U.G. 6th Semester Examination-2024

PHYSICS

[PROGRAMME]

Discipline Specific Elective (DSE)

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

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-02A

(Digital, Analog Circuits and Instrumentation)

[Marks : 40]

GROUP–A

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

   a) Distinguish between zener breakdown and avalanche breakdown.

   b) Write down two uses each of photodiode and LED.

c) Why binary number system is used in digital electronics?

d) Distinguish between class A and B amplifier.

e) State Barkhausen's criterion for self-sustained oscillations.

f) Subtract the binary number $(101101)_2$ from $(1101010)_2$.

g) What do you mean by CMRR related to OP-AMP? What should be the value of CMRR for an ideal OP-AMP?

h) Show the pin-diagram of IC-555. What for this IC is used?

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

a) What are the differences between analog and digital circuits? Construct a two-input OR gate using PN junction diodes and explain its operation. 2+3

b) Qualitatively explain the idea of current flow mechanism in a reverse biased PN junction diode. Distinguish between the static and dynamic resistances of a PN junction diode. 3+2

c) What is photovoltaic effect? Explain the working principle of a solar cell. 1+4

d) What do you mean by open-loop and closed-loop gain of an OP-AMP? Draw the circuit diagram of a subtractor using OP-AMP and explain its operation. 2+3

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

a) What do you mean by minterms and maxterms? Simplify the Boolean expression $Y = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + \bar{A}BC + A\bar{B}C + ABC$ using Karnaugh map. Implement the simplified expression into a logic circuit. Write down the truth table of a half-adder and construct a full-adder using two half-adders. Sketch the block diagram of a 4-bit binary adder using full-adders. 2+3+4+1

b) How a bridge full-wave rectifier works? Calculate the ripple factor for its output. How the frequency of a signal and the phase difference between two signals can be measured using a CRO? –Explain. 3+3+4

c) Explain the operation of a transistor as a CE amplifier. Define DC-load line and Q-point "of a transistor. Define h-parameters of a transistor in CE configuration. If the current gain of a transistor in CE configuration be 50, then what

will be the current gain if the transistor is kept in CB configuration? 3+2+4+1

d) How the characteristics of a practical OP-AMP (IC-741) differ from an ideal OP-AMP? What do you mean by virtual-ground in connection with the OP-AMP network? If a square wave is applied as input to an integrator, then draw the probable waveform of the output. Draw a block diagram of CRO and explain the operations of its major parts. 2+2+1+5

OPTION-B

PHY-G-DSE-T-02B

(Quantum Mechanics)

[Marks : 40]

GROUP–A

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

   a) What is a free particle? Which parameter characterize it?

   b) Why should the wave function $\psi(x)$ be single-valued everywhere ?

   c) What is the probability density in terms of wave function?

   d) Normalize the wave function $\psi(x) = Ne^{-x/2}$.

   e) What is the Hamiltonian operator and energy operator?

   f) Write the Schrodinger equation for Hydrogen like atom.

   g) Why the quantum number n = 0 is not allowed as per the Bohr theory?

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

   a) State and explain Heisenberg uncertainty principle. If $\psi(x,t)$ is a Schrodinger wave function, prove that $\psi^*(x,t)\,\psi(x,t)$ is necessarily real and either positive or zero. 2+3

b) Show that the wave function $\psi(x) = A\cos(kx - \omega t)$ does not satisfy the time-dependent Schrodinger equation for a free particle. 5

c) Starting from time dependent Schrodinger equation in one dimension, derive the equation of continuity for wave function. 5

d) Prove that $exp[i(AB - BA)]$ is a Hermitian operator, if A, B are Hermitian operator. 5

Answer any **two** questions: 10×2=20

3. a) Calculate the lowest energy of an electron confined to move in a one dimensional potential well of width 1Å and of infinite depth. 2

b) What is probability current density **J**? Show that the probability current density vanishes if the wave function is real. 1+3

c) What is normalization of a wave function? The one dimensional wave function is given by $\psi(x) = \sqrt{a}\ e^{-ax}$. Find tne probability of finding the particle between $x = {}^{1}/_{a}$ and $x = {}^{12}/_{a}$. 1+3

4. a) State and explain Pauli's Exclusion Principle. Which particles do not follow Pauli's Exclusion Principle. 3+2

b) Explain LS coupling scheme. What is JJ coupling scheme? Why it is applicable only to heavy elements? 1+1+1

c) What is Lande-g factor? 1

d) What do you mean by Paschen-Back effect? 1

5. a) Using time dependent Schrodinger equation show that the space integrated probability is independent of time. 3

b) What is the relation between angular momentum and linear momentum? Determine the expression for square of total angular momentum operator in spherical polar coordinates. 2+3

c) What do you mean by electronic configuration? 2

6. a) What is the probability density in terms of wave function? 1

b) Show that eigenvalues of a Hermitian operator are real. 2

c) A particle on the x-axis has the wave functions by $\psi(x) = cx^2$ between x = 0 and x = 2.

i) Normalized the wave function over the interval

ii) Find the probability that the particle can be found between x = 0.5 and x=0.6.

iii) Find the expectation value of the particle's position x. 3

d) Show that if for a one-dimensional potential $V(-x) = -V(x)$ the eigenfunctions of the Schrodinger equation are either symmetric or antisymmetric function of x. 2

e) A particle is confined in a one-dimensional box with the infinity hard walls. Find the energy eigenvalues, and normalized the wave function. 2

OPTION-C

PHY-G-DSE-T-02C

(Solid State Physics)

[Marks : 40]

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

a) Explain the term "lattice translation vector" with proper diagram.

b) Define the term Plasma Frequency in solid material.

c) What is Hysteresis Loss? Explain with a proper diagram.

d) Draw the susceptibility vs. temperature graph for ferromagnetic materials and show the Curie temperature.

e) What is London penetration depth?

f) What is Pyroelectric effect? Explain with example.

g) What is 4 probe method in the measurement of conductivity?

h) Define Type 1 and type II Superconductors.

GROUP-B

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

a) Derive an expression for Langevin-Debye formula for the temperature dependence of dipolar polarizability and dielectric constant.

5

b) Show that the diamagnetic susceptibility of an element is independent of temperature. 5

c) By considering the lattice vibration for a diatomic lattice obtain the dispersion relation for one-dimensional diatomic lattice. What are acoustical and optical phonons? 3+2

d) i. The conductivity of a metal decreases with rise of temperature, whereas the conductivity of a semiconductor increases with increase of temperature. Explain both the cases clearly giving appropriate examples.

ii. Write the domain hypothesis of Weiss and explain the physical origin of domain formation from the general thermodynamic principle. 2+1+2

GROUP-C

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

a) Calculate the Miller indices of crystal planes which cut through the crystal axes at (a,b,c), (2a,b,c) and (2a,-3b,-3c).

b) What is reciprocal lattice? Show that the volume of a unit cell in reciprocal lattice is inversely proportional to the volume of a unit cell in direct lattice. 3+7

4 a) Derive the expression of specific heat of a solid using Einstein calculation at high temperature and low temperature limits.

b) Derive Curie-Weiss law from Weiss's Molecular theory of magnetism. Sketch the variation of the magnetic susceptibility with temperature above the Curie point. 5+(4+1)

5. a) What is Meissner effect?

b) Briefly explain how BCS theory accounts for the superconducting state.

c) What is critical temperature of superconductor? Discuss the isotope effect on critical temperature of superconductor.

$(2\frac{1}{2}+2\frac{1}{2})+2+(1+2)$

6. a) What are the basic assumptions of Kronig Penny Model?

b) Explain n-type semiconductor with proper diagram.

c) Draw a schematic diagram with proper labelling of the experimental setup of measuring hall effect in a semiconductor. 2+4+4

OPTION-D

PHY-G-DSE-T-02D

(Elements of Modern Physics)

[Marks : 40]

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

a) In the photoelectric effect, some photoelectrons have kinetic energies less than the maximum kinetic energy. Why?

b) Draw a graph between the frequency of light falling on a metal surface and the kinetic energy of the photoelectrons emitted.

c) What are 'matter waves'? Write down an equation for their wavelength.

d) Define 'isotope' and 'isobar'.

e) Draw a graph between stopping potential and frequency of incident light in photoelectric effect.

f) What is nuclear fission? Give an example. What is a chain reaction?

g) The total energy of electron in H-atom is negative. Why?

h) In Rutherford's scattering of α-particles by a thin gold foil, one can neglect the effect of the atomic electron on α-particles. Why?

2. Answer any **two** questions: $5\times2=10$

a) State de Broglie hypothesis. Show that the relativistic expression for the de Broglie wavelength of an electron accelerated through a high potential difference of V volt is

$$\lambda = \frac{h}{\sqrt{2m_0eV}}\left(1+\frac{eV}{2m_0c^2}\right)^{-\frac{1}{2}}$$ 2+3

b) A particular type of nucleus with decay constant λ, is being produced artificially using accelerator at a steady rate of P nuclei per second. Show that the number of nuclei present at t second after the production starts is

$$N(t) = \frac{P}{\lambda}\left(1-e^{-\lambda t}\right).$$ 5

c) Define mass defect and packing fraction of nuclei. How does the binding energy per nucleon vary with mass number for light, medium and heavy nuclei? 1+1+3

d) Determine the probability density and the probability current density for a wave function given by

$$\psi(x) = A\, exp(-\sigma^2 x^2/2)\, exp(ikx).$$

1+4

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

a) What is Compton effect? What is its basic importance? Obtain an expression for the Compton shift. What is Compton wavelength?

2+2+5+1

b) Define the decay constant λ of a radioactive material. Hence obtain an expression for the number of radioactive atoms at time t, given that their initial number was N_0. Define half-life of a radioactive element. Obtain its expression in terms of λ. A radioactive substance disintegrates for a time equal to its average life. Calculate the fraction of the original substance disintegrated. The half-life of radon is 3.82 days. What fraction of freshly prepared sample of radon will disintegrate in 10 days?

1+3+1+1+2+2

c) State Heisenberg's uncertainty principle. Show that the concept of Bohr orbits violates the

principle of uncertainty. What are group velocity and phase velocity? Obtain the relation between them. 2+3+2+3

d) Write down the Schrodinger equation for non-relativistic particles. Describe Davisson-Germer experiment with diagrams and explain how it establishes the wave nature of matter. Write a short note on thermonuclear reaction. 1+6+3

OPTION-E

PHY-G-DSE-T-02E

(Nuclear & Particle Physics)

[Marks : 60]

GROUP–A

1. Answer any **ten** questions: $2\times10=20$

a) Write down the Geiger-Nuttal law for α-decay by radioactive nuclei.

b) Name the accelerator that works on the principle of electromagnetic induction.

c) A radioactive substance decays to 1/32th of its initial activity in 25 days. Calculate its half life.

d) Why is nuclear fusion difficult to carry out?

e) Distinguish between a Cyclotron and Synchrotron.

f) What are leptons? Name any three Leptons and their antiparticle.

g) What are primary and secondary cosmic rays?

h) Describe the differences between baryons and leptons with one example of each.

i) Why is the Scintillation detector efficient than the GM counter for the detection of Gamma ray.

j) What is the evidence of the shell structure of nucleus?

k) State and explain the Geiger-Nuttal law for α-decay by radioactive nuclei.

l) Write the differences between stripping and pick-up reaction.

m) What are strange particles? Give example.

n) Write down the quark content of proton and pion.

o) What is nuclear force? How does it differ from Coulomb force?

GROUP–B

Answer any **four** questions : $5\times4=20$

2. a) What is cyclotron frequency? Calculate the maximum energy of a charged particle when it is extracted at a radius R. 5

b) Using baryon number and strangeness number conservation laws, find which of the following reactions is allowed?

i) $\pi^- + p \rightarrow \wedge_0 + K_0$

ii) $\pi^- + p \rightarrow \wedge_0 + \pi_0$ $2\frac{1}{2}+2\frac{1}{2}$

c) Derive Bethe-Block formula for Energy loss due to ionization. 5

d) Draw the binding energy per nucleon versus the mass number curve and explain. 5

e) Briefly explain liquid drop model. 5

f) Justify that nuclear density is independent of mass number. What do the peaks on the binding energy curve at lower mass number signify? 2+3

GROUP–C

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

a) i) Consider the following reaction where X is the nucleus at rest, a is the projectile, Y is the residual nucleus and b is the outgoing particle.

$$a + X \rightarrow Y + b.$$

Draw the appropriate vector diagram of the above reaction in the centre of mass frame and laboratory frame.

ii) Let m_a, m_x, m_Y, and m_b are the masses of corresponding particles in the above reaction. Give an expression of Q value of the above reaction. What is the significance of Q? 5+5

b) i) Explain the working principle of photo-multiplier tube (PMT) with diagram.

ii) How Gamma rays interact with matter?

iii) Define cross section of nuclear reaction and write its SI unit. 4+3+3

c) i) Explain clearly what is the energy conservation problem in β-decay phenomenon. How was it solved?

ii) Find out the mass difference between two mirror nuclei in terms of their mass by using the semi empirical mass formula.

iii) Using a Schematic Circuit diagram explain the working principle of a semiconductor detector for detecting nuclear radiation. 3+3+4

d) i) Calculate the Q value and K.E of the following alpha decay $^{214}_{84}Po \rightarrow {}^{210}_{82}Pb + \alpha$.

ii) Draw the Y-I_3 diagram for baryon octate for $J^P = \frac{1}{2}^+$. 5+5
