[This question paper contains 2 printed pages.]

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

**Sr. No. of Question Paper : 5786** **J**

Unique Paper Code : 2222011201

Name of the Paper : Mathematical Physics II

Name of the Course : **B.Sc. (II) Physics (UGCF) – DSC-4**

Semester : II

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. Attempt any **three** questions from the rest.
4. **All** questions carry equal marks.
5. Use of calculator not allowed.
6. Some useful formulae are given at the end.

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

(a) Represent the vector $\vec{A} = z\hat{i} - 2x\hat{j} + y\hat{k}$ in cylindrical coordinates.

(b) What is the period of following functions :

(i) tan(x) (ii) cos(nx), $n \in I$

(c) Evaluate (i) $\int [P_4(x)]^2\, dx$ (ii) $\int P_1(x) P_4(x)\, dx$

(d) Determine whether or not it is possible to solve the following differential equation using Frobenius method about x = 0:

$$x(1-x)\frac{d^2y}{dx^2} + (1-x)\frac{dy}{dx} - y = 0$$

(e) Evaluate the following integral using Gamma function

$$\int_0^\infty x^3\, e^{-2x}\, dx$$

2. Consider the following function :

$$f(x) \begin{array}{l} = 0 \text{ for } -5 < x < 0 \\ = 3 \text{ for } \;\; 0 < x < 5 \end{array}$$

(a) Plot the above function f(x).

(b) Find the Fourier Series expansion of the above function. (5,10)



P.T.O.

3. (a) Using Gamma and Beta functions prove :

$$\int \frac{x^2}{\sqrt{2-x}}dx = \frac{64\sqrt{z}}{15}$$

(b) Prove that for the Orthogonal Curvilinear Coordinates $(u_1, u_2, u_3)$

$$\vec{\nabla}F = \frac{\hat{e}_1}{h_1}\frac{\partial F}{\partial u_1} + \frac{\hat{e}_2}{h_2}\frac{\partial F}{\partial u_2} + \frac{\hat{e}_3}{h_3}\frac{\partial F}{\partial u_3}$$

where F is a scalar field, $h_i$ are scale factors and $\hat{e}_1$ represents unit vector in the increasing i direction. Further derive the expression of the gradient of F in spherical coordinate system. (5,10)

4. Consider the Differential Equation : (5,10)

$$2x^2y''(x) + 3xy'(x) - (x^2 + 1)y(x) = 0$$

(a) Identify and name the nature of all the real singularities (both finite and infinite) of above differential equation.

(b) Solve the above differential equation around $x = 0$ by Frobenius Method.

5. (a) Expand the function $f(x) = 7x^4 - 3x + 1$ in terms of Legendre Polynomials in the interval $[-1, 1]$.

(b) Starting from Generating function of Legendre Polynomails derive the following recurrence relation of Legendre Polynomials

$$P_n(x) = P'_{n+1}(x) - 2xP'_n(x) + P'_{n-1}(x)$$ (10,5)

**Some useful formulae :**

Legendre Polynomails :

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

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

Generating Function of Legendre Polynomails :

$$g(x,t) = \frac{1}{\sqrt{1-2xt+t^2}} = \sum_{n=0}^{\infty} P_n(x)t^n$$



(2000)

[This question paper contains 4 printed pages.]

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

**J**

**Sr. No. of Question Paper : 5806**

**Unique Paper Code : 2222011202**

**Name of the Paper : Electricity and Magnetism**

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

**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 **five** questions in all, including Question No. **1** which is compulsory.
3. **All** questions carry equal marks.

1. Answer **any 6** of the following : (6×3=18)

(a) Find $V_{ab}$ in an electric field $\vec{E} = 2\hat{i} + 3\hat{j} + 4\hat{k}$ N/C where $\vec{r}_a = \hat{i} - 2\hat{j} + \hat{k}$ m and $\vec{r}_b = 2\hat{i} + \hat{j} - 2\hat{k}$ m.

(b) State the Second uniqueness theorem.

(c) What is the work required to bring a charge q from infinity to a distance d above a grounded conducting plane?

(d) At the boundary of two dielectric materials, material 1 has $\epsilon_1 = 2\epsilon_0$, and material 2 has $\epsilon_2 = 4\epsilon_0$. If $e_1^{\perp} = 6$ V/m, what is $\epsilon_2^{\perp}$, assuming no free surface charge?

(e) A solenoid of length 0.5 m and 1000 turns per meter carries a current of 2 A. Find the magnetic field inside the solenoid.

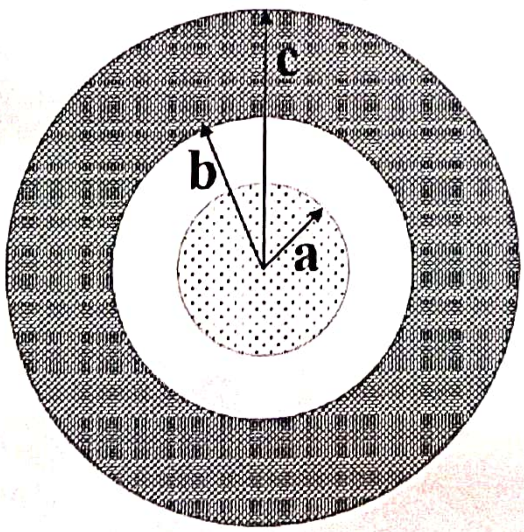
(f) A material placed in a field $H = 800$ A/m shows a $M = -0.08$ A/m. Find its magnetic susceptibility $\chi_m$. What type of material is it?

(g) A cylindrical conductor of uniform cross section, has a voltage drop of 2.0 V along its 100 m length and a current density of $5.0 \times 10^5$ A/m². What is the conductivity of the material in the conductor?

2. (a) A half-infinite line has linear charge density $\lambda$. Find the electric field at a point that is "even" with the end, a distance $l$ from it, as shown in Figure. (8)


(b) Prove that electrostatic field is negative of gradient of electrostatic potential. (2)

(c) State Ampere's law. The coaxial line shown in Figure below carries the same current i up the inside conductor of radius a and down the outer conductor of inner radius b & outer radius c.




Find the magnetic field at all distances r from the center of the conductor. (8)

3. (a) Let a charge q be distributed over a sphere of radius R with a constant volume charge density $\rho$, and thus for $r > R$ the charge density is zero. Applying the Laplace's or Poisson equations, find the electrostatic potential inside $r < R$ and outside $r > R$ the sphere. (8)

(b) For the above system, find the electrostatic field on the surface of the sphere. (2)

(c) What do you understand by magnetization and magnetic polarization of the material? Derive expressions for differential and integral form of Ampere's law in the presence of magnetized materials. (8)

4. (a) A point charge q is situated a distance a from the centre of a grounded conducting sphere of radius R. Applying the method of images, find the electrostatic potential at any point outside the sphere. (8)

(b) The electric field in a region is given by $\vec{E} = x\hat{i}$. Find the total flux passing through a cube bounded by the surfaces, $x = 1$, $x = 2$, $y = 0$, $y = 1$, $z = 0$ and $z = 1$. (2)

(c) Write down the four fundamental Maxwell equations in the differential form along with their explanations. Also, comment on their significance. (8)

5. (a) A sphere of radius R carries a polarization $\vec{P}(\vec{r}) = k\vec{r}$, where k is a constant and $\vec{r}$ is the vector from the center. (a) Calculate the bound charges $\sigma_b$ and $\rho_b$. (b) Find the field inside and outside the sphere. (8)

(b) Show that the potential is constant inside an enclosure completely surrounded by conducting material, provided there is no charge within the enclosure. (2)

(c) A tightly wound cylindrical coil of wire, of radius a and n turns per unit length, is usually called a solenoid. Use Biot Savart law to find the magnetic field at the point on its axis if the wire carries a current I. Consider the turns to be essentially circular and solenoid to be infinite in both directions. (8)

P.T.O.

6. (a) Find the magnetic field $\vec{B}$ and hence the vector potential $\vec{A}$ at a distance r from a long straight wire carrying a current I. (8)

(b) A point charge q is located d distance above an infinite grounded conducting plane. Find the direction of the electric field at the point P directly above the charge, at a height 2d from the plane. (2)

(c) State the Gauss Law in integral and differential form. Suppose the electric field in some region is found to be $\vec{E} = kr^3\hat{r}$, in spherical coordinates (k is some constant). (a) Find the charge density $\rho$. (b) Find the total charge contained in a sphere of radius R, centered at the origin. (8)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 5826

J

Unique Paper Code : 2222011203

Name of the Paper : Electrical Circuits Analysis

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

Semester : II

Duration : 2 Hours

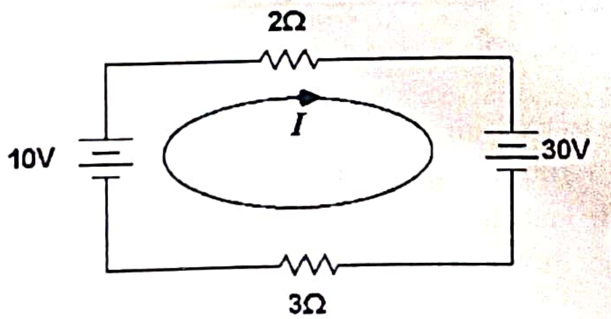
Maximum Marks : 60

**Instructions for Candidates**

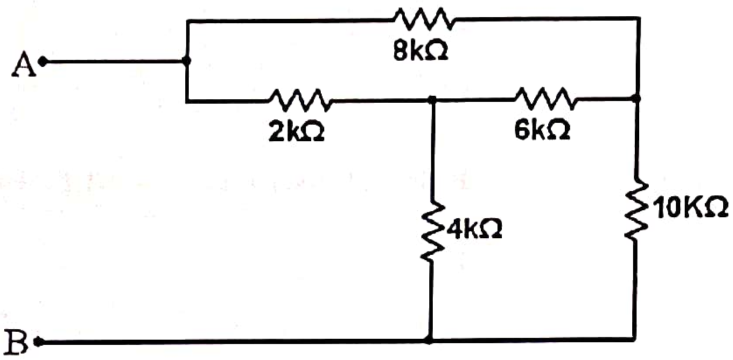
1. Write your Roll No. on the top immediately on receipt of this question paper.
2. **All** questions carry equal marks.
3. Ques. No. **1** is compulsory and attempt any **three** from the remaining **four** questions.
4. Use of non-programmable scientific calculator is allowed.

1. Attempt any **five** of the following : (5×3=15)

(a) For the given circuit determine the power dissipated in the resistors :



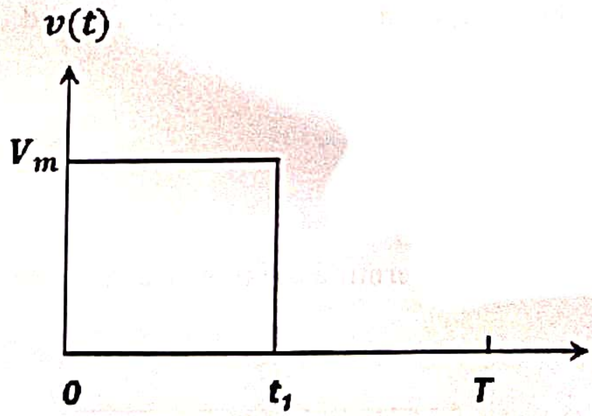
(b) Find the equivalent resistance of the following circuit using Star-Delta transformations:




(c) Define inductive reactance. Write it's S.I. units. Plot a graph showing variation of resistance and inductive reactance with change in the frequency of the ac source.

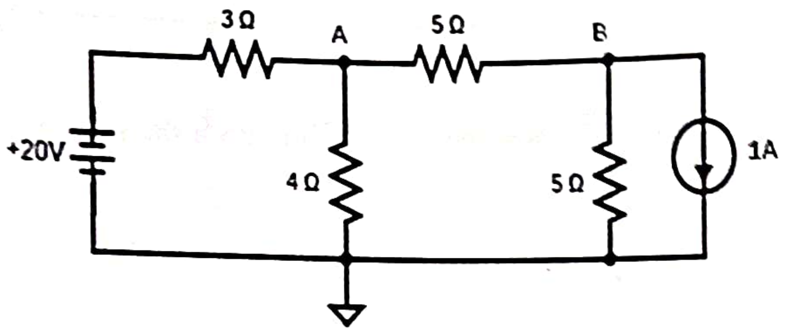
(d) Prove that an ideal capacitor does not dissipate power in an ac circuit.

(e) Find the form factor for the periodic wave shown below with time period T :




(f) A series RC circuit with R = 5 kΩ and C = 20 μF has a constant voltage source of 100 V applied at t = 0. Obtain the value of voltage across the capacitor and the resistor for t > 0 if there is no initial charge on the capacitor.

2. (a) Calculate the direction and magnitude of the current through the 5 Ω resistor between points A and B in the given circuit by Nodal analysis method. (7)




(b) A coil with a self-inductance of 2.4 H and resistance 12 Ω is suddenly switched across a 120 V DC supply of negligible internal resistance. Determine the time constant of the coil, the instantaneous value of the current after 0.1 second, the final steady value of the current and the time taken for the current to reach 5 A. (8)

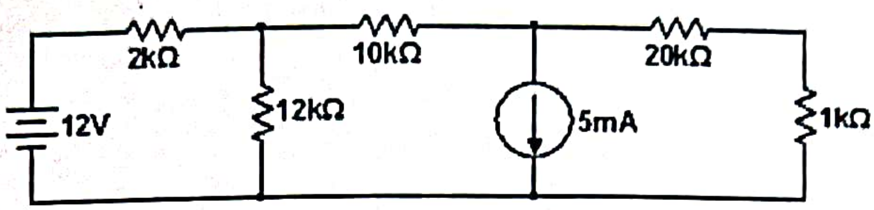
3. (a) In a parallel LCR circuit, the inductance of 0.1 H having a Quality factor of 5 is in parallel with a capacitor. Determine the value of capacitance and coil resistance at resonant frequency of 500 Hz. (7)

(b) In a series RL circuit containing pure resistance and pure inductance, the current and the voltage are expressed as :

$$i(t) = 5\sin(314t + 2\pi/3) \text{ and } v(t) = 15 \sin(314t + 5\pi/6)$$

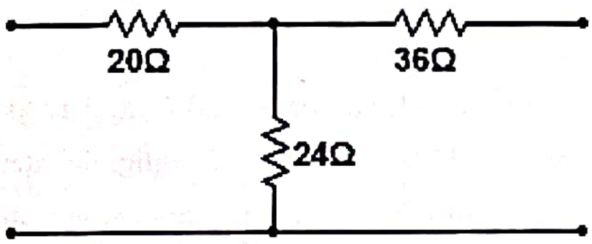
Determine the values of impedance, resistance, inductance and average power drawn by the circuit. (8)

4. (a) Find the Norton equivalent circuit for the given circuit and calculate the load voltage across 1 kΩ resistance. (7)

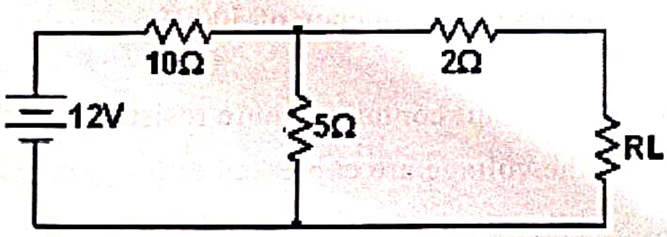



(b) Explain Millman's and Tellegen's theorem for the ac circuits. (8)

5. (a) Find the Y-parameters for the following T-network : (7)




(b) According to Maximum Power Transfer theorem, what should be the value of load resistance $R_L$ to obtain maximum power from the 12 V battery shown in the following circuit? What is the value of this power? (8)



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

**Sr. No. of Question Paper : 5537** **J**

Unique Paper Code : 2222012401

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**

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

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

(a) In the Compton scattering experiment, radiation scattered at each angle generally consists of two distinct wavelengths. Briefly discuss the origins of these wavelengths?

(b) If the uncertainty in a photon's wavelength is one part in a million, determine the uncertainty in its position if the photon's wavelength is 500 nm.

(c) Evaluate the commutator (i) $[\hat{x}, \hat{p}_x]$, (ii) $[\hat{x}, \hat{p}_y]$, and (iii) $[\hat{x}, \hat{p}_x{}^2]$

(d) A particle of kinetic energy 8.5 eV is incident on a potential step of height 4.5 eV. Calculate the reflection coefficient.

(e) Explain the terms (i) induced absorption (ii) spontaneous emission, and (ii) stimulated emission.

(f) State Moseley's law and discuss its significance.

(g) Calculate the radius of $^{235}U$. What would be the mass of 1 $mm^3$ of nuclear matter? Given: $1u = 1.66 \times 10^{17}$ kg/$m^3$.

2. (a) Draw the experimental setup for studying photoelectric effect. What are the main features of the observations? Discuss how classical wave theory fails and how Einstein's quantum theory of light successfully explains the phenomenon. (10)

(b) Determine the wavelength of the incident photon in Compton scattering if the maximum energy imparted to the electron is 50 keV? (8)

3. (a) Obtain the time-dependent Schrodinger equation in one dimension and discuss the statistical interpretation of wave function. (10)

(b) A particle is described by the wave function

$$\psi(x) = 0 \qquad x < 0$$
$$= \sqrt{2}e^{-x/L} \qquad x \geq 0$$

where $L$=2 nm. Calculate the probability of finding the particle in the region $x \geq 1$ nm. (8)

4. (a) Sketch the first three wave functions and corresponding probability densities for a particle confined in a one-dimensional box of length $L$. What are the energy eigenvalues corresponding to these wave functions? Discuss the differences between the classical and quantum mechanical descriptions of such a particle. (10)

(b) A particle of kinetic energy 2.5 eV is incident on a potential step of height 4.0 eV. Calculate the penetration depth of the particle into the classically forbidden region. (8)

5. (a) On what condition does the quantum physics yield the same results as classical physics according to Bohr correspondence principle. Discuss the validity of the principle on the basis of classical and quantum pictures of the Bohr model for hydrogen atom. (10)

(b) Calculate the ratio of Einstein's A and B coefficients, and the ratio of probabilities of spontaneous and stimulated emission for a system in thermal equilibrium at room temperature ($T$ = 300 K) for transition that occur in the visible region ($h\nu$ = 2 eV). Given: $k_B = 1.38 \times 10^{-23}$ J/K. (8)

6 (a) Discuss the various contributions to the binding energy of a nucleus of atomic number $Z$ and mass number $A$, and obtain the Weizsaecker semi-empirical mass formula. (10)

(b) Calculate the binding energy of $\alpha$-particle and express it in MeV and joules. Given: $m_p$ = 1.00758 amu, $m_n$ = 1.00897 amu and $m_{He}$ = 4.0028 amu. (4)

(c) Calculate the distance in free space over which the intensity of a 2 eV neutron beam be reduced by a factor of one-half? Given: Mass of neutron = $1.67 \times 10^{-27}$ kg, Decay constant for a free neutron = $1.14 \times 10^{-3}$ s$^{-1}$. (4)

(5)

[This question paper contains 4 printed pages.]

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

J

Sr. No. of Question Paper : 5597

Unique Paper Code : 2222012402

Name of the Paper : Solid State Physics

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

Semester : IV

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 in total. Question No. 1 is compulsory.
3. All questions carry equal marks.
4. Use of non-programmable scientific calculators is permitted.

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

(a) Draw (221) and (110) planes in a cubic crystal. Also, show [111] direction in a cubic unit cell.

(b) An X-ray beam of wavelength 1.54 Å is diffracted from the (100) planes of a solid with a cubic lattice of lattice constant 3.05 Å. Find the Bragg's angle at which the first-order diffraction occurs.

(c) Hall coefficient of a specimen of a strong n-type silicon is $3.66\times10^{-4}$ $m^3C^{-1}$. The resistivity of the specimen is $8.93 \times 10^{-3}$ $m$. Find the mobility and density of the charge carriers.

(d) Calculate Einstein's frequency for copper (Cu) metal that has an Einstein's température $\theta_E$=230° $K$.

. (e) Discuss various sources of polarizability in a dielectric.

(f) Explain the B-H curve of a ferromagnetic material.

(g) Explain Meissner's effect in the superconductor.

2. (a) Explain Ewald's construction and derive Bragg's law $2\vec{K}.\vec{G} + G^2 = 0$ for X-ray diffraction in a reciprocal lattice, where the symbols have their usual meanings. (12)

(b) Calculate the packing fraction for face-centered cubic (FCC) crystal. (6)

3. (a) For the Kroning-Penney model of electron behaviour in solids, derive the relation $P\frac{sin(\alpha a)}{\alpha a} + cos(\alpha a) = cos(ka)$ where $P$ is proportional to the barrier strength (height and width) between adjacent lattice atoms, $a$ is the lattice constant, $k$ is the wavenumber, and $\alpha = \sqrt{\frac{2mE}{\hbar^2}}$ .. Sketch the general behaviour of this relation as a function of $\alpha a$ clearly indicating the value of ?$\alpha a$ = 0

and the limiting case $\alpha a \rightarrow \infty$. By considering the above condition clearly indicate on your sketch the ranges of $\alpha a$ that correspond to allowed energy bands. (12)

(b) Show that in the limit of $P \rightarrow \infty$ the relation leads to discrete allowed energy given by $E_n = \frac{n^2\hbar^2\pi^2}{2ma^2}$. (6)

4. (a) Derive an expression for the lattice specific heat of a solid based on the Debye model and demonstrate that it varies as $T^3$ at low temperatures. (12)

(b) Calculate the number of optical and acoustical phonon branches for a NaCl crystal, containing two atoms per primitive unit cell. (6)

5. (a) Describe the Langevin theory of para-magnetism and explain Weiss modification in this theory assuming the existence of an internal molecular field. (12)

(b) A paramagnetic salt contains $10^{28}$ ions/m$^3$, each with magnetic moment 9.27 x $10^{-24}$ A-m$^2$. Calculate paramagnetic susceptibility produced in a uniform magnetic field H = $10^6$ A/m at 300° K. (6)

6. (a) Define the term "Local electric field" at an atom. Deduce Lorentz relation for $E_{Loc}$ inside a dielectric. (12)

(b) Draw a typical P-E hysteresis curve for a ferroelectric material and give one example. (6)

Charge of an electron = $1.602 \times 10^{-19}$ C

Planck's Constant = $6.62 \times 10^{-34}$ J-s

Boltzmann Constant = $1.38 \times 10^{-23}$ J/K

$\mu_0 = 4\pi \times 10^{-7}$ Kg m $s^{-2}$ $A^{-2}$

6

[This question paper contains 2 printed pages.]

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

**Sr. No. of Question Paper : 5676** **J**

Unique Paper Code : 2222012403

Name of the Paper : Analog Electronics

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

Semester : IV

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.

1. Attempt **any five** parts. (3×5=15)

   (a) Explain the working principle of a photodiode. Also Draw I-V characteristics.

   (b) Draw the I-V characteristics of a Zener diode and explain its use as a voltage regulator.

   (c) A diode is used in a half-wave rectifier. If the peak input voltage is 12 V, calculate the average output voltage (assume ideal diode).

   (d) Why is voltage divider bias preferred over fixed bias in amplifier circuits?

   (e) A transistor has $\beta = 120$ and base current = 30 μA. Find the collector current.

   (f) Define the slew rate of an op-amp. If an op-amp has a slew rate of 0.5 V/μs, how much time will it take to swing from 0 to 3 V?

   (g) State any three differences between an ideal op-amp and a practical op-amp.

2. (10+5)

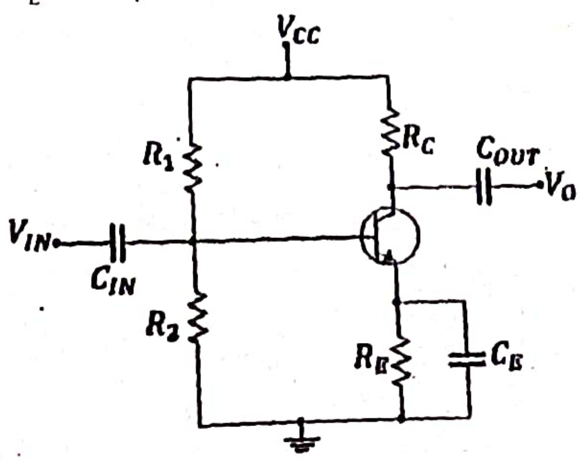
   (a) Explain the construction and working of a full-wave bridge rectifier. Derive expressions for average output voltage and ripple factor.

(b) A Zener diode voltage regulator circuit is connected with 15 V input and a 9 V Zener. Calculate the current through Zener if the load draws 10 mA and the series resistance is 100 Ω. Also draw the proper circuit diagram of a Zener diode voltage regulator.

3. (10+5)

(a) Explain the input and output I-V characteristics of a transistor in CE configuration. Describe the active, cut-off, and saturation regions.

(b) In the voltage divider bias circuit, $R_1$ = 33 kΩ, $R_2$ = 10 kΩ, $R_C$ = 2 kΩ, $R_E$ = 1 kΩ, $V_{CC}$ = 15 V, and β = 100. Calculate the base voltage $V_B$, emitter voltage $V_E$, and collector current Ic. Assume $V_{BE}$ = 0.7 V, $C_{in}$ = $C_{out}$ = 10 μA and $C_E$ = 50 μA.




4. (10+5)

(a) Explain the construction and working of RC phase shift oscillator. Derive the condition for sustained oscillation and expression for its frequency.

(b) A Hartley oscillator operates at a frequency of 1 MHz. The capacitor in the tank circuit is 200 pF, and the mutual inductance is 0.002 mH. If both the inductors in the circuit are of same value, calculate the value of L.

5. (10+5)

(a) Draw the circuit diagram of a basic integrator using an operational amplifier and derive the expression for its output voltage. Draw the circuit of a practical integrator and explain the need for modifications over the basic integrator.

(b) A zero-crossing detector is used to process a sinusoidal input signal with a peak-to-peak voltage of 5 V and a frequency of 60 Hz. What will be the period of the output waveform generated by the detector. If the output of the op-amp swings from –5 V to +5 V and the slew rate of the op-amp is 0.5 V/μs, estimate the minimum time the op-amp takes to complete this transition.

(2)

[This question paper contains 4 printed pages.]

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

J

Sr. No. of Question Paper : 5758

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

**Instructions for Candidates**

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

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

(a) Show that the three cube roots of unity form an abelian group under complex multiplication. (3)

(b) Do vectors (2,1) and (3,0) form basis for $\mathbb{R}^2$? (3)

(c) Let W, a subspace of $\mathbb{R}^3$, be: $W = \{(a, b, c): a + 2b + c = 0\}$. What are its dimensions and basis. (3)

(d) Is the following mapping T linear? Give reasons.
$T: \mathbb{R}^2 \rightarrow \mathbb{R}^2$ defined by $T(x, y) = (x + y, x)$ (3)



*P.T.O.*

(e) Two matrices are given as $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$ and $B = \begin{bmatrix} 1 & 4 \\ 3 & 2 \end{bmatrix}$,
Find the direct sum of A and B. (3)

(f) Consider the matrix:

$$A = \begin{bmatrix} 1 & 0 \\ -3 & 2 \end{bmatrix}$$

Find elementary matrices $E_1$ and $E_2$ such that $E_2E_1A = I$. (3)

(g) Transformation $T: \mathbb{R}^2 \to \mathbb{R}^2$ is reflection about the y-axis. Give the matrix representation for the transformation using standard basis for $\mathbb{R}^2$. (3)

2. (a) Let $\mathbb{R}^3$ have the Euclidean inner product and W be the space spanned by the vectors:

$w_1 = (0,1,0)$ and $w_2 = (1,0,-2)$. Resolve the vector $u = (1,1,1)$ into components perpendicular to W and in W. (10)

(b) Find basis and dimension of the following subspace W of $\mathbb{R}^4$:
$W = \{(a,b,c,d): a+b=0, c=2d\}$. (8)

3. (a) For a linear transformation $T: \mathbb{R}^3 \to \mathbb{R}^2$ defined by $T(x, y, z) = (x, y+z)$, find the basis and dimension of its range space and its kernel. (10)

(b) If T be a linear operator on the real vector space $\mathbb{R}^2$ defined by :

$$T(x, y) = (x+3y , x-y)$$

Find $T^2$. (8)

**4.** (a) Let T be a linear transformation on $\mathbb{R}^3$ defined by:

$$T(1, 0, 0) = (2, 1, -1)$$
$$T(0, 1, 0) = (1, 3, 5)$$
$$T(0, 0, 1) = (-1, 2, -1)$$

Find the matrix representing T relative to the basis $S = \{(1, 1, 1), (1, 1, 0), (1, 2, 3)\}$. (10)

(b) Evaluate det(A) by reducing A in an upper triangular. (8)

$$A = \begin{bmatrix} 0 & 1 & 5 \\ 3 & -6 & 9 \\ 2 & 6 & 1 \end{bmatrix}$$

5. (a) C is a $3 \times 3$ matrix such that one of its eigenvalues is 3 and Tr(C) = 11, Det(C) = 36. Find the other eigenvalues. (4)

(b) If $\begin{bmatrix} 2 \\ 1 \\ 2 \end{bmatrix}, \begin{bmatrix} -1 \\ 2 \\ 0 \end{bmatrix}, \begin{bmatrix} 0 \\ 2 \\ -1 \end{bmatrix}$ are the eigenvectors of matrix $M = \begin{bmatrix} 3 & 2 & 4 \\ 2 & 0 & 2 \\ 4 & 2 & 3 \end{bmatrix}$, find the corresponding eigenvalues and determine whether M can be diagonalised or not. (7)

(c) It is given that $A^T = -A$ and $(I + A)$ is invertible. Show that $(I - A)(I + A)^{-1}$ is orthogonal. (7)

6. (a) State and verify Cayley-Hamilton theorem for the matrix

$$K = \begin{bmatrix} 4 & 2 \\ 1 & 3 \end{bmatrix}$$

Hence, find $K^{-1}$. (8)

(b) Determine $\cos(Q)$ for $Q = \begin{bmatrix} 3 & 1 \\ -3 & 7 \end{bmatrix}$. (10)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 5517 J

Unique Paper Code : 2222013601

Name of the Paper : Statistical Mechanics

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

Semester : VI

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. Use of non-programmable scientific calculators is allowed.

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

(a) Find the total number of microstates and macrostates available to an isolated system of 3 distinguishable particles. Assume that each particle can exist in three energy states of energy $-\varepsilon$ , 0 and $\varepsilon$.

(b) A three state system has one state at energy $\varepsilon_0$ and two other states at energy $\varepsilon_1 = \varepsilon_0 + \Delta$. Show that the probability of occupying the energy state $\varepsilon 0$ is equal to the probability of occupying the state $\varepsilon_1$ at the temperature

$$T = \frac{\Delta}{k_B \ln 2}.$$

(c) The Fermi energy of a metal is 8.5 eV. At what energy is the probability of occupation by a conduction electron 98% at temperature 300K?

(d) The conduction electron density in silver $5.8 \times 10^{28}/m^3$. Show that the gas of conduction electrons is strongly degenerate at room temperature.

(e) According to the Big-Bang models of expanding universe, the Cosmic Microwave Background Radiation (CMBR) was formed when the temperature of the universe was about 3000K. The temperature of the CMBR now is 2.7K. The volume of the universe has increased by how many times since the formation of CMBR? Assume that the CMBR is a perfect black body radiation, and the expansion is adiabatic.

(f) Five bosons are to be arranged in two energy levels with three and four states respectively. Find the number of microstates for the macrostate (3,2), i.e. the state with three and two bosons in the two levels respectively.

(g) At what temperature does the Rubidium –87 gas with peak density $2.1 \times 10^{14}$ atoms / $cm^3$ begin to show signs of Bose-Einstein condensation? ($m_{RB} = 1.443*10^{-25}$ Kg)

2. (a) Consider an isolated system of N distinguishable particles. Each particle can occupy only one of two energy levels of energy $\varepsilon_1 = -\mu B$ and $\varepsilon_2 = +\mu B$. Particles are distributed in such a way that N - n particles resides in energy level 82 and n particles are present in level of energy $\varepsilon_1$. ( Assume N is very large).

(i) Obtain an expression for the number of microstates accessible to this system, $\Omega$ (U, N, B).

(ii) Prove that the entropy of the system is:

$$S(U,N,B) = Nk_B \left[\ln 2 - \frac{1}{2}\left(1 + \frac{U}{N\mu B}\right)\ln\left(1 + \frac{U}{N\mu B}\right) - \frac{1}{2}\left(1 - \frac{U}{N\mu B}\right) ln\left(1 - \frac{U}{N\mu B}\right)\right].$$

Here U is the total internal energy of the system, B is the magnetic field and $\mu$ is the magnetic moment.

(b) Explain the emergence of negative temperature in a system of magnetic dipoles placed in an external magnetic field. (12+6)

3. (a) Using the partition function of classical ideal monoatomic gas consisting of N indistinguishable particles of mass m at fixed temperature T in volume V:

$$Z(N, V, T) = (V^N / N!) [2 \pi m k_B T / h^2]^{3N/2}$$

(i) Prove that the entropy of an ideal gas can be written as :

$$S = CV \ln T + Nk_B \ln (V/N) + S_0$$

where CV is the specific heat of an ideal monoatomic gas and $S_0$ is a constant in the classical theory (Assume $N >> 1$).

(ii) Check whether the above expression of entropy is extensive, or not.

(iii) Show that the result obtained in part (i) is not in accordance with the Third law of thermodynamics. Explain.

(b) A partition divides a box of volume V into two chambers I and II, of volume V/4 and 3 V /4 respectively. Assume that chamber 1 contains N particles of an ideal gas and chamber II is completely empty. Using the Sackur-Tetrode relation, calculate the change in entropy after the partition is removed and the gas is allowed to expand to reach equilibrium (assume that the temperature remains constant throughout the process). (12+6)

4. (a) Show that the number of vibration modes of electromagnetic radiation per unit volume, per unit frequency interval in a cavity is $\frac{8\pi\nu^2}{C^3}$. Use equipartition theorem to derive Rayleigh Jeans formula for black body radiation. Discuss how does this lead to the ultra-violet catastrophe.

(b) The Sun's radiation intensity at Earth's surface is about 1000 $W/m^2$. If the surrounding air has temperature $T_0$, estimate the temperature of a black surface placed normally under the Sun at thermal equilibrium. Assume that the surface is a perfect 'black body', and that it loses energy only by radiation from the side receiving the radiation. (14+4)

5. (a) Values of specific heat of conduction electrons in metals using the mass of free electron in the formula do not match with observed values. This happens because the effective mass of an electron in metals, which arises from its interactions with the lattice and other electrons, is different from the mass of an isolated electron. The observed value of the specific heat of conduction electrons in Cu is found to be 30% more than the value predicted using mass of the free electron. Estimate the effective mass of an electron in Cu.

(b) Sirius B is the nearest white dwarf to the solar system. Its mass is $2.03 \times 10^{30}$kg, radius is 5640 km, and the average internal temperature is about $10^7$K.

(i) Assuming that Sirius B is made up completely of ionized He, find the Fermi momentum of electrons in it.

(ii) Show that the electrons in it are relativistic, and the electron gas is almost completely degenerate.

(iii) Find the pressure of the electron gas at zero point.

(Use $m_p \cong m_n \cong 1.7 \times 10^{-27}$kg ) (4+14)

6. (a) Obtain Planck's black body radiation formula following Bose's derivation. Show that the pressure of a photon gas in a cavity $P = \frac{u}{3}$, where u is the radiation energy density.

(b) Find the number of different ways n bosons can be arranged in g states. (14+4)

**Useful Physical Constants**

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

$\sigma = 5.67 \times 10^{-8}$Wm$^{-2}$K$^{-4}$

[This question paper contains 4 printed pages.]

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

**Sr. No. of Question Paper : 5577** **J**

Unique Paper Code : 2222013603

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. Use of statistical tables are allowed.

1. Attempt **any five** of the following: (3×5=15)

(a) What do we mean by Cumulative Distribution Function (CDF)? Mention a few properties of a CDF. How can we get CDF from a given probability density function?

(b) A particular study showed that 12 % of men will likely develop prostate cancer at some point in their lives. A man with prostate cancer has a 95% chance of a positive test result from a medical screening exam. A man without prostate cancer has a 6% chance of getting a false positive test result. What is the probability that a man has cancer given that he has a positive test result?

(c) State central limit theorem. Give an example of one distribution for which we cannot use this theorem.

(d) Suppose we have a 6-sided white dice and a 4-sided black dice. Each dice is fair. If X and Y are the outcomes of white and black dice respectively. Assuming each dice is fair, find the covariance of X and Y.

(e) What do you mean by joint probability distribution? Consider X and Y be two jointly continuous random variables with joint probability density function given by

$$f_{XY}(x,y) = x + Cy^2 \qquad 0 \le x \le 1, 0 \le y \le 1$$
$$= 0 \qquad \text{otherwise}$$

Find $P[0 \le x \le 1/2,\ 0 \le y \le 1/2]$.

(f) What does conjugate priors mean? If you are using bayesian linear regression to estimate the parameters and the distribution of the likelihood is binomial, what should be the conjugate prior (write expression also) so that the posterior is normalized?

2. (a) State and derive Bayes theorem. Discuss at least two advantages of using Bayes theorem for the parameter estimation. What does the denominator in Bayes theorem represent? (7)

(b) A coin has an unknown bias θ, representing the probability of landing heads. If our prior belief is that θ Beta(2, 2) and we toss the coin 5 times and observe 4 heads and 1 tail.

(a) Determine the posterior distribution of θ given this data.

(b) Compute the posterior mean.

(c) Compute the MAP estimate of θ. (8)

3. (a) Derive posterior mean for Gaussian likelihood with known variance and Gaussian prior. (7)

(b) Normally distributed IQ scores have a mean of 100 and standard deviation of 15. Use the standard z-table to answer the following questions.

(i) What is the probability of randomly selecting someone with an IQ score less than 80?

(ii) What is the probability of randomly selecting someone having IQ between 95 and 100?

(iii) What IQ score corresponds to the 90th percentile?

(iv) The middle 30% of the IQs fall between what two values? (8)

4. (a) What do you mean by point estimation? State the properties that a good point estimate should have. Write two different methods that can be used for the point estimation. (7)

(b) Suppose we have a factory which makes diodes. The diodes have a lifetime which is modelled by an exponential distribution with parameter $\lambda$. Suppose we check 5 diodes and find that their lifetimes are 2,3,1,3 and 4 years. What is the maximum likelihood estimate for $\lambda$.

(Exponential distribution: $f(x|\lambda) = \lambda e^{-\lambda x}$). (8)

5. (a) What do you understand by the term "Bayes Factor"? At the ITO intersection, vehicles pass through at an average rate of 600 per hour.

(i) Find the probability that none passes in a given minute.

(ii) What is the expected number passing in 5 minutes? (7)

(b) Consider a crime scene. The police find that there are two different types of blood on the crime scene left by the criminals- one is type O and other type AB. We know that in the population, type O is found in 60% of the population and type AB in 1% of the population. The police arrest two people R and S. R has a blood group O. Does the data, that is two types O and AB are found on the scene, support the hypothesis that R is one of the criminals? (8)

6. (a) What do we mean by Bayesian linear regression? Discuss (in brief) the significance of using conjugate priors while estimating the posterior density function of the parameter. (7)

(b) In a bayesian linear regression, the prior ($\theta$) follows the normal distribution with mean 0 and standard deviation 1. If the data is as follows: (Assume variance =1)

| | | | | |
|---|---|---|---|---|
| x | 2 | 4 | 6 | 8 |
| y | 4 | 16 | 36 | 64 |

Compute the posterior distribution of the $\theta$. (8)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 5649 J

Unique Paper Code : 2223010021

Name of the Paper : Advanced Mathematical Physics – II

Name of the Course : B. Sc. (H) Physics (NEP UGCF)

Semester : VI

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.
4. Question number 1 is compulsory.

1. Attempt *any six* questions (6 × 3 = 18)

(a) If $A_i$ is a vector, show that $F_{ij} = \frac{\partial A_i}{\partial x_j}$ is a Cartesian tensor of rank two.

(b) If $A_i$ and $B_i$ are two Cartesian tensors, prove that $A_i B_i$ is a scalar.

(c) Using Cartesian tensors, show that the curl of gradient of a scalar is zero.

(d) Show that $\frac{\partial A_p}{\partial x^q}$ is not a tensor under a general coordinate transformation, even though $A_p$ is a covariant tensor of rank one.

(e) Let $A(i, j, k)$ be a set of $N^3$ functions of coordinates in $N$-dimensions. If $A_{ijk}B^{jk} = C_i$ where $B^{jk}$ is an arbitrary contravariant tensor of rank-2 and $C_i$ is a covariant tensor of rank-1. What can you conclude about $A_{ijk}$ ?

(f) What is polarizability tensor?

(g) Prove that $\left\{ {s \atop p\ q} \right\} = \left\{ {s \atop q\ p} \right\}$ where $\left\{ {s \atop p\ q} \right\}$ is the Christoffel Symbol of the second kind.

2. (a) Show that $\delta_{ij}$ is an isotropic Cartesian tensor of rank two and $\varepsilon_{ijk}$ is an isotropic Cartesian tensor of rank three. (8)

(b) Let $X_{ijkl}$ be a Cartesian tensor of rank four such that $X_{ijkl} = X_{jikl}$ and $X_{ijkl} = -X_{ijlk}$ i.e. it is symmetric with respect to the first two indices and anti-symmetric with respect to the last two indices. How many independent components are there in $X_{ijkl}$ in three dimensions? (6)

(c) Show that any rank two Cartesian tensor can be expressed as a sum of symmetric and antisymmetric tensors. (4)

3. (a) A rigid body consists of three point masses of 1 kg, 2 kg and 1 kg, connected by massless rods. The coordinates of the three masses are (1,1,0) , (2, -1,2) and (0, -1, -1) in meters, respectively. Determine the inertia tensor of the system. If the body is rotating with an angular velocity $\boldsymbol{\omega} = 3\hat{\imath} - 2\hat{\jmath} + 4\hat{k}$, what is the angular momentum of the body? (12)

(b) Stress tensor $\sigma_{ij}$ and strain tensor $e_{kl}$ are related as $\sigma_{ij} = C_{ijkl}e_{kl}$ where, elastic tensor $C_{ijkl}$ is symmetric in $i, j$ and $k, l$ and its most general isotropic form is given by $C_{ijkl} = \lambda\delta_{ij}\delta_{kl} + \mu\delta_{ik}\delta_{jl} + \nu\,\delta_{il}\delta_{jk}$ where λ, μ and ν are constants. Prove that $C_{ijkl} = \lambda\delta_{ij}\delta_{kl} + \mu(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk})$ (6)

4. (a) If $ds^2 = 5(dx^1)^2 + 4(dx^2)^2 - 3(dx^3)^2 + 4\,dx^1dx^2 - 6\,dx^2dx^3$ , find the following matrices:

(i) $[g_{ij}]$

(ii) $[g^{ij}]$

(iii) the product of $[g_{ij}]$ and $[g^{ij}]$ (4, 4, 2)

(b) If $A_i$ are the component of a covariant vector, show that $\frac{\partial A_i}{\partial x^j} - \frac{\partial A_j}{\partial x^i}$ are components of a skew-symmetric covariant tensor of rank 2 (8)

5. (a) Write the Lorentz transformation for coordinates $(ct, x, y, z)$ in an inertial frame $\boldsymbol{S}$ to coordinates $(ct', x', y', z')$ in another frame $\boldsymbol{S'}$ moving with velocity $v$ along the $x$ axis. Write these equations in matrix form. Show that the invariance of spacetime interval in the two frames leads to the condition

$$\eta_{\mu\nu}\Lambda^{\mu}{}_{\alpha}\Lambda^{\nu}{}_{\beta} = \eta_{\alpha\beta}$$

where $\Lambda^{\mu}_{\alpha}$ and $\Lambda^{\nu}_{\beta}$ are Lorentz transformation matrices and $\eta_{\alpha\beta}$ *and* $\eta_{\mu\nu}$ are Minkowski metric tensors. (10)

(b) Calculate the values of the following Christoffel symbols of the first kind for cylindrical coordinates $(x^1 = \rho,\ x^2 = \phi,\ x^3 = z)$ for which the metric is given by $ds^2 = d\rho^2 + \rho^2 d\phi^2 + dz^2$

(*i*) [12,2]

(*ii*) [22,1] (8)

6. (a) Prove the following vector identities using Cartesian tensors:

(i) $\vec{\mathbf{A}} \times (\vec{\mathbf{B}} \times \vec{\mathbf{C}}) = (\vec{\mathbf{A}} \cdot \vec{\mathbf{C}})\vec{\mathbf{B}} - (\vec{\mathbf{A}} \cdot \vec{\mathbf{B}})\vec{\mathbf{C}}$

(ii) $\vec{\nabla} \times (\vec{\nabla} \times \vec{A}) = \vec{\nabla}(\vec{\nabla} \cdot \vec{A}) - \nabla^2 \vec{A}$ (5,5)

(b) Check if the matrix T given by $T = \begin{bmatrix} -x_1x_2 & -x_2^2 \\ -x_1^2 & -x_1x_2 \end{bmatrix}$ is a tensor of rank two. (8)

(11)

[This question paper contains 2 printed pages.]

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

**Sr. No. of Question Paper : 5650** **J**

Unique Paper Code : 2223010022

Name of the Paper : Microprocessor

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

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, including Question No. 1 which is compulsory.
3. All questions carry equal marks.

1. Attempt any five questions: (5×3=15)

(a) Explain the function of the following registers in a 8085μP

(i) Program counter

(ii) Stack pointer

(iii) Accumulator.

(b) How EPROM and EEPROM differ in the erasing process of the stored content?

(c) What is the use of the following pins: RESET, HOLD and READY?



P.T.O.

(d) Explain the instruction XRA A? Specify the status of zero and carry flags after the execution of this instruction.

(e) What is an interrupt? List them in order of priority.

(f) The memory address of the last location of 1K bytes of memory chip is given as FF00 H. Calculate the starting address.

2. (a) Draw the logic pin out diagram of 8085 microprocessor wherein all the different signals are depicted and classified in different groups.

(b) Write an assembly language program to exchange the contents of memory location 2020 H and 2021 H. (7, 8)

3. (a) Write an assembly language programs to add six 8-bit numbers (stored at memory location 2000H to 2005H). The sum is to be stored in the memory locations 2006H and the carry in 2007H (if any).

(b) A microprocessor with 16-address lines uses 4K bytes RAM chip. How many chips would be needed for total of 24 Kbytes RAM. Write the address ranges for each chip. (10, 5)

4. (a) Explain the function of the ALE and $IO/\overline{M}$ signals of the 8085 microprocessor. Explain the need to demultiplex the bus $AD_7 - AD_0$.

(b) Write an assembly language program to add list of 10 numbers available at memory location 2051 to 205A (8, 7)

5. (a) Describe the steps and timing of data flow when the instruction code 0100 01111 (4FH – MOV C, A), stored in location 2005 H, is being fetched.

(b) Write an assembly language program to add two 16-bit numbers:

(i) (02A1) H and

(ii) (0361) H

Add these two numbers using DAD and without using DAD instructions. (10, 5)

(12)

[This question paper contains 2 printed pages.]

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

Sr. No. of Question Paper : 5870 J

Unique Paper Code : 2222513601

Name of the Paper : Solid State Physics (DSC paper)

Name of the Course : B.Sc. Prog. -Physical sciences with Physics_NEP: UGCF-2022

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. Answer any **four** questions. **Q1** is compulsory.
3. **All** questions carry equal marks.
4. Use of scientific calculator is allowed.

Q1 Answer any *five* questions:

(i) The primitive translation vectors of the hexagonal space lattice are $\mathbf{a}_1 = (3^{1/2}a/2)\hat{x}$ ; $\mathbf{a}_2 = (3^{1/2}a/2)\hat{y}$ ; $\mathbf{a}_3 = c\hat{z}$
Show that the volume of the primitive cell is $V = 3^{1/2}a^2c$

(ii) Define primitive and non-primitive unit cell of a 2D oblique lattice.

(iii) Explain the concept of local electric field in a dielectric material.

(iv) In a hexagonal plane lattice the translation vector is $\mathbf{T} = 2\mathbf{a} + 3\mathbf{b}$ where $\mathbf{a} = \mathbf{b} = 3$ Å and angle is 120°. Determine magnitude and direction of $\mathbf{T}$.

(v) How Hall effect can be used to identify n-type and p-type semiconductors?

(vi) What are ferromagnetic domains? Give examples of ferromagnetic materials.

**[5 x 3=15]**

Q2

(a) Show that reciprocal of BCC lattice is a FCC lattice in real space.

(b) If **k** is the wavevector and **G** is reciprocal lattice vector, write the Bragg's condition of crystal diffraction using Ewald's construction.

(c) Copper has fcc structure and the atomic radius is 1.278 Å. Determine its density (Atomic weight of Cu = 63.54, Avogadro number = $6.023 \times 10^{23}$).

**[6,6,3]**

Q3

(a) Draw the labelled periodic potential diagram of a Kronig-Penney model and explain the salient features of the model. Explain conductors, semiconductors and insulators based on energy bands.

(b) Obtain the mathematical relation for effective mass of electron in solids.

(c) What is superconductivity? Give an example of a superconductor. [6,6,3]

Q4

(a) Explain lattice vibrations for a linear diatomic chain of atoms. Derive the dispersion relation and draw the diagram showing optical and acoustic branches.

(b) Derive Dulong and Petit's law for specific heat of solids. Explain the conditions suggested by Einstein and Debye for further improvement. [8,7]

Q5

(a) Derive Langevin's theory of diamagnetism and show that diamagnetic susceptibility is negative and independent of temperature.

(b) Draw B-H hysteresis loop a ferromagnetic material. Explain the B-H lopp with the help of domain theory.

(c) Define electronic, ionic and orientational dipolar polarizability for dielectric materials. [6,6,3]