[This question paper contains 2 printed pages.]

Sr. No. of Question Paper : **1795**

Unique Paper Code : 2222011201

Your Roll No..............

L

Name of the Paper: : Mathematical Physics II

Name of Course : B.Sc. Hons. (Physics) NEP: UGCF-2022

Semester : II

Duration : 2 Hrs

Maximum Marks : 60

Instructions for candidates:

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **Four** questions in all.
3. Question number 1 is compulsory. Attempt any **three** questions from the rest.
4. **All** questions carry equal marks.
5. Some useful formulae are given at the end.

1. Attempt any **five** questions. All questions carry equal marks. (5×3=15)

   (a) Evaluate $\iiint_V dV$ where V is the volume of the sphere of radius 4 using spherical polar coordinates.

   (b) Find the period of (i) $\tan nx$ and (ii) $\cos 2\pi x$

   (c) Evaluate $\int_0^\infty x^6 e^{-2x}\, dx$ using beta and gamma functions.

   (d) Evaluate $\int_{-1}^{+1} [P_2(x)]^2\, dx$

   (e) Locate and name the singularity for $x^3y'' + 2x^2y' + y = 0$.

   (f) Write Parseval's identity for Fourier series.

2. (a) Find the unit vectors $\widehat{e_r}, \widehat{e_\theta}, \widehat{e_\phi}$ for spherical coordinate system in terms of $\hat{\imath}, \hat{\jmath}, \hat{k}$. Also solve for $\hat{\imath}, \hat{\jmath}, \hat{k}$ in terms of $\widehat{e_r}, \widehat{e_\theta}, \widehat{e_\phi}$. (10)

   (b) Represent the vector $\vec{A} = 2y\hat{\imath} - z\hat{\jmath} + 3x\hat{k}$ in terms of spherical coordinates and determine A_r, A_θ and A_ϕ. (5)

3. (a) Represent $f(x) = x^2$ in the interval $-\pi < x < \pi$ in form of Fourier series. (10)

   (b) Evaluate $\int_0^{\pi/2} sin^4\theta\ cos^5\theta\, d\theta$ using beta and gamma functions. (5)

4. Solve $xy'' + (x-1)y' - y = 0$ around $x = 0$ by Frobenius method. (15)

5. (a) Derive the recurrence relation $nP_n(x) = xP_n{}'(x) - P'_{n-1}(x)$ (7.5)

   (b) Expand x^2 in series of Legendre polynomials. (7.5)

Some useful formulae:

Legendre Polynomials:

$$P_0(x) = 1, P_1(x) = x,\ P_2(x) = \frac{1}{2}(3x^2 - 1)$$

[This question paper contains 2 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : **1796** **L**

Unique Paper Code : 2222011204

Name of the Paper : MATHEMATICAL PHYSICS II

Name of the Course : **B.SC. HONS (PHYSICS) NEP: UGCF-2022(ADMN. YEAR 2025)**

Semester : II

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt any Five questions.
3. Question no. 1 is compulsory. Attempt any four questions from the rest
4. All questions carry equal marks.
5. Some useful formulae are given in the end.

1. Attempt any **six** questions. All questions carry equal marks. (6×3=18)

(a) Express the scalar function $\Phi(x,y,z) = \frac{z}{x^2+y^2}$ in cylindrical coordinates and hence compute $\vec{\nabla}\Phi$ in cylindrical coordinates.

(b) Evaluate $\iiint_V dV$ where V is the volume of a cylinder of radius 2 and height 4 using cylindrical coordinates.

(c) Determine the period of function $f(t) = (10\ \cos t)^2$.

(d) Show that if f(x) is an even function on $[-\pi,\pi]$, then $b_n = 0$ for all values of n.

(e) Locate and name the singularity for $x^3y'' + y = 0$. Can Frobenius method be used to find its solution?

(f) Evaluate $\int_{-\infty}^{\infty} e^{-x^2}[H_3(x)]^2\, dx$

(g) Evaluate $\int_0^{\pi/2} sin^2\theta cos^4\theta\, d\theta$ using beta and gamma functions.

2. (a) Using spherical polar coordinates, evaluate $\iiint_V (x^2+y^2+z^2)\ dV$ where V is a sphere having center at the origin and radius equal to a. (9)

(b) Represent the vector $\vec{A} = 2z\hat{\imath} + x\hat{\jmath} - y\hat{k}$ in terms of cylindrical coordinates. (9)

3. (a) Obtain cosine series expansion of the function $f(x) = 1 + x$ in the interval $0 \le x \le 2$. (12)

(b) Using the results obtained in part (a) deduce that $\frac{1}{1^2} + \frac{1}{3^2} + \frac{1}{5^2} + \cdots = \frac{\pi^2}{8}$ (6)

4. (a) Solve $xy'' + y' - y = 0$ around $x = 0$ by Frobenius method. (12)

   (b) Show that $\int_{-1}^{+1} P_m(x)P_n(x)\, dx = 0$ if $m \neq n$; where, P_m and P_n are Legendre polynomials. (6)

5. (a) Compute the divergence and curl of the vector field $\vec{A} = \hat{e}_r + r\hat{e}_\theta + r\cos\phi\,\hat{e}_\phi$ in spherical polar coordinates (r, θ, ϕ). (9)

   (b) Derive Rodrigue's formula $P_n(x) = \frac{1}{2^n n!}\frac{d^n}{dx^n}(x^2 - 1)^n$ for Legendre polynomials. (9)

6. (a) Derive the relation $2xH_n(x) = 2nH_{n-1}(x) + H_{n+1}(x)$ (9)

   (b) Express x^3 in a series of Hermite polynomials. (6)

   (c) Using beta and gamma functions evaluate $\int_0^1 \sqrt{\frac{1-x}{x}}\, dx$ (3)

Some useful formulae:

Legendre Polynomials:

$$P_0(x) = 1, P_1(x) = x,\ P_2(x) = \frac{1}{2}(3x^2 - 1)$$
$$P_3(x) = \frac{1}{2}(5x^3 - 3x), P_4(x) = \frac{1}{8}(35x^4 - 30x^2 + 3)$$

Hermite Polynomials:

$$H_0(x) = 1, H_1(x) = 2x,\ H_2(x) = (4x^2 - 2)$$
$$H_3(x) = (8x^3 - 12x),\ H_4(x) = (16x^4 - 48x^2 + 12)$$

[This question paper contains 2 printed pages.]

Sr. No. of Question Paper : **2060** **Your Roll No...............**

L

Name of Course : B.Sc. (Hons.) Physics-NEP: UGCF

Semester : **II**

Name of the Paper: : Electricity and Magnetism

Unique Paper Code : **2222011202**

Duration: 3 Hours **Maximum Marks: 90**

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. **All** questions carry equal marks.
3. Q. No. **1** is compulsory.
4. Answer **any four** of the remaining five questions.
5. Use of non-programmable scientific calculators are allowed.

1. Attempt **any six** questions from the following: $(6 \times 3 = 18)$

(a) Two negative charges of unit magnitude and a positive charge q are placed along a straight line. At what position and for what value of q will the system be in equilibrium? Discuss if it is stable or unstable equilibrium.

(b) The linear charge density on a rod of length L is given by $\lambda(x) = \lambda_0 + \frac{x}{2}$, where λ_0 is a constant and x is the distance from one end of the rod. Find the total charge on the rod.

(c) A charge $-q$ is placed in vacuum at the point $(d, 0,0)$, where $d > 0$. The region $x \leq 0$ is filled uniformly with a conductor. Find the electric field at the point $\left(\frac{d}{2}, 0,0\right)$.

(d) Given that $\vec{E_1} = 5\hat{\imath} - 2\hat{\jmath} + 3\hat{k}$ (V/m) at the charge-free dielectric interface between two different dielectric materials with relative permittivity's $\epsilon_1 = 4$ and $\epsilon_2 = 3$ respectively. Find the electric field $\vec{E_2}$ and electric displacement $\vec{D_2}$ in the second dielectric.

(e) A magnetic field is given by the expression $\vec{B} = axz\,\hat{\imath} + byz\,\hat{\jmath} + c\hat{k}$, where *a*, *b* and *c* are some constants. Find a relation between a and b.

(f) A vector potential in a region is given by $\vec{A} = az^2\hat{\imath}$. Find the volume current density in the region.

(g) Write down Maxwell's equations for free space in differential form explaining their physical significance.

2.

(a) The electric potential of a charge configuration is expressed as $V(r) = A\frac{e^{-\lambda r}}{r}$, where A and λ are constants. Find the electric field $\vec{E}(r)$, the charge density $\rho(r)$, and total charge Q. (8)

(b) State and prove First uniqueness theorem. (7)

(c) Use Laplace's equation to find the potential for the region between two concentric spheres when $V_1 = 0$ volt at $r = 2\ m$ and $V_2 = 150$ volt at $r = 3\ m$. (3)

3. (a) A conducting sphere of radius R, is placed at the origin. The point charges $\pm q$ are located at distance $\mp d$ from the centre of the sphere (with $d > R$). Using method of images, determine the magnitude and positions of the image charges. Also, find the electric potential at an arbitrary field point P due to the real charges and image charges. (8)

(b) A long, straight wire carries a uniform line charge density λ. The wire is surrounded by a cylindrical layer of rubber insulation extending up to a radius a. Determine the electric displacement field $\vec{D}$ and the electric field $\vec{E}$ both inside and outside the rubber insulation. (7)

(c) Thin dielectric rod of cross-section A extends along z −axis from $z = 0$ to $z = L$. The polarization of the rod is along its length and is given by $\vec{P} = (ax^3 + b)\hat{k}$, where a and b are some constants. Obtain the bound volume and surface charge densities at each end of the rod. (3)

4. (a) Derive an expression for magnetic field along the axis of two identical coaxial coils of radius R and turns N, separated by a distance d and carrying current I in the same direction. Plot a graph showing the variation of the magnetic field along the axis. (8)

(b) Find the magnetic field of an infinite uniform surface current described by surface current density $\vec{K} = K\hat{\imath}$ flowing over $z = 0$ plane. (7)

(c) Explain the significance of continuity equation in electromagnetism. (3)

5. (a) Starting from Biot-Savart's law for a volume current, show that

$$\vec{\nabla} \times \vec{B} = \mu_o \vec{J}$$

and hence show that $\oint \vec{B} . \vec{dl} = \mu_o I$. (8)

(b) Show that the energy density of a magnetic field B in vacuum is given by $\frac{B}{2\mu_0}$, where μ_0 is the permeability of free space. (7)

(c) Distinguish diamagnetic, paramagnetic and ferromagnetic materials. (3)

6. (a) State and prove Gauss's law in electrostatics. Prove that the electrical intensity at a distant r from a charged wire of infinite length is $\vec{E} = \frac{\lambda}{2\pi\varepsilon_o r}\hat{r}$, where λ is the linear charge density and $\hat{r}$ is the unit vector along distance r. (8)

(b) Show that the electric potential due to a polarized object is given by

$$V = \frac{1}{4\pi\varepsilon_o}\left(\oint_S \frac{\sigma_b}{r} dS + \int_V \frac{\rho_b}{r} d\tau\right)$$

where σ_b and ρ_b are bound surface charge density and bound volume charge density respectively. (7)

(c) At a certain point in a region the magnetic field is given by the expression $\vec{B}(t) = B_0 \cos(kz - \omega t)\hat{\jmath}$, where, B_0, k and ω are some constants. Find the curl of the induced electric field at that point. If the z −component of the induced electric field is zero, find the x −component of the induced electric field. (3)

[This question paper contains 2 printed pages.]

Sr. No. of Question Paper : 2079

Your Roll No...............

L

Name of Course : B.Sc. (Hons.) Physics-NEP: UGCF-2022

Semester : II

Name of the Paper: : Electrical Circuit Analysis

Unique Paper Code : 2222011203

Duration: 2 Hours **Maximum Marks: 60**

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. All questions carry **equal marks.**
3. **Question No. 1** is compulsory and attempt **any three** questions from the remaining four questions.
4. Use of non-programmable Scientific Calculator is allowed.

1. Attempt **any five questions.** Each question carries equal marks. (3x5=15)

(a) What is the internal resistance of an ideal voltage and an ideal current source? Convert a current source of 4A in parallel with 2Ω resistor into an equivalent voltage source.

(b) What is the principle of duality in network analysis? How can it be used to solve problems in network analysis?

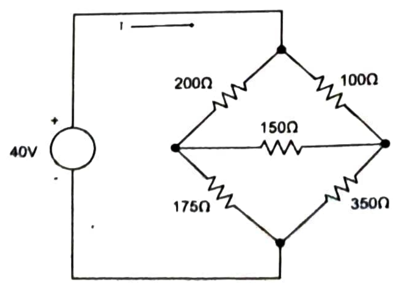
(c) Draw a half -rectified sinusoidal wave and determine its form factor and peak factor.

(d) State Thevenin's theorem and its usefulness in circuit analysis.

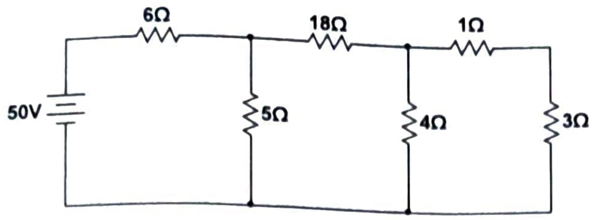
(e) Define the sharpness of resonance in LCR circuit. How it is related to the resistance of the electric circuit?

(f) A capacitor of 200μF initially charged to 15V and is discharged through a resistor R of value 5 kΩ. Determine the time when the voltage across the capacitor becomes 3V.

2. (a) Determine the current *I* using Δ – Y or Y – Δ conversion method. (9)



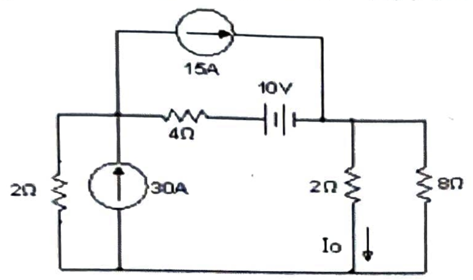
(b) Find the current along 6Ω resistor using mesh analysis for the given network. (6)



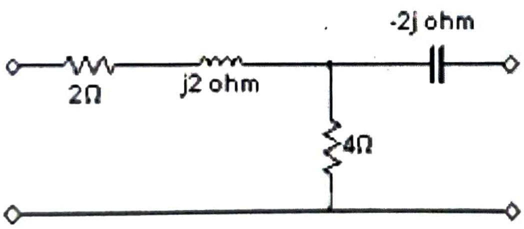
3. (a) A series LCR circuit with R= 10Ω, L= 0.1H and C=100μF is driven by a sinusoidal voltage source $v = \sqrt{2}.20 \sin 377t$. Determine the input impedance, and current I in phasor form of the series LCR circuit. Draw impedance diagram also. (9)

(b) A parallel LCR circuit is driven by a current source I= 50A∠30°. If the capacitor with reactance X_C = 8Ω is connected in parallel with a coil of resistance R = 3Ω and an inductor with reactance X_L = 4Ω, calculate the current flowing through the branches. (6)

4. (a) State superposition theorem. Find the value of **Io** using superposition theorem. (9)



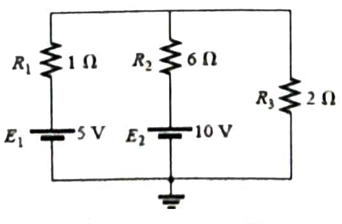
(b) What are ABCD or transmittance parameters? Obtain ABCD parameters for the given circuit. (6)



5. (a) Derive an expression for the sharpness of resonance of a series LCR circuit, driven by a sinusoidal source. (5)

(b) A series LCR circuit is connected to 230V, 50Hz ac supply. Calculate (i) total reactance (ii) the impedance (iii) resonant frequency (iv) the current drawn at resonance and (v) Quality factor if R=5Ω, L=13mH and C=140μF. (5)

(c) Find the current through 2 Ω resistor using Millman's theorem. (5)



[This question paper contains 2 printed pages.]

Sr. No. of Question Paper : 1815 **Your Roll No................**

Unique Paper Code : 2222012401 **L**

Name of the Paper : Modern Physics (DSC)

Name of the Course : B.Sc. (Hons.) Physics – NEP UGCF-2022

Semester : IV

Duration: 3 Hours Maximum Marks : 90

Instructions for Candidates

Write your Roll No. on the top immediately on receipt of this question paper.

Question No. 1 is compulsory. Attempt any four from the remaining five questions.

All questions carry equal marks.

Use of non-programmable calculators is allowed.

1. Attempt any **six** of the following questions: (6×3=18)

(i) Explain the term "Ultraviolet Catastrophe" and mention which classical law led to this discrepancy.

(ii) Prove that the complete absorption of a photon by a free electron at rest is not permitted by conservation laws of momentum and energy.

(iii) Consider an electron in an infinitely deep well of width 0.6 Å. Calculate the energy of the electron in the third excited state (n = 4). (Mass of electron = 9.1×10^{-31} kg)

(iv) Using Moseley's relation, calculate the wavelength of the K_α line for iron ($Z = 26$).

(v) Discuss the production mechanism of continuous X-rays and characteristic X-rays.

(vi) Determine the binding energy per nucleon for ^{235}U. ($Z = 92$, $M_U = 230.033087$ u, $m_p = 1.007825$ u, $m_n = 1.008665$ u)

(vii) What is the activity of 1 g of ^{226}Ra, whose half-life is 5.05×10^{10} s?

2. (a) Define the Compton effect. Derive the formula for the kinetic energy of the recoil electron as a function of the incident photon energy hν and the scattering angle θ. Explain why Compton scattering is predominantly observed with X-rays or Gamma-rays rather than ultra-violet radiation. (10)

(b) Use the Heisenberg uncertainty principle ***($\Delta x \cdot \Delta p) \geq \hbar/2$)*** to estimate the minimum kinetic energy (in MeV) of a proton confined within a nucleus of radius **R ≈ 10^{-15} m**. Contrast this value with the typical binding energy per nucleon **(≈ 8 MeV).** (8)

3. (a) Show that for a plane wave state given by $\psi(x) = A\, e^{i(kx-\omega t)}$, the probability current density is $J = |A|^2 v$, where v is the classical velocity of the particle. Explain the physical meaning of a negative value for the probability current density J(x,t). (10)

(b) The wavefunction of a particle is represented by $\psi(x) = Ae^{-ax^2}$, $-\infty < x < \infty$, where a is a constant ($a > 0$). Normalize the wave function. (8)

4. (a) A stream of particles of mass m and energy E moves from right to left, strikes a potential step $V(x) = V_o$ for $x \le 0$ and $V(x) = 0$ for $x > 0$. Taking $E > V_o$, obtain expressions for the reflection coefficient and transmission coefficients. Discuss the differences between the classical and quantum behaviour of the particle. (10)

(b) Using Heisenberg uncertainty principle, explain the quantum mechanical possibility of a particle penetrating the classically forbidden region ($x > 0$) for $V_o > E$. (8)

5. (a) Discuss Einstein's A and B coefficients. State the principle of detailed balancing and derive the general thermodynamic relationships between them when the upper and lower electronic states possess explicit degeneracies (g_2 *and* g_1). (10)

(b) In 2p → 1s transition in a hydrogen atom, the lifetime of 2p state for spontaneous emission is given by 1.6×10^{-9} sec. The energy of this transition is 10.2 eV. Calculate Einstein's A and B coefficients. (8)

6. (a) What is a synchrotron? Discuss the principle, construction, working, advantages and disadvantages of a synchrotron. (10)

(b) In a cyclotron, magnetic field of 1.6 Tesla is used to accelerate protons. Calculate the (i) frequency to accelerate the protons, (ii) maximum energy of protons in Mev. The radius of cyclotron is given, $r = 0.5$ m. (Mass of proton = 1.67×10^{-27} kg). (4)

(c) Why does the number of neutrons tend to exceed the number of protons in stable nuclei? Why are even-even nuclei most stable? (4)

Show that for a plane wave state given by $\psi(x) = A\, e^{i(kx-\omega t)}$, the probability current density is $J = |A|^2 v$, where v is the classical velocity of the particle. Explain the physical meaning of a negative value for the probability current density J(x,t).

1

S. No. of Question Paper : 1901

Unique Paper Code : 2223012003

Name of the Paper : **Advanced Mathematical Physics I - DSE**

Name of the Course : **B. Sc. (Honors) Physics (NEP)**

Semester : **IV**

Duration: 3 Hours Maximum Marks: 90

Instruction for Candidates

1. Write your Roll No. on the top immediately on the receipt of the question paper.
2. **Question 1 is compulsory**. Attempt ***any four*** questions from the rest.
3. All questions carry equal marks.
4. Use of non-scientific calculator is allowed.

1. Compulsory Question: Attempt ***any six***.

(a) Show that the set of all non-zero complex numbers with operation of multiplication form a group. (3)

(b) Show that the set of vectors S: {(1,0,0), (1,1,0), (1,1,1)} forms a basis of $\mathbf{R}^3$. (3)

(c) Show that a linear transformation T : U→ V is one to one, if and only if $K_T = \{\theta\}$ where θ is the zero vector. (3)

(d) A linear transformation F : $\mathbf{R}^3 \rightarrow \mathbf{R}$ is defined as: $F(x, y, z) = x - 2y + z$. Find the matrix representation of F relative to the standard basis of $\mathbf{R}^3$ and $\mathbf{R}$. (3)

(e) Find the dimension and a basis of the solution space W of the system of linear homogeneous equations:

$$x + 2y - 4z + 3r - s = 0$$

$$x + 2y - 2z + 2r + s = 0$$

$$2x + 4y - 2z + 3r + 4s = 0$$

(3)

(f) Find the characteristic equation of matrix $A = \begin{bmatrix} 1 & 2 & 3 \\ 3 & 4 & 5 \\ 4 & 6 & 8 \end{bmatrix}$ (3)

(g) Show that the eigenvalues of a skew symmetric matrix are zero or purely imaginary. (3)

2. (a) Find the subspace W of $\mathbb{R}^3$ spanned by vectors $u_1 = (1, -2, 1)$, $u_2 = (-2, 0, 3)$ and $u_3 = (3, -2, -2)$. Show that the vector $v = (4, -4, -1)$ lies in the same plane. (6)

(b) If V be the set of all ordered pair $(x, y)\ \forall\, x, y \in R$. The addition and scalar multiplication are defined as:

$$(x_1, y_1) + (x_2, y_2) = (x_1 + x_2, y_1 + y_2) \qquad x_1, x_2, y_1, y_2 \in R \text{; and}$$
$$\alpha(x, y) = (\alpha x, y) \qquad \alpha \in R.$$

Show that V is not a vector space. (6)

(c) If φ and ψ are the state vectors in an inner product space, show that they satisfy the triangle inequality

$$\|\varphi + \psi\| \leq [\![\varphi]\!] + [\![\psi]\!] \tag{6}$$

3. (a) Find a linear transformation T that maps the vector space $\mathbb{R}^2 \to \mathbb{R}^3$ such that T (1, 1) = (2, 0, 5) and T (1, 2) = (3, -1, 8). (8)

(b) Let T be a linear operator on the real vector space $\mathbb{R}^3$ defined by:

$$T(x, y, z) = (x+y-2z,\ x+2y+z,\ 2x-2y+3z)$$

Show that T is invertible. Find T^{-1}. (10)

4.(a) Let the Linear Transformation T: $\mathbb{R}^3 \to \mathbb{R}^2$ is defined by

$$T(x, y, z) = (y + z, y - z)$$

Determine matrix of T with respect to the ordered basis {(0, 1, 1), (1, 0, 1), (1, 1, 0)} in $\mathbb{R}^3$ and {(1, 1), (1, −1)} in $\mathbb{R}^2$. (9)

(b) Find the change of basis matrix from the standard basis of $\mathbb{R}^3$ to the basis S: {(1, 0, 1), (2, 1, 2), (1, 2, 2)}. Find the coordinates of vector α = (3, -2, 1) relative to basis S. (9)

5. (a) If A and B are non-singular matrices such that $A = P^{-1}BP$, show that:
(i) det(A) = det(B)
(ii) Tr(A) = Tr(B) (6)

(b) Prove that the eigenvectors associated with distinct eigenvalues of a Unitary matrix are mutually orthogonal. (4)

(c) Using matrix method, solve the coupled differential equations

$$\dot{x} = y$$
$$\dot{y} = 6x - y$$

such that $x(0) = a$ and $y(0) = b$. (8)

6. (a) Find the eigenvalues and eigenvectors of the matrix

$$M = \begin{bmatrix} 0 & 2-i \\ 2+i & 4 \end{bmatrix}, \text{ where, } i = \sqrt{-1}.$$

Are the eigenvectors orthogonal? (8)

(b) Determine Cos(B) for $B = \begin{bmatrix} 2 & 1 \\ 2 & 3 \end{bmatrix}$. (10)

L

[This question paper contains 2 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 1934
Name of the course : B. Sc. Hons. (Physics)_NEP: UGCF-2022
Semester : IV-Semester
Name of the Paper : Solid State Physics
Unique Paper Code : 2222012402

Duration: 3 Hour **Maximum Marks: 90**

Instructions to the students:

(i) Attempt any five questions in total. Question No. 1 is compulsory.

(ii) All questions carry equal marks.

(iii) Use of non-programmable scientific calculators is permitted.

Q.1: Attempt any six of the following: (3 x 6 = 18)

(a) Draw $(\bar{2}31)$, (102) and $(1\bar{3}2)$ planes in a cubic crystal.

(b) The Bragg angle corresponding to the first order reflection from (1 1 1) planes in a crystal is 30^0, when X-rays of wavelength 1.75 Å are used. Calculate the interplanar spacing.

(c) The resistivity of a semiconductor is 1 Ω-m at room temperature. Calculate the mobility of conducting electrons if the density of conducting electrons is 10^{21} m^{-3}.

(d) The dispersion relation for phonons in a solid is given by $\omega^2(k) = \omega_m^2[5 - \cos(ka)]$. Find the group velocity of phonons in the large wavelength region.

(e) For aluminum, the heat capacity at constant volume C_v and at 30 K is 0.81 J/mol-K and the Debye temperature is 375 K. Estimate the specific heat at (i) 50 K and (ii) 425 K.

(f) A ferromagnetic material has a Curie temperature of 100 K. If its magnetic susceptibility at 300 K is 2×10^{-3}, find its magnetic susceptibility at 200 K using the Curie–Weiss law.

(g) Explain why the dielectric constant of water is 81 at zero frequency and 1.8 at frequency in visible range.

Q.2: (a) What is packing fraction? Also determine the value of packing fraction of body centered cubic (BCC) structure. (6)

(b) Determine the reciprocal lattice vectors of the reciprocal lattice defined by the primitive translation vectors $\vec{a} = 5\hat{\imath} + 5\hat{\jmath} - 5\hat{k}$, $\vec{b} = -5\hat{\imath} + 5\hat{\jmath} + 5\hat{k}$, $\vec{c} = 5\hat{\imath} - 5\hat{\jmath} + 5\hat{k}$, where $\hat{\imath}$, $\hat{\jmath}$ and $\hat{k}$ are the unit vectors along X, Y and Z axes. (6)

(c) Show that BCC lattice is reciprocal to a FCC lattice. (6)

Q.3: (a) Describe direct and indirect band gaps. Obtain an expression of effective mass of an electron in a band. Explain the concept of negative effective mass. (12)

(b) Explain the concept of critical magnetic field in a superconductor. The critical temperature of a superconducting material is 3.7 K. The maximum critical magnetic field of this material is 0.0306 Tesla. Calculate the critical magnetic field at 2 K. (6)

Q.4: (a) For one dimensional diatomic crystal with atomic masses M (heavier) and m (lighter), force constant β and lattice constant a:

(i) Show that the phonon dispersions have two solutions given as

$$\omega(k) = \sqrt{\frac{\beta}{mM}} \cdot \sqrt{m + M \pm \sqrt{m^2 + M^2 + 2mM\cos(ka)}}$$

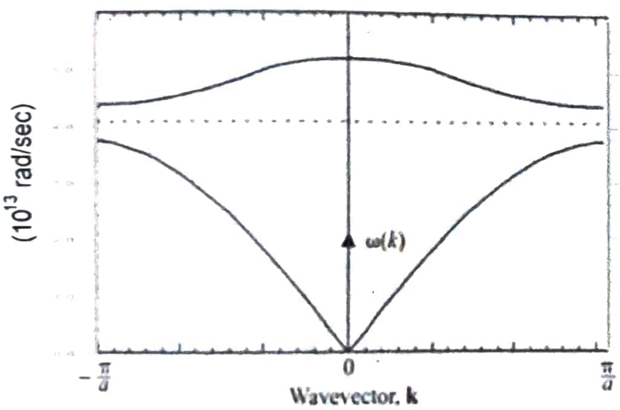
(ii) Sketch the two $\omega(k)$ as a function of k ($\frac{-\pi}{a} \leq k \leq \frac{+\pi}{a}$), and label each of them as "acoustic" or "optical" phonons.

(iii) Find the two frequencies at the edge of the Brillouin zone, i.e. find $\omega(k)$ where $k = \pi/a$ and also find the expression of the energy difference (i.e., the acoustic-optical phonon bandage) between these two frequencies.

(iv) Evaluate phonon group velocity v_g for these two phonon modes at $k = \pi/a$.

(12)

(b) A plot of phonon dispersion relation is shown in the figure below. What is the shortest wavelength in (nm) if the lattice constant is a = 5.5Å.



(6)

Q.5 (a) Obtain an expression for the diamagnetic susceptibility of a material using Langevin's theory. What is the significance of negative susceptibility? (12)

(b) Differentiate between soft and hard ferromagnetic materials with the help of a hysteresis loop. Give one example of each type. (6)

Q.6 (a) Derive the relation $\overrightarrow{E_{Loc}} = \vec{E} + \frac{\vec{P}}{\epsilon_0}$ for local electric field in solids, where the symbols have usual meanings. Explain the significances of electric fields $\overrightarrow{E_{Loc}}$ and $\vec{E}$. (12)

(b) Derive relations between (i) electric susceptibility and dielectric constant, and (ii) electric susceptibility and polarizability. (6)

Charge of an electron = 1.6×10^{-19} C

Gas Constant R = 8.314 J mol^{-1} K^{-1}

[This question paper contains 4 printed pages.]

Sr. No. of Question Paper : 2041 **Your Roll No...............**

L

Name of Course : B.Sc. Hons.-(Physics)_NEP: UGCF-202

Semester : IV- Semester

Name of the Paper: Analog Electronics

Unique Paper Code: 2222012403

Medium of setting the Question paper: English Language

Duration: 2 Hours Maximum Marks: 60

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt any **Four** questions in all. Question No. 1 is compulsory.
3. Simple Non-programmable calculators are allowed.

Q1 Attempt any five parts (3x5=15)

(a) Sketch typical output characteristics curves for a PNP transistor in CB configuration. Label all variables and indicate the active, cut-off and saturation regions of operation.

(b) What value of a series resistance is required to limit the current through a LED to 20 mA with a forward voltage drop of 1.6V when connected to a 10 V supply.

(c) What is Barkhausen criterion for sustained oscillations?

(d) Write equations for h-parameter model of an NPN transistor in CE configuration, and draw its equivalent circuit.

(e) An Op-Amp has a CMRR value of 55 dB and a differential mode gain of 1200. Find the common mode gain.

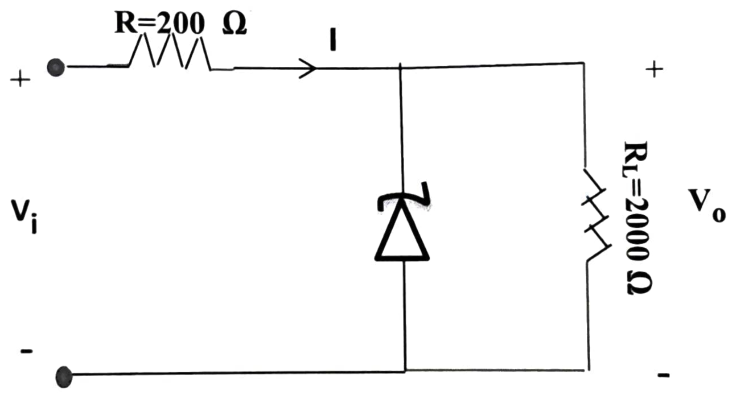
(f) Draw the circuit for the zero-crossing detector using an Op-Amp. Draw the output waveform if the input is a 1kHz sinusoidal waveform and peak value 50 mV.

Q-2 (a) Derive the expressions for the r.m.s value of current, ripple factor and rectification efficiency of a Full wave bridge rectifier. Also sketch the output waveform resulting from a sinusoidal input voltage. What is the P.I.V of each diode used in the circuit. (10)

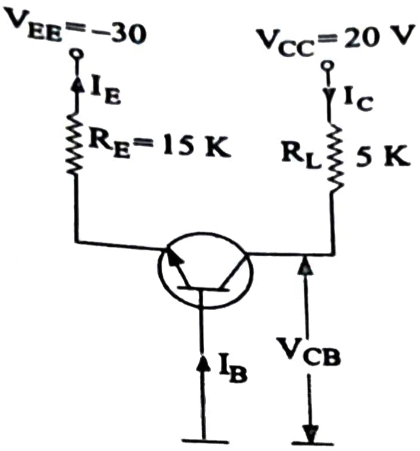
(b) A transistor is connected in common emitter (CE) configuration in which V_{cc} is 8V and voltage drop across collector resistance (R_c) is 0.5V and R_c= 800 Ω. If alpha=0.96 determine (i) Collector- emitter voltage (ii) base current (I_B) (5)

Q-3 (a) Over what range of input voltage will the Zener circuit shown below will maintain 30 V across R_L=2000Ω, assuming that series resistance R=200Ω and Zener current rating is 25 mA.

(5)



(b) For the circuit given below, find (i) I_B (ii) I_C (iii) I_E and (iv) V_{CE}. Neglect V_{BE}. (5)



(c) Draw the output waveform corresponding to a sinusoidal input signal of frequency 1 kHz and amplitude 50mV applied to the inverting input of an ideal op-amp. The op-amp is operating in open loop configuration with supply voltages ± 15V. (5)

Q-4 (a) Draw the circuit diagram of a 3 section RC Phase Shift Oscillator, and derive the expression for frequency of the generated oscillations. (10)

(b) Determine the oscillating frequency of a BJT Hartley oscillator, given the component values as L1=L2=4.7mH, C1=600 pF and the mutual inductance between L1 and L2 is 100 µH. (5)

Q-5 (a) Explain the working of an ideal integrator circuit designed using Op-amp. Explain the problems associated with the ideal circuit and how they are rectified in a practical integrator. Draw the frequency response of the ideal and practical Integrator and mark the region of integration for the practical integration. (10)

(b) In a non-inverting summing amplifier, input voltages $V_1 = 2$ V and $V_2 = 4$V are applied through resistors 10kΩ and 20kΩ respectively. If $R_f = 30$kΩ and $R_1 = 10$kΩ, calculate the output voltage. (5)

[This question paper contains 4 printed pages.]

Roll No. ________

Sr. No. of questions Paper : **1735**

Name of the Department: Physics and Astrophysics

Name of Course : B.Sc. Hons.–(Physics)_NEP: UGCF-2022

Name of the Paper: Statistical Mechanics

Semester : VI

Unique Paper Code : 2222013601

Question paper Set No. : II

Duration: 3 Hours

Maximum Marks: 90

(Write your Roll No. on the top immediately on receipt of this question paper)

Attempt **five** questions in all

Question No. 1 is compulsory.

All questions carry equal marks.

Use of non-programmable scientific calculator is allowed.

1. Attempt any six. (6 x 3 = 18)

i) At a high temperature T, calculate the average energy per particle of a non-interacting gas of two-dimensional classical harmonic oscillators (No derivation required)

ii) 5 distinguishable particles are to be distributed amongst three energy levels with energy 0, ε and 2ε. For a fixed energy of 5ε, enumerate the number of macrostates. Identify which macrostate is the most probable?

iii) Consider the blackbody radiation contained in a cavity whose walls are at temperature T = 500 K. The radiation is in equilibrium with the walls of the cavity. If the temperature of the walls is increased to 1000 K and the radiation is allowed to come to equilibrium at the new temperature, by what factor will the entropy change for the blackbody radiation in the cavity.

iv) Calculate the chemical potential of strongly degenerate system of N bosons (N >> 1) at temperature T ($T < T_C$), if the energy of the lowest state is ε_0.

v) Explain and draw a qualitative graph of the temperature dependence of pressure exerted by bosons for all temperatures starting from T = 0 including $T = T_c$ and going upto $T \gg T_C$.

vi) Show graphically the variation of radius of white dwarf star (consisting of relativistic electrons) as a function of its mass. Hence explain the physical significance of Chandrasekhar mass limit.

vii) Calculate the value of $\frac{\partial f(\varepsilon)}{\partial \varepsilon}$ at $\varepsilon = \mu$, where $f(\varepsilon)$ represents Fermi-Dirac distribution function. Explain the result.

2(a) Consider an isolated system of $N \gg 1$ weakly interacting classical particles. These particles can be in any of the states with energies $0, \varepsilon, 2\varepsilon, 3\varepsilon, ...$ The temperature of the system may be written as

$$\frac{1}{T} \cong \frac{\Delta S}{\Delta E}$$

where ΔS is the change in the entropy of the system corresponding to change in internal energy of the system by ΔE.

i) What is the entropy of the system when it is in its ground state.

ii) If the total energy of the system is ε, what will be its entropy?

iii) Determine the change in entropy and the corresponding temperature when the energy of the system is increased from ε to 2ε ? (12)

(b) An isolated physical system consisted of N distinguishable particles is characterized by two energy states: a ground state of energy ε_1 with a degeneracy g_1 and number of particles n_1. An excited state is characterised by energy ε_2 with degeneracy g_2 having number of particles n_2. Show that the entropy of this system can be written as

$$S = -k_B[P_1 ln(P_1/g_1) + P_2 ln(P_2/g_2)]$$

where P_1 and P_2 are the probabilities that the system will be found in the ground and the first excited states respectively (Here $N = n_1 + n_2$). (6)

3 (a) A system of H-atoms is enclosed in a cavity of volume V at a very high temperature that results in the thermal ionization of the H atom into H^+ ion and e^- electron.

$$H \rightleftharpoons H^+ + e^-$$

Show that the degree of ionization x for this system in terms of the temperature T., pressure p and ionization energy ε^{*} can be expressed as:

$$\frac{x^2}{1-2x} = \left(\frac{2\pi m_e}{h^2}\right)^{3/2} \frac{(k_B T)^{5/2}}{p} \left(\frac{2g_I}{g_a}\right) \exp\left(-\frac{\varepsilon^{*}}{k_B T}\right)$$

where g_I, g_a are the ground state degeneracies of the ion and the atom respectively and m_e is the mass of electron. (12)

(b) A system of N classical particles confined to a volume V has the partition function given by

$$Z_N = (V - Nb)^N (2\pi m k_B T)^{3N/2} \exp(aN^2/Vk_B T)$$

Obtain the expressions for pressure, total internal energy and the specific heat at constant volume for this system. (6)

4 (a) (i) What assumptions were made by Planck to derive the black body radiation formula.

(ii) The number of vibration modes per unit volume in frequency interval ν to $\nu + d\nu$ is $\frac{8\pi\nu^2}{c^3} d\nu$. Use this to derive the black body radiation formula as proposed by Planck.

(iii) Derive Wien's displacement law in the form involving peak frequency and temperature, $\nu_{peak} = 2.822 \frac{k_B}{h} T$. (Use $3(e^x - 1) - xe^x = 0 \rightarrow x = 2.822$) (12)

(b) The power radiated by a blackbody at temperature T_1 is P_1 and it radiates the maximum energy at λ_1. If the temperature of the same blackbody is changed to T_2 so that it radiates the maximum energy at $\lambda_2 = \lambda_1/2$. The power radiated by it becomes P_2. Find the ratio of P_2 / P_1. (6)

5(a)Obtain an expression for thermodynamic probability of a macrostate using Fermi-Dirac statistics, hence derive the equilibrium distribution function for a system of fermions having fixed number of particles and energy at temperature T using Stirling's approximation. Also calculate the value of unknown Lagrange multipliers. (12)

(b) Consider a system of N electrons moving non relativistically in a two-dimensional sheet of area A at temperature T = 0 °K. Calculate the Fermi energy of this system. (6)

6. Consider a gas of N non-interacting Bose particles with spin 0 and mass m in Volume V. In the ultra-relativistic limit, the dispersion relation (energy-momentum relation) can be approximated as: $\varepsilon = c\, p$, where c is a constant and p is the momentum.

(a)Prove that the condensation temperature, $T_C = \frac{hc}{2\pi k} \left[\frac{\pi^2 n}{\zeta(3)}\right]^{1/3}$, where $n = N/V$. (12)

(b)Show that the number of particles in the ground state (N_0) is equal to

$$N_0 = N \left[1 - \left(\frac{T}{T_C}\right)^3\right]$$ (6)

Useful Formulae and Constants

Stefan's constant $\sigma = 5.67 \times 10^{-8}\, Wm^{-2}K^{-4}$

Boltzmann constant $k_B = 1.38 \times 10^{-23} JK^{-1}$

Planck's constant $h = 6.62 \times 10^{-34} Js$

Gas constant $R = 8.314 J K^{-1} mol^{-1}$

$$\int_0^{\infty} x^3 e^{-x} dx = 6 \;; \quad \int_{-\infty}^{\infty} exp(-ax^2)\, dx = \sqrt{\frac{\pi}{a}} \quad ; \quad \int_{-\infty}^{\infty} exp(-a\, x^4)\, dx = \frac{\Gamma(1/4)}{2\, a^{1/4}}$$

[This question paper contains 2 printed pages.]

Your Roll No..............

Sr. No. of Question Paper : 1754 **L**

Name of the Course : B.Sc. Hons.–(Physics)_NEP: UGCF-2022

Semester : VI- Semester

Name of the Paper : DSC Atomic, Molecular and Nuclear Physics

Unique Paper Code : 2222013602

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **five** questions in all.
3. **Question No. 1 is compulsory.**
4. Attempt ***four*** questions from the rest of the paper
5. Non- programmable scientific calculators are allowed.

1. Answer any **six** of the following: **(6X3=18)**

   (a) What causes the fine structure of hydrogenic atoms?

   (b) State and explain Larmor's theorem.

   (c) In the near infrared spectrum of $^{12}C^{16}O$ molecule there is an intense band at $2144cm^{-1}$. Calculate the zero point energy of the molecule.

   (d) Distinguish between Raman scattering and Rayleigh scattering.

   (e) What is the role of neutrino in the phenomenon of β- decay?

   (f) Write the law of conservation of momentum for the Gamow-Teller transitions.

   (g) Show how each line belonging to Lyman series splits into a doublet in Hydrogen atom.

2. (a) Derive an expression for the fine structure splitting of an (n, l) level of a hydrogenic system due to spin-orbit interaction. Calculate the magnitude of this shift in cm^{-1} for $2p_{1/2}$ and $2p_{3/2}$ states of the Hydrogen atom.

   (b) In a Stern-Gerlach experiment, a beam of silver atoms moves a horizontal distance of 1m in a region with vertical magnetic field gradient 0.387 T/m. If the speed of silver atoms is 100 m/s, calculate the maximum separation between the traces on the detector plates. [Given: Mass of silver atoms =1.79×10^{-25}kg] **(12+6)**

3. (a) Give main features of the pure rotational band spectrum of a heteronuclear diatomic molecule. How are they explained, treating molecule as a rigid rotator. Also, discuss rotational spectrum of a diatomic molecule, treated as a non-rigid rotator.

P.T.O.

(b) In rigid rotator approximation for CO, the $J = 0 \rightarrow J = 1$ absorption line occurs at a frequency of 1.15×10^{11}Hz. What is the (i) Moment of inertia and (ii) bond length of the CO molecule.

(10+8)

4. (a) Explain the classical theory of the observed Raman spectrum of a diatomic molecule. How is it used to explain the structure of a diatomic molecule?

(b) Distinguish between Normal and Anomalous Zeeman Effects. Show that the total magnetic moment of an orbital electron in weak magnetic fields for the state with total angular momentum J is given by: $\boldsymbol{\mu_J} = g\mu_B \boldsymbol{J}/\hbar$

Where $g = 1 + \frac{J(J+1)+S(S+1)-L(L+1)}{2J(J+1)}$

(8+10)

5. (a) State and explain the Geiger–Nuttall law. Outline a barrier penetration model for α-decay and explain the concept of quantum tunneling.

(b) Give any three evidences indicating the presence of shell structure in nuclei.

(c) Predict the ground state spins and parities based on the shell model for the following nuclei: (i) ${}^{11}_{5}B$ (ii) ${}^{17}_{8}O$

(8+6+4)

6. (a) Give a brief account of multipole radiation associated with the process of γ- decay. Consider a γ transition from an initial excited state of angular momentum 3/2 and even parity to a final state 5/2 with even parity. What are the possible values of angular momentum for the multipole radiation emitted in the process? Determine the type of corresponding multipole radiation as electric or magnetic.

(b) Describe the process of electron capture. Under what conditions is it more likely to occur than the beta decay?

(c) Draw and discuss the characteristic Morse potential energy curve for anharmonic vibrations of a diatomic molecule.

(7+6+5)

Useful information:

$$\langle \frac{1}{r} \rangle = \frac{Z}{n^2 a_0}; \quad \langle \frac{1}{r^2} \rangle = \frac{Z^2}{(l+1/2)n^3 a_0^2}; \quad \langle \frac{1}{r^3} \rangle = \frac{Z^3}{l(l+\frac{1}{2})(l+1)n^3 a_0^3}$$

a_0 is the Bohr radius, Z is nuclear charge, l is the orbital quantum number and n is the principal quantum number

Bohr Magneton $\mu_B = 9.27 \times 10^{-24} J$; Fine structure constant $\alpha = \frac{1}{137}$

$h = 6.625 \times 10^{-34} Js$; $1U = 1.66 \times 10^{-27} kg$

(2500)

[This question paper contains 4 printed pages.]

Your Roll No................

Sr. No. of Question Paper : 1775 **L**

Unique Paper Code : 2222013604

Name of the Paper : Tensor Analysis and Applicaions

Name of the Course : **B.Sc. Hons. – (Physics)_NEP: UGCF-2022**

Semester : VI – (DSC Paper)

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **FIVE** questions in all.
3. **All** questions carry equal marks (**18** marks each).
4. Question No. **1** is compulsory.

(3X6)

1. (a) Consider a frame of reference S' :(x' , y') rotated at an **angle of** 150° with respect to a frame of reference S :(x , y). Determine the transformation matrix which determines the rotation of coordinates to (x' , y').

(b) Determine the equation of a line in tensorial form with length ' r ' and direction cosines ' l_i '.

(c) The Moment of Inertia Tensor of a system is given below:

$$\mathbf{I}_m = \begin{bmatrix} a & 0 & 0 \\ 0 & a & 0 \\ 0 & 0 & a \end{bmatrix}$$

What can be said about the distribution of mass of the system and principal moments of inertia.

(f) Write down the components of four velocity.

(g) Express $\vec{A}\cdot(\vec{B}\times\vec{C})$ in Cartesian tensor notation.

2. (a) Using Cartesian tensor notation prove the following vector identities:

i) $\vec{\nabla}\times\left(\vec{\nabla}\times\vec{A}\right)=\vec{\nabla}\left(\vec{\nabla}\bullet\vec{A}\right)-\left(\vec{\nabla}^2\vec{A}\right)$

ii) $\vec{\nabla}\bullet\left(\vec{\nabla}\times\vec{A}\right)=0$

iii) $\left(\vec{A}\times\vec{B}\right)\times\left(\vec{C}\times\vec{D}\right)=\vec{C}\left(\vec{A}\bullet\vec{B}\times\vec{D}\right)-\vec{D}\left(\vec{A}\bullet\vec{B}\times\vec{C}\right)$ (3X5)

(b) If B_{ijk} is a tensor of order 3, then is the quantity B_{iik} a tensor? If so, what is its order. (3)

3. (a) **Given that** : $\in_{hku}\in_{pcm}=\begin{bmatrix}\delta_{hp} & \delta_{hc} & \delta_{hm}\\ \delta_{kp} & \delta_{kc} & \delta_{km}\\ \delta_{up} & \delta_{uc} & \delta_{um}\end{bmatrix}$

(i) Prove that $\in_{hku}\in_{pcu}=\delta_{hp}\,\delta_{kc}-\delta_{hc}\,\delta_{kp}$ (8)

(ii) Prove that $\in_{hku}\in_{pku}=2\,\delta_{hp}$ (6)

(b) If B_k and A_{ij} are Cartesian tensors such that $A_{ij}=\in_{ijk}\,B_k$

Show that $B_k=(\in_{ijk}A_{ij})/2$ (4)

4. (a) Given a line AB between two points a_i and x_i having direction cosines l_i and length r. Show that $\sum(l_i)^2=1$. (4)

(b) **Arrive at the components of four potential and four current density.**

(You may use the following if needed : (14)

(i) $\vec{E}=-\vec{\nabla}\varphi-\dfrac{\partial\vec{A}}{\partial t}$,

(ii) The Lorentz Gauge condition : $\vec{\nabla} \bullet \vec{A} + \mu_0 \varepsilon_0 \frac{\partial \varphi}{\partial t} = 0$,

(iii) Gauss' Law : $\vec{\nabla} \bullet \vec{E} = \frac{\rho}{\varepsilon_0}$,

(iv) Ampere's Law (Corrected) : $(\vec{\nabla} \times \vec{B}) = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$,

(v) Continuity Equation : $\vec{\nabla} \bullet \vec{J} + \frac{\partial \rho}{\partial t} = 0$

where $\vec{E}$ is Electric Field, $\vec{B}$ is Magnetic Field, φ is the scalar (Electric) potential, $\vec{A}$ is the magnetic vector potential, $\vec{J}$ is current density and ρ is volume charge density.)

5. **Given** the :

(i) Christoffel Symbols of the first kind:

$$[\,p\,q\,,r\,] = \frac{1}{2}\left(\frac{\partial g_{pr}}{\partial x^q} + \frac{\partial g_{qr}}{\partial x^p} - \frac{\partial g_{pq}}{\partial x^r}\right) \text{ and}$$

(ii) the Christoffel Symbols of the second kind:

$$\Gamma_{pq}^{\ s} = \left\{ {s \atop pq} \right\} = g^{sr}\,[\,p\,q\,,r\,],$$

prove the following for a coordinate system where $g_{pq} = 0$ when $p \neq q$.

(i) $\frac{\partial g_{rs}}{\partial x^t} = [\,r\,t\,,s\,] + [\,s\,t\,,r\,]$ (4)

(ii) $\frac{\partial g^{rs}}{\partial x^t} = -\, g^{rn} \left\{ {s \atop tn} \right\} - g^{sn} \left\{ {r \atop tn} \right\}$ (14)

---

6. Consider two points P (x_i) = P (x_1, x_2, x_3) and Q $(x_i + h_i)$ = Q$(x_1 + h_1,\ x_2 + h_2,\ x_3 + h_3)$ within a deformable body. These two points are an infinitesimal distance h_i apart. When stress acts on the body, it undergoes a deformation such that the points P and Q shift respectively to P' and Q'. $f_i\ (x_i)$ are functions which represent the change from P to P'.

(a) Show that the above deformation leading to a strain in the body is given by : $P'Q' - PQ = \frac{\partial f_i}{\partial x_j} h_j$. (8)

(b) Show that the deformation in part (i) can be separated into a symmetric part η_{ij} and an anti-symmetric part ξ_{ij}. (6)

(c) What do η_{ij} and ξ_{ij} represent. (4)

(This Question paper contains 2 printed page) Roll No. ________

S.No. of Question Paper	:	2007	L
Name of Department	:	Physics	
Name of Course	:	B.Sc. Hons. - (Physics)_NEP: UGCF-2022	
Name of the Paper	:	Microprocessor	
Semester	:	VI- Semester (DSE Paper)	
Unique Paper Code	:	2223010022	
Question paper Set number	:	SET A	

Duration: 2 hours **Maximum Marks: 60**

Instructions for Candidates:

(a) Attempt four questions in all.

(b) Question no. 1 is compulsory.

(c) All questions carry equal marks.

(d) Symbols have their usual meanings.

1. Attempt any five questions: **(5x3=15)**

(a) What are the key components of a microprocessor?

(b) Draw schematic diagram of a 1KB R/W memory interfaced with a microprocessor having 16 address lines spanning the address range from 0000H to 03FFH. How many address lines are used for selecting the chip?

(c) Give the status of carry flag and zero flag after the instruction CMP B is executed, if

(i) data in accumulator > data in register B

(ii) data in accumulator = data in register B

(iii) data in accumulator < data in register B

(d) Identify the addressing modes of the following 8085 microprocessor instructions:

(i) MVI B, CDH

(ii) MOV B, A

(iii) STA 2000

(e) How many address lines are required to address 256KB memory locations? If address of first memory location of a 1KB memory chip is 2000H, what is the address of last memory location of the chip?

(f) What happens when a microprocessor receives an interrupt signal? List the hardware interrupts in order of their priority in 8085 microprocessor.

2. **(a)** An instruction (MOV C, A) with the Hex-code 4FH is stored in the memory location 2006H. Draw timing diagram for the execution of the instruction.

(b) If the clock frequency is 5MHz, determine the time taken by the microprocessor to execute the instruction MOV C, A.

(10,5)

3. **(a)** Draw and explain the complete Bus structure (Address Bus, Data Bus, Control Bus) of 8085 microprocessor.

(b) What is the function of accumulator, program counter, stack pointer and Flag register in 8085 microprocessors? Show the bit position of each flag in the Flag register.

(7,8)

4. **(a)** How many M-cycles are required to implement CALL instruction. Give the sequence of events in each machine cycle. How much time is required to execute CALL instruction (18 T-states) if the clock frequency of 8085 microprocessor is 5MHz.

(b) Write an assembly language program for 8085 micro-processor to multiply two eight-bit numbers 20H and 03H, using a subroutine.

(10,5)

5. **(a)** Draw pin-out diagram of 8085 microprocessor.
(b) Write a short note on primary and secondary memory highlighting their differences and giving examples of each.

(7,8)

[This question paper contains 4 printed pages.]

Sr. Number of the Question paper	:	**2009**	Your Roll No............
Unique Paper Code	:	**2223010045**	
Name of the Paper	:	**Statistical Analysis in Physics**	
Name of the Course	:	**B.Sc.(H) Physics**	
Semester	:	**VI**	

Duration : 2 Hours

Maximum Marks : 60

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt four questions in all.
3. Question number 1 is compulsory.
4. Non-programmable calculators are allowed.
5. Use of statistical tables are allowed.

1. Attempt any five of the following:

3*5=15 M

a) Differentiate between discrete and continuous probability distributions. Give one suitable example of each.

b) Let the joint probability density function of two random variables X and Y be given by $f(x,y) = kxy,\ 0 \le x \le 2\ 0 \le y \le 1$. Find: (i). The value of k (ii). $P(X < 1, Y < \frac{1}{2})$

c) A coin has probability θ of landing heads. Assume the prior distribution of θ is $\theta \sim Beta(3,1)$, The coin is tossed 5 times and 4 heads are observed. Determine the posterior distribution of θ and compute the posterior mean.

d) State Bayes' theorem. Briefly explain the relationship between prior probability and posterior probability with the help of a suitable example.

e) State the probability mass functions of the Binomial and Poisson distributions, and the probability density function of the Gaussian (Normal) distribution. Also write the mean and variance of each distribution.

f) Differentiate between Bayesian Regression and Ordinary Linear Regression. Discuss how uncertainty in model parameters is treated in both approaches.

2. (a) Two crystals are selected at random without replacement from a box containing 6 red, 7 green, and 9 white crystals. Let X denote the number of red crystals selected and Y denote the number of green crystals selected. Find:

(i) The joint probability distribution of X and Y

(ii) The marginal probability distributions of X and Y.

(iii) The conditional distribution of X given that $Y = 1$.

8M

(b) A factory has three machines, M_1, M_2 and M_3, producing electric components.

(i) Machine M_1 produces 40% of the total components, and 2% of its products are defective.

(ii) Machine M_2 produces 35% of the total components, and 3% of its products are defective.

(iii) Machine M_3 produces 25% of the total components, and 5% of its products are defective.

A component is selected at random and found to be defective. Find:

(i) The overall probability that a randomly selected component is defective.

(ii) The probability that the defective component was produced by machine M_1.

4M+3M

5. A coin has an unknown bias θ, representing the probability of landing heads. Assume that the prior distribution of θ is $\theta \sim Beta(3,2)$. The coin is tossed 6 times and 5 heads are observed.

(i) Determine the posterior distribution of θ.

(ii) Compute the posterior mean.

(iii) Compute the MAP estimate.

The coin is then tossed 4 more times, resulting in 1 head and 3 tails.

(iv) Update the posterior distribution again.

(v) Compute the new MAP estimate and briefly compare it with the previous estimate.

3+3+3+3+3M

6. A researcher models the relationship between study hours x and examination score y using the Bayesian linear regression model

$$y = \beta_0 + \beta_1 x + \epsilon$$

where

$$\epsilon \sim N(0, \sigma^2), \qquad \sigma^2 = 4$$

The prior distributions for the regression parameters are:

$$\beta_0 \sim N(0,10), \qquad \beta_1 \sim N(1,5)$$

A dataset consisting of the observations (1,4), (2,5), (3,8) is obtained.

(i) Write the likelihood function for the data.

(ii) Determine the posterior distribution of the parameter vector (β_0, β_1)

up to proportionality.

(iii) Explain how the posterior distribution combines prior belief and observed data.

(iv) Predict the expected score for a student studying $x = 4$ hours.

3+4+4+4M

[This question paper contains 4 printed pages.]

Sr. No. of Question Paper	:	**1716**
Unique Paper Code	:	2222014801
Name of the Paper	:	Adv. Statistical Mechanics
Name of the Course	:	B.Sc. Hons.-(Physics)_NEP: UGCF-2022
Semester	:	VIII (DSC Paper)
Duration	:	3 hours
Maximum Marks	:	90

Instructions for Candidates

1. Write your Roll on the top immediately on receipt of this question paper.

2. Attempt **five** questions in all.

3. Question No. 1 is compulsory.

4. Use of non-programmable scientific calculators is allowed.

---

1. Attempt any six of the following:

(a) Show that the graph of $\ln \Omega$ versus E for a system with no bound on its energy is concave downwards (i.e. its slope decreases with E, but remains positive). Ω is the number of accessible microstates.

(b) The log of the partition function of a photon gas in volume V is $\ln Z = A\frac{V}{\beta^3}$, where A is a constant and $\beta = 1/k_B T$. Show that VT^3 remains constant during the adiabatic expansion of the photon gas .

(c) Show that the entropy of a system in the grand canonical ensemble can be written as

$S = -k \sum_{r,s} P_{r,s} \ln P_{r,s}$, where $P_{r,s}$ is the probability of the system in a state with N_r number of particles and energy E_s .

(d) Differentiate between microcanonical, canonical and grand canonical ensemble.

(e) Distinguish between Pure and Mixed states. Prove that $Tr[\rho^2] = 1$ for a pure state.

(f) Density matrix elements of the canonical ensemble of a quantum harmonic oscillator in energy eigen states are $\rho_{nm} = A \exp(-(n + 1/2)\beta\hbar\omega)\delta_{nm}$. Find the value of constant A.

(g) For a one-dimensional Ising model with nearest-neighbor interaction strength $J =$

0.1 eV and zero external field, evaluate the ratio of probabilities of aligned to anti- aligned spin pairs at $T = 100$ K.

(3 × 6 = 18)

2. (a) Find the partition function for a distribution of N distinguishable quantum simple harmonic oscillators ($\epsilon_n = (n + 1/2)\hbar\omega$). What is the mean energy and specific heat at constant volume C_V of this system? Show that this system satisfies the Third Law of Thermodynamics ($C_V \to 0$ as $T \to 0$) . Using the fact that a system of classical harmonic oscillators satisfies equipartition theorem, show that it does not satisfy the third law.

(12)

(b) The number of microstates of an ideal monatomic gas in two-dimensions, occupying area A, and having N particles and energy U is given as:

$$\Omega(N,U,A) = \frac{1}{N!}\frac{A^N}{h^{2N}}\frac{\pi^N}{N!}(2mU)^N$$

where h is Planck's constant and m is the molecular mass.

(i) Determine the entropy of the gas.

(ii) Find the gas temperature.

(iii) Is the equipartition theorem valid for this system?

(6)

Q 3 (a) Show that the mean variance of energy distribution of a system in grand canonical ensemble is $\overline{(\Delta E)^2} = \overline{(\Delta E)^2}_{Canonical} + \left[\left(\frac{\partial \bar{E}}{\partial \bar{N}}\right)_{T,V}\right]^2 \overline{(\Delta N)^2}$, where $\overline{(\Delta E)^2}_{Canonical} = kT^2 C_V$ are the energy fluctuations of a system in canonical ensemble, and $\overline{(\Delta N)^2} = kT\left(\frac{\partial \bar{N}}{\partial \mu}\right)_{T,V}$ is the mean variance of the number of particles in the system.

(12)

(b) The relative value of fluctuations in the number density of particles in a gas is $\frac{\overline{(\Delta n)^2}}{\bar{n}^2} = \frac{k_B T}{V} \kappa_T$, where κ_T is the compressibility of the gas. Use this result to argue that the results of grand canonical ensemble analysis are not equivalent to those of canonical ensemble during phase transition from liquid to gas phase, or vice versa. (6)

4. (a) Show that the density matrix in the coordinate representation for a particle of mass m with periodic boundary conditions in a 1D box of length L, and in a canonical ensemble at temperature T is $\varrho_{xx'} = \frac{1}{L}\exp\left[-\frac{m}{2\beta\hbar^2}|x-x'|^2\right]$. What is the mean energy of the particle?

(12)

(b) Verify that for a system in statistical equilibrium, the density matrix must commute with the Hamiltonian ($[\rho, H] = 0$). (6)

5. (a) A one-dimensional Ising system consists of N spins $s_i = \pm 1$ with nearest-neighbor interaction strength J and zero external field. (i) Write the Hamiltonian and construct the transfer matrix in the cyclic boundary condition. (ii) Find the internal energy and heat capacity per spin. (14)

(b) The transfer matrix of a one dimensional spin system has eigenvalues $\lambda_1 = 2.5$ and $\lambda_2 = 1.5$. Find the correlation length of the system. (4)

6. (a) Show that there is no specific correlation between spin orientation of nearest neighbours in a lattice in the mean field approximation.

(b) The diagonal elements of the density matrix of one dimensional harmonic oscillator in position representation are given as $\langle q|\varrho|q\rangle = A\exp\left\{-\frac{m\omega}{\hbar}q^2\tanh(\beta\hbar\omega/2)\right\}$. Find the value of constant A. Use the above expression to argue that the probability distribution of the position of harmonic oscillator is Gaussian, and derive an expression for its variance.

(c) Show that the grand partition function of a non relativistic ideal gas confined to volume is $Z_G = \exp\left(\frac{zV}{\lambda_T^3}\right)$, where $\lambda_T = \frac{h}{\sqrt{2\pi mkT}}$. You can use the fact that the partition function for a single particle in volume V is $z_1 = \frac{V}{\lambda_T^3}$. (6,6,6)

Useful Physical Constants

$k_B = 1.38 \times 10^{-23} \text{J/K}$

[This question paper contains 4 printed pages.]

Your Roll No.--------------------------

Serial Number of Question Paper : **7440**

Unique Paper Code : **2223010038**

Name of the Paper : **Adv. Quantum Mechanics-II**

Name of the Course : **B.Sc. Hons.-(Physics) NEP: UGCF-2022**

Semester : **VIII- Semester (DSE Paper)**

Duration : 3 Hours **Maximum Marks: 90**

Instructions

i. Write your Roll Number on the top immediately on the receipt of the question paper.

ii. Attempt five questions in all. Question number 1 is compulsory. Attempt any four questions amongst questions 2-6.

iii. All questions carry equal marks.

iv. Use of non-programmable scientific calculators is allowed.

1. Attempt any 6 of the following: **[6×3=18]**

a) An electron in an atom is placed in a magnetic field of strength $B = 1\text{T}$. Calculate the energy shift in the strong Zeeman effect for a state with $m_l = 1, m_s = -\frac{1}{2}$. Use Bohr magneton: $\mu_B = 9.27 \times 10^{-24}\text{J/T}$

b) A particle is confined in a one-dimensional infinite potential well of width a. A weak perturbation of the form $H' = \lambda x$ is applied, where λ is a constant. Determine which unperturbed states contribute to the first-order correction to the ground-state wavefunction.

c) A perturbation acts for time interval δt. Determine whether the process is sudden or adiabatic if $\delta t \ll \hbar/\delta E$ where δE is the characteristic energy difference of the system. Justify your answer.

d) For a quantum transition, the matrix element is 3×10^{-24} J and the density of states is $5 \times 10^{22}\ \text{J}^{-1}$. Using Fermi's Golden Rule, calculate the transition rate.

e) Under what conditions does scattering amplitude have azimuthal symmetry? Justify your answer.

f) Show that the scattering matrix (S-matrix) is unitary and explain the physical significance of this property.

g) A beam of low-energy particles with wave number $k = 1 \times 10^{10}$ m^{-1} is scattered by a spherically symmetric potential. Determine the differential cross-section if only the s-wave with phase shift $\delta_0 = \frac{\pi}{4}$ contributes and all higher partial wave phase shifts are negligible.

2.

a) Derive the variational principle for the ground state energy and show that for any arbitrary normalized trial wavefunction $|\Psi_t\rangle$, the expectation value of the Hamiltonian provides an upper bound to the true ground state energy $\langle\Psi_t|H|\Psi_t\rangle \geq E_0$. Under what condition does equality hold? Explain how the variational principle may be extended to estimate the first excited state energy. [9]

b) Consider a two-level quantum system with states $|a\rangle$ and $|b\rangle$ being the eigenstates of unperturbed Hamiltonion $H^{(0)}$ having energies E_a and E_b respectively. Define $\omega_{ab} = \frac{E_a - E_b}{\hbar}$. A time-dependent perturbation $H'(t) = V\cos(\omega t)$ is applied, where $V_{ab} = \langle a|V|b\rangle \neq 0$ and $V_{aa} = V_{bb} = 0$. Using first-order time-dependent perturbation theory, derive an expression for the transition amplitude $c_b(t)$ for the transition $|a\rangle \to |b\rangle$. Hence show that the transition probability $P_{a\to b}(t)$ is proportional to

$$\left[\frac{\sin^2\left(\frac{(\omega_{ab} - \omega)t}{2}\right)}{(\omega_{ab} - \omega)^2} + \frac{\sin^2\left(\frac{(\omega_{ab} + \omega)t}{2}\right)}{(\omega_{ab} + \omega)^2}\right].$$

[9]

3.

a) Consider the Hamiltonian

$$H = V_0\begin{pmatrix} 1-\epsilon & 0 & 0 \\ 0 & 1 & \epsilon \\ 0 & \epsilon & 2 \end{pmatrix}, \quad \epsilon \ll 1$$

i. Write down the eigenvalues and eigenvectors of the unperturbed Hamiltonian H^0 ($\epsilon = 0$). Identify the degenerate and non-degenerate eigenvalues.
ii. Using first-order degenerate perturbation theory, find the first order correction to the two initially degenerate eigenvalues.
iii. Use first order non-degenerate perturbation theory to find the corrected eigenvalue corresponding to the non-degenerate eigenvector of H^0.

[9]

b) Derive the expression for the differential cross-section in terms of the scattering amplitude and hence obtain the expression for the total cross-section. Discuss the physical interpretation of these quantities in terms of measurable scattering processes.

[9]

4.

a) Define the interaction-picture state vector in terms of the Schrödinger-picture state vector. Starting from the Schrödinger equation, derive the equation of motion for the interaction-picture state vector. State one advantage of the interaction picture in time-dependent perturbation theory. [9]

b) The spin–orbit interaction of an electron in a central potential is described by

$$H_{SO} = \frac{1}{2m^2c^2}\frac{1}{r}\frac{dV}{dr}\boldsymbol{L}\cdot\boldsymbol{S}.$$

Obtain the explicit radial dependence of the interaction for a Coulomb potential. Express $\boldsymbol{L}\cdot\boldsymbol{S}$ in terms of J^2, L^2, and S^2, and hence determine the eigenvalue of $\boldsymbol{L}\cdot\boldsymbol{S}$ for a state labelled by j, ℓ, s. [9]

5.

a) A particle is initially in the ground state of an infinite, one-dimensional potential well, with walls at $x = 0$ and $x = a$. If the wall of this well at $x = a$ is now suddenly moved (at $t = 0$), to $x = 8a$, calculate the probability of finding the particle in the ground state, and first excited state, of the new potential well. [9]

b) Using partial wave analysis, describe the asymptotic behaviour of the radial wavefunction for a particle scattered by a central potential. Show that the large-r form of the radial solution can be written in terms of phase shifts. Explain how the effect of the potential is entirely contained in the phase shifts. [9]

6.

a) Calculate the scattering cross-section for a low-energy particle from a potential given by

$$V(r) = \begin{cases} -V_0, & r < a \\ 0, & r > a \end{cases}$$

using Born approximation. [9]

b) Consider scattering of a particle of mass m and energy $E = \frac{\hbar^2 k^2}{2m}$ by a repulsive potential $V(r) = B\,\delta(r - a)$ where B and a are positive constants. Obtain an equation that determines s-wave phase shift $\delta_0(k)$. [9]

(This Question paper contains 4 printed page)

S. No. Of Question Paper	:	**7441**
Name of the Course	:	**B.Sc. Hons.–(Physics)_NEP: UGCF-2022**
Semester	:	**VIII- Semester**
Name of the Paper	:	**Electrodynamics (DSE Paper)**
Unique Paper Code	:	**2223010039**
Question Paper Set No.	:	**Set – A**

Duration : 3 Hours **Maximum Marks: 90**

Instructions

1. Write your Roll Number on the top immediately on the receipt of the question paper.
2. Attempt five questions in all. Question number 1 is compulsory. Attempt any four questions amongst questions 2-6.
3. All questions carry equal marks.
4. Use of non-programmable scientific calculators is allowed.
5. Unless specified, the paper uses SI units.
6. The metric used is $g_{\mu\nu} = (+,-,-,-)$.
7. Students are advised to mention the units and metric they are using.
8. Some useful formulae are provided at the end of question paper.

Q1. Attempt any six parts. All parts carry equal marks.

a) The electric and magnetic fields in an inertial frame have values $\vec{E} = (6, 8, 0)$V/m and $\vec{B} = (0, 0, 2 \times 10^{-8})$T respectively. Determine whether there exists a frame in which the electric field vanishes.

b) Show that the Lorenz Gauge condition $\vec{\nabla} \cdot \vec{A} + \frac{1}{c^2}\frac{\partial \Phi}{\partial t} = 0$ can be written in a manifestly covariant form.

c) Express the quantity $\partial_\mu(A_\nu F^{\mu\nu})$ in terms of electric and magnetic fields. Here $F^{\mu\nu}$ is the electromagnetic field tensor satisfying Maxwell's equations in vacuum and A_ν is the corresponding four-potential.

d) A proton moves in a region where the fields are $\vec{E} = 3.0 \times 10^4\, \hat{\imath}$ V/m, $\vec{B} = 0.10\, \hat{k}$ T. If the initial velocity is zero determine the drift velocity.

e) In which direction(s) is the radiation intensity maximum and zero for an oscillating electric dipole?

f) What are the conditions that characterise the radiation (far) zone? Mention two approximations which are valid in this zone?

g) A system is described by a Lagrangian $L(q_i, \dot{q}_i, t)$. If under an infinitesimal transformation of generalised coordinates given by $q_i \to q_i + \epsilon\delta q_i$ the Lagrangian changes by $\delta L = \epsilon\frac{dK}{dt}$, show that the Euler-Lagrange equation satisfied the system does not change.

(3 × 6 = 18)

Q2.

a) Suppose that the vector potential $\vec{A}$ satisfies Coulomb gauge condition. Let the current density $\vec{J}$ be decomposed as $\vec{J} = \vec{J}_\ell + \vec{J}_t$ with $\vec{\nabla} \times \vec{J}_\ell = 0$ and $\vec{\nabla} \cdot \vec{J}_t = 0$. Using Maxwell's equations and continuity equation, show that

i. $\frac{1}{c^2}\vec{\nabla}\frac{\partial \Phi}{\partial t} = \mu_0 \vec{J}_\ell$

ii. $\frac{1}{c^2}\frac{\partial^2 \vec{A}}{\partial t^2} - \vec{\nabla}^2 \vec{A} = \mu_0 \vec{J}_t$

b) Starting from the transformation law of electromagnetic field tensor $F^{\mu\nu}$ as a rank-2 tensor under a Lorentz boost along the x-axis, derive the transformation equations for the components of electric field $\vec{E}$ and magnetic field $\vec{B}$.

(10, 8)

Q3.

a) A charged particle moves in uniform, static crossed fields $\vec{E} = E_0\,\hat{j}$ and $\vec{B} = B_0\,\hat{k}$. Determine the trajectory of the particle and derive the $\vec{E} \times \vec{B}$ drift velocity.

b) A proton starts from rest and is accelerated by a uniform electric field $\vec{E} = 10^6$ V/m. Using the relativistic equation of motion, determine its position and velocity at time $t = 10$ ns. Compare your result with the corresponding non-relativistic motion.

(10, 8)

Q4.

a) The electric and magnetic field vectors in an inertial frame K are given by

$$\vec{E} = (0, E_0, 0), \quad \vec{B} = \left(0, \frac{E_0}{c}, 0\right)$$

where E_0 is a constant. Determine the velocity of an inertial frame K', moving along x-axis relative to frame K, such that the transformed fields $\vec{E'}$ and $\vec{B'}$ make an angle 60° with each other.

b) The total power radiated by an accelerated relativistic charge q, moving with velocity $\vec{v}$ and acceleration $\vec{a}$, is given by the Liénard formula

$$P = \frac{1}{4\pi\epsilon_0}\frac{2q^2\gamma^6}{3c}\left[\left|\dot{\vec{\beta}}\right|^2 - \left|\vec{\beta} \times \dot{\vec{\beta}}\right|^2\right], \quad \text{where } \vec{\beta} = \frac{\vec{v}}{c}, \quad \dot{\vec{\beta}} = \frac{\vec{a}}{c}, \quad \gamma = \frac{1}{\sqrt{1-\beta^2}}$$

Obtain the corresponding expressions and interpret the result physically in the following limiting cases:

i. Non-relativistic motion of the charge
ii. Velocity and acceleration of the particle are collinear
iii. Velocity and acceleration of the particle are perpendicular to each other.

(9, 9)

Q5.

a) The scalar potential $\Phi(\vec{r}, t)$ in Lorenz gauge satisfies the inhomogeneous wave equation

$$\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\Phi(\vec{r}, t) = -\frac{\rho(\vec{r}, t)}{\epsilon_0}.$$

For which the Green's function is defined by

$$\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right) G(\vec{r}, \vec{r}'; t, t') = -4\pi\delta^3(\vec{r} - \vec{r}')\delta(t - t').$$

i. Using Fourier transform in time and the result

$$(\nabla_{\mathbf{R}}^2 + k^2)\frac{e^{ikR}}{R} = -4\pi\delta^3(\vec{R}), \qquad \vec{R} = \vec{r} - \vec{r}', \qquad R = |\vec{r} - \vec{r}'|$$

(where $\nabla_{\mathbf{R}}^2$ is the Laplacian with respect to $\vec{R}$), show that

$$G_{\text{ret}}(\vec{r}, \vec{r}'; t, t') = \frac{\delta\left(t - t' - \frac{|\vec{r} - \vec{r}'|}{c}\right)}{|\vec{r} - \vec{r}'|}$$

is the retarded Green's function for the wave equation.

ii. Why is the retarded Green's function physically preferred over the advanced Green's function?

iii. Using $G_{\text{ret}}(\vec{r},\vec{r}\,';t,t')$, derive the expression for the retarded scalar potential:

$$\Phi_{\text{ret}}(\vec{r},t) = \frac{1}{4\pi\epsilon_0}\int \frac{\rho(\vec{r}\,',t_r)}{|\vec{r}-\vec{r}\,'|}\, d^3r', \qquad t_r = t - \frac{|\vec{r}-\vec{r}\,'|}{c}$$

b) An oscillating charge distribution has a characteristic size of 1 cm and radiates at 10 GHz. Estimate the wavelength of the emitted radiation. Hence determine the ranges of the observation distance r from the source corresponding to the near, intermediate, and far (radiation) zones.

(12, 6)

Q6.

a) Write the Lagrangian density for the electromagnetic field interacting with a four -current J^μ. Derive the Maxwell's inhomogeneous equations using the Euler–Lagrange equations for the fields.

b) Show that the trace of the electromagnetic energy-momentum tensor vanishes: $T^\mu_\mu = 0$. What is the physical significance of this result?

(10, 8)

Some Useful Expressions

1. The Electromagnetic Field Tensor $F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu$

   $F^{0i} = -\frac{E^i}{c} = -F^{i0}$ and $F^{ij} = -\epsilon^{ijk} B_k$ for metric signature $(+\,-\,-\,-)$.

   $F^{0i} = \frac{E^i}{c} = -F^{i0}$ and $F^{ij} = \epsilon^{ijk} B_k$ for metric signature $(-\,+\,+\,+)$.

2. Dual field tensor: $\tilde{F}^{\mu\nu} = \frac{1}{2}\epsilon^{\mu\nu\alpha\beta} F_{\alpha\beta}$

3. Lorentz Transformation of Fields for Boost along x-axis:

$$E'_x = E_x \quad E'_y = \gamma(E_y - v\,B_z) \quad E'_z = (E_z + v\,B_y)$$
$$B'_x = B_x \quad B'_y = \left(B_y + \frac{v}{c^2}E_z\right) \quad B'_z = \gamma\left(B_z - \frac{v}{c^2}E_y\right)$$

4. Energy Momentum Tensor :

$$T^{\mu\nu} = \frac{1}{\mu_0}\left(-F^{\mu\alpha}F^{\nu}_{\alpha} + \frac{1}{4}g^{\mu\nu}F^{\alpha\beta}F_{\alpha\beta}\right) \text{ with } g_{\mu\nu} = \text{diag}(+,-,-,-)$$

5. Useful Vector Identities:

   a. $\vec{a}\times(\vec{b}\times\vec{c}) = (\vec{a}\cdot\vec{c})\vec{b} - (\vec{a}\cdot\vec{b})\vec{c}$

   b. $(\vec{a}\times\vec{b})\cdot(\vec{c}\times\vec{d}) = (\vec{a}\cdot\vec{c})(\vec{b}\cdot\vec{d}) - (\vec{a}\cdot\vec{d})(\vec{b}\cdot\vec{c})$

   c. $(\vec{a}\times\vec{b})\times(\vec{c}\times\vec{d}) = (\vec{a}\cdot\vec{b}\times\vec{d})\vec{c} - (\vec{a}\cdot\vec{b}\times\vec{c})\vec{d}$

   d. $\vec{\nabla}\cdot(\vec{a}\times\vec{b}) = \vec{b}\cdot(\vec{\nabla}\times\vec{a}) - \vec{a}\cdot(\vec{\nabla}\times\vec{b})$

   e. $\vec{\nabla}\times(\vec{a}\times\vec{b}) = \vec{a}(\vec{\nabla}\cdot\vec{b}) - \vec{b}(\vec{\nabla}\cdot\vec{a}) + (\vec{b}\cdot\vec{\nabla})\vec{a} - (\vec{a}\cdot\vec{\nabla})\vec{b}$

   f. $\vec{\nabla}(\vec{a}\cdot\vec{b}) = (\vec{a}\cdot\vec{\nabla})\vec{b} + (\vec{b}\cdot\vec{\nabla})\vec{a} + \vec{a}\times(\vec{\nabla}\times\vec{b}) + \vec{b}\times(\vec{\nabla}\times\vec{a})$

6. Vector Differential Operators in Cylindrical Coordinates (ρ, ϕ, z),

a. $\vec{\nabla} f = \frac{\partial f}{\partial \rho}\hat{\rho} + \frac{1}{\rho}\frac{\partial f}{\partial \phi}\hat{\phi} + \frac{\partial f}{\partial z}\hat{z}$ for a scalar field $f(\rho, \phi, z)$

b. $\nabla^2 f = \frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho\frac{\partial f}{\partial \rho}\right) + \frac{1}{\rho^2}\frac{\partial^2 f}{\partial \phi^2} + \frac{\partial^2 f}{\partial z^2}$ for a scalar field $f(\rho, \phi, z)$

c. $\vec{\nabla} \cdot \vec{A} = \frac{1}{\rho}\frac{\partial(\rho A_\rho)}{\partial \rho} + \frac{1}{\rho}\frac{\partial A_\phi}{\partial \phi} + \frac{\partial A_z}{\partial z}$ for a vector field $\vec{A} = A_\rho\hat{\rho} + A_\phi\hat{\phi} + A_z\hat{z}$

d. $\vec{\nabla} \times \vec{A} = \hat{\rho}\left[\frac{1}{\rho}\frac{\partial A_z}{\partial \phi} - \frac{\partial A_\phi}{\partial z}\right] + \hat{\phi}\left[\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial \rho}\right] + \hat{z}\left[\frac{1}{\rho}\frac{\partial(\rho A_\phi)}{\partial \rho} - \frac{1}{\rho}\frac{\partial A_\rho}{\partial \phi}\right]$

7. Vector Differential Operators in Spherical Polar Coordinates (r, θ, ϕ),

a. $\vec{\nabla} f = \frac{\partial f}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial f}{\partial \theta}\hat{\theta} + \frac{1}{r\sin\theta}\frac{\partial f}{\partial \phi}\hat{\phi}$ for a scalar field $f(r, \theta, \phi)$,

b. $\nabla^2 f = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial f}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial f}{\partial \theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 f}{\partial \phi^2}$

c. $\vec{\nabla} \cdot \vec{A} = \frac{1}{r^2}\frac{\partial(r^2 A_r)}{\partial r} + \frac{1}{r\sin\theta}\frac{\partial(\sin\theta A_\theta)}{\partial \theta} + \frac{1}{r\sin\theta}\frac{\partial A_\phi}{\partial \phi}$ for a vector field $\vec{A} = A_r\hat{r} + A_\theta\hat{\theta} + A_\phi\hat{\phi}$

d. $\vec{\nabla} \times \vec{A} = \hat{r}\frac{1}{r\sin\theta}\left[\frac{\partial(\sin\theta A_\phi)}{\partial \theta} - \frac{\partial A_\theta}{\partial \phi}\right] + \hat{\theta}\frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial A_r}{\partial \phi} - \frac{\partial(rA_\phi)}{\partial r}\right] + \hat{\phi}\frac{1}{r}\left[\frac{\partial(rA_\theta)}{\partial r} - \frac{\partial(A_r)}{\partial \theta}\right]$

8. Useful Physical Constants

Quantity	Value (SI Units)
Electron mass	$m_e = 9.11 \times 10^{-31}$kg
Proton Mass	$m_p = 1.67 \times 10^{-27}$kg
Proton charge	$e = 1.6 \times 10^{-19}$ C
Speed of light	$c = 3 \times 10^8$ms^{-1}
Vacuum permittivity	$\epsilon_0 = 8.854 \times 10^{-12}$Fm^{-1}
Vacuum Permeability	$\mu_0 = 1.257 \times 10^{-6}$ Hm^{-1}

[This question paper contains 4 printed page]

Your Roll No.------------------------------

Serial Number of Question Paper	:	**8118**
Unique Paper Code	:	**2223010038**
Name of the Paper	:	**Adv. Quantum Mechanics-II**
Name of the Course	:	**B.Sc. Hons (Physics) NEP: UGCF-2022**
Semester	:	**VIII- Semester (DSE Paper)**

Maximum Marks: 90

Duration : 3 Hours

Instructions

1. Write your Roll Number on the top immediately on the receipt of the question paper.
2. Attempt five questions in all. Question number 1 is compulsory. Attempt any four questions amongst questions 2-6.
3. All questions carry equal marks.
4. Use of non-programmable scientific calculators is allowed.

1. Attempt any 6 of the following : **[6×3=18]**

   a) For a linear harmonic oscillator, the force constant changes from k to $k+\lambda$, where $\lambda \ll k$. Treat the change in force constant as a perturbation and write the perturbation Hamiltonian.

   b) A variational trial wave function gives expectation energy values $6eV$, $5eV$, and $4.5eV$ for three different choices of the variational parameters. Which value gives the best variational estimate of ground-state energy? Justify your answer.

   c) A perturbation acts on a quantum system for time interval δt. Determine whether the evolution is sudden or adiabatic if $\delta t \gg \hbar/\delta E$ where δE is a characteristic energy difference of the system. Justify your answer.

   d) A particle in a box of length L suddenly expands to length $2L$. If initially, the particle was in the ground state, what is the probability that after the expansion, it would still be in the new ground state?

   e) In the first-Born approximation, the scattering amplitude is $f(\theta) = \frac{A}{1+\cos\theta}$ where $A = 2 \times 10^{-11}$ m. Calculate the differential cross-section at $\theta = 30°$.

   f) Explain the meaning of the scattering matrix (S-matrix) in quantum scattering theory. What physical information is obtained from its diagonal elements?

g) For a scattering process, the forward scattering amplitude is $f(0) = (2 + i5) \times 10^{-11}$ m. The wave number of the incident particle is $k = 2 \times 10^{10}\text{m}^{-1}$. Using the optical theorem, calculate the total scattering cross-section.

2.

a) Consider a quantum system with Hamiltonian $H = H_0 + \lambda V$, where H_0 has a complete set of non-degenerate eigenstates. Using time-independent perturbation theory, derive the expressions for the first-order correction to the energy and the first-order correction to the eigenfunction. [9]

b) Consider the one-dimensional quantum anharmonic oscillator described by the Hamiltonian $H = H^{(0)} + H'$ with $H^{(0)} = \frac{\hat{p}^2}{2m} + \frac{1}{2}m\omega^2\hat{x}^2$ and $H' = \lambda\hat{x}^4$ a small perturbation. Using a characteristic length scale $d = \sqrt{\frac{\hbar}{m\omega}}$ and the ladder operator representation of the position operator, $\hat{x} = \sqrt{\frac{\hbar}{2m\omega}}(a + a^\dagger)$, express the perturbation in terms of the creation and annihilation operators. Using first-order time-independent perturbation theory, compute the correction to the ground state energy due to the perturbation. [9]

3

a) Combine the relativistic and spin--orbit corrections for the hydrogen atom to obtain the fine-structure energy correction. Show that the corrected energy levels depend only on the principal quantum number n and the total angular momentum quantum number j. What is the physical significance of the remaining degeneracy of states having the same values of n and j? [9]

b) Starting from the Lippmann-Schwinger equation, derive the first-Born approximation for the scattering amplitude $f(\theta, \phi)$. Show that, for a central potential $V(r)$, the scattering amplitude depends only on the scattering angle θ and can be written as

$$f(\theta) = -\frac{2m}{\hbar^2 q}\int_0^\infty r\,V(r)\sin(qr)\,dr$$

where $q = |\vec{k_f} - \vec{k_i}|$ is the momentum transfer. State the conditions for the validity of the Born approximation. [9]

a) Using the interaction picture, derive the coupled differential equations for the time evolution of the expansion coefficients in the time-dependent perturbation theory. Hence obtain the first-order transition amplitude from an initial state to a final state. State the conditions under which higher-order terms in the perturbation expansion may be neglected. [9]

b) The Yukawa potential describing the nucleon-nucleon interaction is given by,

$$V(r) = -r_0 V_0 \frac{e^{-r/r_0}}{r}$$

where r is the distance between the nucleons, and r_0 is the range related to the mass of the meson (m_π) by $r_0 = \frac{\hbar}{m_\pi c}$. Using the normalized trial wavefunction $\psi(r) = \sqrt{\frac{\beta^3}{\pi r_0^3}}\, e^{-\frac{\beta r}{r_0}}$, calculate the variational estimate of the ground-state energy of the proton--neutron system. Obtain the condition under which the Yukawa potential can support the existence of the deuteron (a bound state of the proton and the neutron)? [9]

5.

a) A two-level quantum system, initially in its ground state $|1\rangle$, is subjected to a weak time-dependent perturbation

$$V(t) = V_0 \sin(\omega t), \qquad 0 < t < T,$$

where V_0 is a constant. The matrix element between the two states is given by $\langle 2|V_0|1\rangle = V_{21}$. In the first-order time-dependent perturbation theory near resonance, the transition probability $P_{1\to 2}(T)$ may be approximated as

$$P_{1\to 2} \cong \frac{|V_{21}|^2}{\hbar^2}\left[\frac{\sin\left\{\frac{(\omega_{21}-\omega)T}{2}\right\}}{\omega_{21}-\omega}\right]^2, \quad \omega_{21} = \frac{(E_2-E_1)}{\hbar}, \quad \hbar = 1.05 \times 10^{-34}\ \text{Js}$$

Given that $V_{21} = 2.0 \times 10^{-23}$ J and the perturbation is applied for time $T = 1.5 \times 10^{-6}$ s, calculate the resonant angular frequency ω_{21} and the transition probability at exact resonance. Estimate $\Delta\omega = \omega - \omega_{21}$ for which the transition probability first becomes zero. [9]

b) Using partial wave analysis of scattering, derive the expression for scattering amplitude and the total scattering cross-section in terms of phase shifts δ_l. For s-wave scattering only ($l = 0$) with phase shift $\delta_0 = \pi/6$, calculate the total cross-section. [9]

6. Consider scattering of a particle of mass m from an attractive spherical square-well potential

$$V(r) = \begin{cases} V_0 & \text{for } r \le a \\ 0 & \text{for } r > a \end{cases}, \qquad V_0 < 0.$$

a) Using partial wave analysis for scattering states ($E > 0$), obtain the matching condition that determines the s-wave ($\ell = 0$) phase shift δ_0. shift δ_0. Hence show that, at high energies, $\delta_0(k) = maV_0/\hbar^2$, where $k = \sqrt{2mE}/\hbar$. [9]

b) Show that the above high energy result for $\delta_0(k)$ also follows from the Born approximation. [9]

[This question paper contains 2 printed pages.]

Sr. No. of Question Paper : **3083** **Your Roll No................**

Name of Course : B.Sc. (Prog.)-NEP: UGCF-2022 **L**

Semester : **II**

Name of the Paper: : Electricity and Magnetism

Unique Paper Code : **2222511201**

Duration: 2 Hours **Maximum Marks: 60**

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **any four** questions in total. **All** questions carry equal marks.
3. Question **No. 1** is compulsory.
4. Non-programmable calculator is allowed.

1. Attempt **any five** questions. $(3 \times 5 = 15)$

(a) The electric field in a given region of space is $\vec{E} = 5x\hat{\imath} + 6y\hat{\jmath} + 3z\hat{k}$. Find the volume charge density.

(b) Establish the relation between magnetic permeability and magnetic susceptibility.

(c) Write Faraday's laws of electromagnetic induction in integral and differential forms.

(d) Explain atomic polarizability and polarization of dielectric material.

(e) Find the constant 'a' so that the vector field $\vec{A} = (x + 3y)\hat{\imath} + (2y + 3z)\hat{\jmath} + (x + az)\hat{k}$ is solenoidal.

(f) Explain superposition theorem with a suitable diagram.

2. (a) Define electric field and electric flux. State the Gauss's law of electrostatic and derive it for a dielectric material. Discuss its physical significance. (10)

(b) In a parallel plate capacitor with air between them, each plate has area of $12 \times 10^{-3} m^2$ separated by 6 mm. Calculate the capacitance of the capacitor. If the capacitor is connected with 50 V supply, find out the charge on each plate. (5)

3. (a) State Biot-Savart's law. Using this law, obtain the expression for the magnetic field due to circular coil carrying a current at a point along its axis. (10)

(b) What are dia, para and ferromagnetic substances? Discuss their properties. (5)

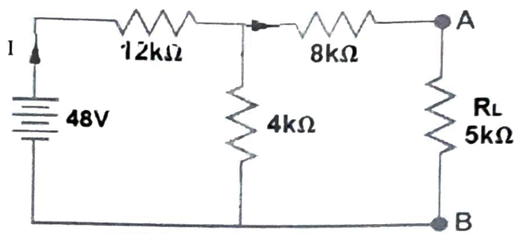
4. (a) Show that the Ampere's law is inconsistent under a time varying field. Explain the concept of displacement current? Write the modified Ampere's law in integral and differential forms. (10)

(b) Given a ferrite material with relative permeability $\mu_r = 50$, operating in a linear mode with magnetic field $B = 0.005\,T$, calculate the value of magnetic susceptibility χ_m and magnetization field $\vec{M}$. (5)

5. (a) Explain Thevenin's theorem and Norton's theorem with well labelled equivalent circuit diagrams. Show that maximum power is transferred by a source to the load resistance in a network when internal resistance and load resistance are equal.

(10)

(b) Find Thevenin voltage (V_{TH}) and Thevenin resistance (R_{TH}) of the given circuit diagram. (5)



[This question paper contains 2 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 2931 **L**

Unique Paper Code : 2222513601

Name of the Paper : Solid State Physics

Name of the Course : **B.Sc. Prog. – Physical Sciences with Physics_NEP: UGCF-2022**

Semester : VI (DSC Paper)

Duration : 2 Hours Maximum Marks : 60

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **four** questions in all.
3. Question No. **1** is compulsory.
4. Non-programmable scientific calculators are allowed.

Q. 1 Answer any *five* of following: (3x5 = 15)

(a) Determine the Miller indices of a plane having intercept of 8a, 4b and 2c on the a-, b- and c-axes respectively.

(b) What is Ewald's sphere? What does its radius represent?

(c) What is a phonon? Name the kinds of phonons present in vibrational spectrum of a diatomic lattice.

(d) State the conditions under which superconductivity can be destroyed.

(e) Distinguish between diamagnetism, paramagnetism and ferromagnetism.

(f) Explain why the dielectric constant of a ferroelectric material changes with frequency and temperature.

Q. 2 (a) Discuss the construction of a reciprocal lattice? How are the reciprocal lattice vectors related to those of a direct lattice? A monochromatic X-ray of wavelength 1.4 Å is incident on a crystal which is having interatomic spacing as 1.5Å. Calculate the maximum possible order of diffraction. (7)

(b) What are Brillouin Zones? Draw the first three Brillouin Zones for a two-dimensional square lattice. (8)

Q. 3 (a) Consider a one-dimensional diatomic linear chain consisting of two types of atoms with masses m_1 and m_2, arranged alternately and connected by identical springs of spring constant C. Derive the dispersion relation for lattice vibrations in the crystal. Sketch the dispersion curves (ω versus k) for acoustic and optical branches. (12)

(b) A dielectric material is placed in an external electric field of 2.0×10^5 V/m with polarization 3.0×10^{-3} C/m^2. Calculate the local electric field acting at an atom.

(3)

Q. 4 (a) What is the effective mass of an electron? Derive the expression for the effective mass of an electron and explain how it differs from the mass of a free electron. Draw the variation of (i) Energy, (ii) velocity of electron and (iii) effective mass of electron with respect to the wave vector k. (10)

(b) Copper has an FCC structure and the atomic radius is 1.245 Å. Determine the interplanar spacing for (111) planes. (5)

Q. 5 (a) Explain the Langevin theory of paramagnetism and derive the expression for the magnetic susceptibility of a paramagnetic substance. Explain its dependance on temperature. (12)

(b) Define polarizability and state the Claussius-Massoti relation. (3)