U.G. 4th Semester Examination - 2022

PHYSICS

[PROGRAMME]

Course Code : PHY-G-CC-T-04(A-D)

Full Marks : 40 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.

Answer all the questions from selected option.

OPTION–A

PHY-G-CC-T-04A

(Quantum Mechanics)

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

   i) Give the physical interpretation of wave function $\psi(r, t)$ in quantum mechanics.

   ii) Define expectation value of a dynamical variable in quantum mechanics.

   iii) What is space quantization?

   iv) Define probability density and probability current density for a quantum system.

   v) What do you mean by stationary states?

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

   vii) What is quantum mechanical operator?

   viii) Write down the time independent Schrodinger equation of a free particle in one dimension.

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

   i) Write down the Schrodinger equation for hydrogen atom in spherical polar coordinates. Are the following pairs of quantum mechanical operators commuting or noncommuting?

   $\hat{x}$ *and* $\widehat{p_x}$; $\widehat{p_y}$ *and* $\widehat{p_z}$; and $\widehat{L_x}$ *and* $\widehat{L_y}$.

   2+3

   ii) Calculate the normalization constant 'A' for a wave function given by $(\text{at } t=0)$, $\psi(x) = A\exp\left(-\sigma^2 x^2/2\right)\exp(ikx)$. Determine the probability current density for this case.

   2+3

   iii) Apply the space quantization principle to determine the values of J for the following values of L and S vector: L=l, S=l; L=2, S=1; L=l, S=3/2; L=2, S=3/2. How many electrons can occupy the f sub shell of an atom? 4+1

   iv) What is zero point energy of a linear harmonic oscillator in one dimension? A one dimensional linear harmonic oscillator has an

angular frequency of 5×10^{14} per sec. Calculate its zero point energy. 2+3

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

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

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

c) 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 $l_2 = 2$. 4+3+3

ii) a) Consider a particle of mass m moving in an one dimensional infinite potential well of width l. Show that the energy eigen values are given by $E_n = \frac{n^2\pi^2h^2}{2ml^2}$, while the corresponding normalized eigen functions are

$$\psi_n(x) = \left(\frac{2}{l}\right)^{\frac{1}{2}} \sin\left(\frac{n\pi x}{l}\right),$$

where n=l, 2, 3...

b) Write down the ground state wave function and ground state energy expression for hydrogen atom.

c) An eigen function of the operator $\frac{d^2}{dx^2}$ is $\psi = \sin(2x)$. Find the corresponding eigen value. 5+3+2

iii) a) Describe the theory which explains the anomalous Zeeman effect. Illustrate with diagrams the Zeeman splitting of sodium D_1 and D_2 lines.

b) Find the precessional frequency of an electron orbit when placed in a magnetic field of 5T. Hence find the wavelength in normal Zeeman splitting. Express it as a percentage of the spectrum line of $\lambda = 5893\,\text{Å}$.

c) What is Bohr magneton? What is its value? 5+3+2

iv) a) What is uncertainty principle? If 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.

b) Suppose that you measure now the position of this particle. What is the probability of finding it between x=0 to x= +0.5nm.

c) Show that the position probability density corresponding to a stationary states are constant in time. (2+2)+3+3

OPTION–B

PHY-G-CC-T-04B

(Statistical Mechanics)

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

   a) What is the equal apriori theory of statistical mechanics?

   b) What do you mean by statistical ensemble?

   c) Find out the Fermi energy of the electrons in silver. Given that the atomic wt. of silver is 108, and density 10.5 gm/c.c.

   d) What is the statistical definition of temperature?

   e) Define phase space.

   f) What do you mean by Grand Canonical Ensemble?

   g) What is Gibbs paradox?

   h) State and explain Ultraviolet Catastrophe.

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

   a) What do you mean by macroscopic and microscopic states of a system? If two systems A and B are in contacts and having microstates $\Omega_1(N_1, V_1, E_1)$ and $\Omega_2(N_2, V_2, E_2)$, if the

systems are allowed only energy exchange, calculate the condition of thermal equilibrium of A and B in contact with each other. 2+3

b) Define free energy of a thermodynamic system. Using the form of Helmholtz free energy $F = -NKT \ln Z$ shows that $S = NK\left[\ln Z + \beta \bar{E}\right]$. 2+3

c) What do you mean by accessible state of a system? Define entropy using the concept of accessible state. Using the definition of entropy, explain the validity of third law of thermodynamics. 2+1+2

d) What is Fermi energy? Determine the phase space trajectory of a bullet of unit mass fired straight upwards with an initial speed of 392 m/s. Acceleration due to gravity is 9.8 m/s^2. 2+3

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

a) State Dulong Petit's Law of specific heat of solid. Explain the limitation of this Law. How does Einstein solve the problem of specific heat at lower temperature? Write down the properties of liquid Helium. 2+2+4+2

b) What is partition function? State the principle of equipartition of energy. Using Maxwell-Boltzmann distribution function show that the mean kinetic energy per degrees of freedom along X-direction is $\frac{1}{2}KT$. Calculate the average thermal energy (in eV) of a classical electron in the system at 300K. 2+2+4+2

c) Consider N indistinguishable non-interacting particles obey Pauli Exclusion Principle; calculate the number of ways in which N particles are arranged in g_i quantum states. Hence calculate the total number of ways in which $N_1, N_2, ..., N_n$ are distributed in *n* energy levels. Now using the concept of statistical equilibrium find out the distribution function for such system. Draw the curve for distribution function with energy. 2+3+3+2

d) Five classical particles are distributed in energy states E = 0, ε, 2ε. How many total configurations are possible for this system? Derive Planck's Law using BE distribution function. Hence derive Wines Distribution law. Explain the BE-condensation phenomena. 2+4+2+2

OPTION–C

PHY-G-CC-T-04C

(Solid State Physics)

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

   a) Distinguish between amorphous and crystalline state of matter.

   b) How many atoms are there in a fcc unit cell?

   c) What is phonon?

   d) State Curie-Weiss Law for a ferromagnetic material.

   e) What is piezoelectricity?

   f) State Dulong and Petite's law.

   g) What is Meissner effect?

   h) Explain conduction band and valence band of a conductor.

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

   a) Explain the Hall effect. What is Hall coefficient? The direction of current is along x-axis, magnetic field direction is along z-axis, what will be direction of the Hall voltage? 2+2+1

   b) Draw a (110) plane in the unit cell of a cubic crystal. What are the Miller indices of a lattice plane? Find the Miller indices of a plane that makes an intercept of 3a, 2b, and 3c along the three crystallographic axes, where a, b, c being the lattice parameters. 2+1+2

   c) What is superconductivity? Discuss London's theory of superconductivity. What is London penetration depth? 1+3+1

   d) Write down the expression for the specific heat of solid following the Debye model. Explain the Debye temperature (θ_D). Show that the Debye model reduces to the classical model when $T \gg \theta_D$. 1+2+2

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

   a) Discuss the Kronig-Penny model for a linear lattice. How does it lead to the formation of energy bands in solids? What happens to the width of an allowed and forbidden bands with the changes in the strength of a periodic potential. 3+4+3

   b) Derive an expression for the local electric field acting at an atom. What is polarizability? Discuss the difference between electronic and orientational polarizability. 6+2+2

c) What is diamagnetism? Derive an expression of diamagnetic susceptibility on the basis of classical theory. Draw the temperature dependence of the magnetic susceptibility for the diamagnetic material. 2+6+2

d) Explain the concept of reciprocal lattice. Show that the reciprocal lattice of a simple cubic structure is also simple cubic. Show that in cubic lattice the distance between the successive planes of indices (hkl) is given by

$$d_{hkl} = \frac{a}{\left(h^2 + k^2 + l^2\right)^{\frac{1}{2}}}.$$ 2+4+4

OPTION–D

PHY-G-CC-T-04D

(Electromagnetic Theory)

GROUP–A

1. Answer any **five** questions from the following: $2\times5=10$

a) What is displacement current? Distinguish between conduction and displacement currents.

b) If the electric field $E=0.$ and $€=4€_0$ then find out the displacement current crossing an area $0.1m^2$ at t=0.

c) A magnetic field $B=(+2-4)$ exists at a point. If a test charge is moving with a velocity $v=v_0(3-+2)$ experiences no force at a certain point then find out the electric field at that point.

d) Write down the important properties of Maxwell's equations.

e) Two polaroid are adjusted so as to obtain maximum intensity. Through What angle should one polaroid be rotated to reduce the intensity to i) half and ii) one fourth?

f) What is elliptically polarized light? Can its transmission is prevented by an analyzer?

g) The conductivity of metal is $\sigma = 5.8\times10^{7}$ mho.m^{-1}. Find out the attenuation of an electromagnetic wave of frequency 1kHz by a metal plate of thickness 0.1 mm.

h) What do you mean by graded index fibre? What are the advantages of graded index fibre over step index fibre?

GROUP–B

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

a) Derive the law of conservation of charge from Maxwell's field equations. At time t=0, a charge distribution $\rho(,0)$ exists within an ideal homogeneous conductor of permittivity € and conductivity σ. Find out the expression for $\rho(,t)$. 2.5+2.5

b) A uniform plane wave propagating in a medium having electric field $E = 4\sin(10^{8}t - \beta z)a_z$ V/m. If the medium is characterized by $\epsilon_r = 1$, $\mu_r = 20$ and $\sigma = 3$ mhos/m then find out the value of α, β and H. 5

c) What is a waveguide? For transverse electric waves propagating along a rectangular waveguide with perfectly conducting walls. Find out the expression for i) cut off wave length, ii) guide wavelength and iii) velocity of energy propagation. 1+1+1.5+1.5

d) Derive an expression for Poynting's vector and explain its significance. Discuss what do you mean by Poynting's theorem. 4+1

GROUP–C

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

a) Write down the Maxwell's equations for electromagnetic waves in free space. Hence derive the wave equation for Electric and Magnetic fields and also show that velocity of propagation of electromagnetic wave is 3×10^{8} m/s. 2+3+3+2

b) Explain the terms:

i) double refraction,

ii) optic axis

iii) positive and negative crystals,

iv) principal section of a crystal and

v) E-rays and O–rays. 2+2+2+2+2

c) What is optical activity or rotatory polarisation? What do you mean by optically active substance? Define specific rotation. A 20cm long tube is filled with a solution of 15g of cane sugar in 100cc of water. Find the angle of rotation of the plane of polarization of a beam of plane-polarized light when it passes through the solution. Specific rotation of cane sugar=65.5^{o} per dm per g/cc. 2+2+2+4

d) An Electromagnetic wave is incident on the plane interface between two different media

i) Show that the frequency of the wave remains unchanged upon reflection or refraction.

ii) Find the relation between the angles of incidence, reflection and refraction.

iii) Show that the wave vectors of the incident, reflected and refracted waves all lie on the same plane. 3+4+3

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