectric effect. Photoelectric threshold wave length of tungsten is 2300Å. Calculate the maximum kinetic energy of the electrons ejected by the radiation of wavelength 1800Å. 2+3

GROUP–C

3. Answer any **two** questions: 10×2=20

a) What are slow neutrons? Describe the construction of a nuclear reactor with a suitable diagram. What is the use of control rods in a nuclear reactor? 2+6+2

OPTION-E

PHY-G-DSE-T-02

(Elements of Modern Physics)

[Marks : 40]

GROUP–A

1. Answer any **five** questions: 2×5=10

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b) What do you understand by the wave function ψ of a moving particle?

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GROUP–C

3. Answer any **two** questions: 10×2=20

a) What are slow neutrons? Describe the construction of a nuclear reactor with a suitable diagram. What is the use of control rods in a nuclear reactor? 2+6+2

b) State the properties of nuclear forces. Write down semi-empirical mass formula related to nuclear binding energy. Explain the origins of every energy term in the said formula. How $N - Z$ graph explain nuclear stability?

2+1+5+2

c) The wavefunction Y of a particle with mass m in an infinite square well with walls at x=0 and x=L, is given by $A\sin\left(\frac{n\pi}{L}x\right)$.

i) Normalize Y to find A. Show that

$$\int_0^L \Psi_m(x) * \Psi_n(x)dx = 0 \; if m \neq n.$$

ii) Find the momentum of the particle.

3+3+4

d) What are matter waves? Determine the wavelength of an electron that has been accelerated through a potential difference of 150 Volt. A proton is confined to a nucleus of radius 5×10^{-15} m. Calculate the minimum uncertainty in its momentum. Also, calculate the minimum kinetic energy of the proton. Proton mass $m_p = 1.67\times10^{-27}$ kg. 2+4+4