



1288

1115 May 2025

Roll. No.

Name of the Course : B.Sc. Hons.-(Physics)- CBCS_Core
Semester : VI - Semester
Name of Paper : Electromagnetic Theory
Unique Paper Code : 32221601
Duration : 3 Hours Maximum Marks : 75

Instructions for Candidates:

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

Question No.1 is compulsory. Answer any four of the remaining six.

Use of non-programmable scientific calculator is allowed.

Q1. Attempt any five parts of this question -
(5x3=15)

- (a) The E-field in free space $\vec{E} = 50\cos(10^8t + kx)\hat{j}$. Find the direction of propagation, the magnitude of propagation vector and time it takes to travel a distance $\lambda/2$.
- (b) If the frequency of a plane EM wave is 8×10^9 Hz and it propagates through a non-magnetic conductor with conductivity $\sigma = 5.8 \times 10^7$ S/m, find the skin depth of the conductor.
- (c) A sugar solution in a tube of length 20 cm produces optical rotation of 13° . The solution is diluted to $1/3$ of its previous concentration. Find optical rotation produced by 30 cm long tube containing the diluted solution.
- (d) In a material for which $\sigma = 5.0$ mho/m, $\epsilon_r = 1$ and $|\vec{E}| = 250 \sin 10t$ (V/m). Find $\vec{J}_c$ and $\vec{J}_d$ and frequency at which they have equal magnitude.
- (e) Derive the equation of continuity using Maxwell's equations.
- (f) For the glass-air interface calculate Reflection and Transmission coefficients (for normal incidence at interface between two linear dielectric media). Given $\eta_{air} = 1$, $\eta_{glass} = 1.5$.

Q2. (a). State and establish the Poynting theorem for conservation of energy for electromagnetic fields. Explain the physical significance of each term in the equation.

(10)

- (b) In a non-magnetic medium $\vec{E} = 4\sin(2\pi \times 10^7 t - 0.8x)\hat{a}_z$ V/m. Find the (i) velocity of propagation of EM waves through this medium, (ii) ϵ_r , (iii) intrinsic impedance η and (iv) the average power carried by EM wave. (Take $\mu_r = 1$)

(5)

Q3. (a) Derive Fresnel's relations for reflection and refraction of plane EM waves at an interface between two dielectric media when the electric field vector of the incident wave is perpendicular to the plane of incidence.

(10)

- (b) The average density of electrons in an ionosphere is $9 \times 10^9/\text{m}^3$. Calculate the plasma frequency and the phase velocity of the plane EM wave of frequency 200 MHz propagating through the ionosphere.

(5)

Q4. (a) A plane EM wave propagating in a conducting medium is characterized by the parameters ϵ , μ and σ . Show that the propagation constant is complex in this case. Discuss the propagation of EM waves in a good and bad conductor. Here ϵ , μ and σ are respectively

permittivity, permeability and conductivity of the medium. (10)

(b) Calculate the Reflection coefficient (for normal incidence) for light at an Air to Silver interface at optical frequency $\omega = 4 \times 10^{15}$ rad/s. [given $\mu_1 = \mu_2 = \mu_0$, $\epsilon_1 = \epsilon_0$, $\sigma = 6 \times 10^7 (\Omega.m)^{-1}$].

(5)

Q5. (a) Show that in an anisotropic dielectric medium Electric field, Magnetic field and the Poynting vector on one hand and the Electric displacement, the Magnetic field and the wave normal on the other hand form orthogonal triplets. (10)

(b) Find out the thickness of a Calcite QWP (Quarter Wave Plate) having its optic axis Parallel to the surface so that it can introduce a phase difference of $\pi/2$ between ordinary and extra-ordinary components at wavelength $\lambda_0 = 5893 \text{ \AA}$. (given $\eta_o = 1.65836$, $\eta_e = 1.48641$). (5)

Q6. (a) Starting from Maxwell's equations derive the wave equations for propagation of an electromagnetic wave in an inhomogeneous non-magnetic medium. Solve the appropriate wave equation for the TE modes in a step index symmetric planar dielectric wave guide. (10)

(b) For a typical step-index (multimode) fiber with $\eta_1 = 1.45$ and $\Delta = 0.01$. Find the numerical aperture (NA) of the optical fiber. (Here Δ is a parameter given by $\Delta = \frac{\eta_1^2 - \eta_2^2}{2\eta_1^2}$ with $\eta_2 < \eta_1$ and η_1, η_2 being the refractive index of core and cladding respectively). (5)

Q. 7(a) State Biot's laws for rotatory polarization. Using the Fresnel's theory of optical rotation, obtain the formula for the angle of rotation of plane of vibration. (7)

(b) A beam of light is passed through a polarizer. If the polarizer is rotated with the beam as an axis, the intensity I of the emergent beam does not vary. What are the possible states of polarization of the incident beam? How to ascertain its state of polarization with the help of the given polarizer and a quarter wave plate? (3)

(c) Discuss the State of Polarization (SOP) when the x and y components of the Electric fields are given by the following equations.

(i) $E_x = E_0 \cos(\omega t + kz)$

$$E_y = \left(\frac{E_0}{\sqrt{2}}\right) \cos(\omega t + kz + \pi)$$

(ii) $E_x = E_0 \sin(\omega t + kz)$

$$E_y = E_0 \cos(\omega t + kz)$$

(5)

Value of Constants:

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ farad/m} = \frac{10^{-9}}{36\pi} \text{ farad/m}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ henry/m}$$

$$\eta_0 = 120\pi \Omega = 377 \Omega$$

$$\text{Mass of electron} = 9.11 \times 10^{-31} \text{ Kg}$$

$$c = 3 \times 10^8 \text{ m/s}$$



1289

(22/5/25) R

Set B

Sr. No. of Question Paper :
Unique Paper Code : 32221602
Name of the Paper : Statistical Mechanics
Name of the Course : B. Sc. (Hons) Physics (CBCS-LOCF)
Semester : VI

Duration : 3 Hours

Maximum Marks : 75

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. All questions carry equal marks.
5. **Non-programmable scientific calculator** is allowed.

1. Attempt all parts. (5 × 3 = 15)
 - (a) Electromagnetic radiation inside a cavity of volume V is in equilibrium at temperature T . If the temperature of the cavity is halved, by what factor does the pressure change?
 - (b) Draw the phase trajectory in phase space for a free particle (mass m) moving with energy E along x -axis in the range $[0, L]$. Find the total number of micro-states available to it.
 - (c) A system has two non-degenerate energy levels having energy gap of 0.1 eV. If the probability that the system is in the higher level is 0.25, determine its temperature.
 - (d) Partition function of a single particle is Z_s . Write the partition function of a system of N such particles if these particles are
 - (i) classical (identical and distinguishable)
 - (ii) classical (identical and indistinguishable)
 - (e) What is the difference between a degenerate gas and a degenerate energy level?
2. (a) The partition function of a system is given by the equation
$$Z = e^{bT^3V}$$
where b is some constant. Prove that
 - (i) mean energy, $\bar{E} = 3bVk_B T^4$
 - (ii) mean pressure, $\bar{P} = bk_B T^4$
 - (iii) entropy, $S = 4bVk_B T^3$ (4, 4, 4)
- (b) The thermodynamic probability of an ideal gas increases from e^{10} to e^{1000} .

Find the change in entropy.

(3)

3. (a) Partition function of classical ideal monoatomic gas consisting of N indistinguishable particles at fixed temperature T in volume V is given as:

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

Derive the Sackur-Tetrode equation and hence show that the entropy given by the Sackur-Tetrode equation is an extensive parameter.

(6, 2)

- (b) State and derive the principle of equipartition of energy using statistical method. Mention its two limitations.

(5, 2)

4. (a) Show that at transition temperature ($T = T_c$), pressure of an ideal quantum gas consisting of N particles of spin zero moving non-relativistically in 3-dimensions is given by

$$P(T_c) = 0.513 \frac{N k_B T_c}{V} \quad (10)$$

- (b) Consider a blackbody radiation inside a cavity maintained at absolute temperature T . Determine the number of photons per unit volume inside this cavity.

(5)

5. (a) Show that at absolute zero, the pressure of a non-relativistic gas of electrons is $p_F = \frac{2}{5} \left(\frac{N}{V} \right) \epsilon_F$. Find the pressure of the free electron gas in MKS units in a monovalent metal which has number density of free electrons $6 \times 10^{28} m^{-3}$ and $\epsilon_F = 6eV$.

(5, 2)

- (b) At $T = 0$ K, maximum energy of fermions (spin = 1/2) is $\epsilon_F(0)$ and the speed of randomly selected fermion is v . For non-relativistic case, prove that

$$(i) \quad v_{rms} = \sqrt{\frac{6}{5m}} \epsilon_F(0)$$

$$(ii) \quad \frac{v_{max}}{v_{rms}} = \sqrt{\frac{5}{3}} \quad (5, 3)$$

6. (a) The entropy of a blackbody radiation is given as

$$S = \frac{4}{3} \sigma V^{1/4} E^{3/4}; \quad \sigma \text{ is a constant}$$

Show that the temperature of the radiation is given by

$$T = \frac{1}{\sigma} \left(\frac{E}{V} \right)^{1/4} \quad (3)$$

- (b) Write Planck's law of blackbody radiation in terms of frequency and hence deduce Stefan-Boltzmann law. (2, 5)
- (c) A spherical blackbody of radius 5 cm is maintained at temperature 327°C. Calculate the power radiated and the wavelength at which the maximum energy is radiated? (3, 2)

7. In a hypothetical system, 4 particles are distributed over 4 degenerate energy levels (0, ϵ , 2 ϵ , 3 ϵ) such that the total energy of the system is 3 ϵ . Degeneracies of these energy levels are respectively (5, 4, 3, 2). Find all the possible **macrostates** and their corresponding **microstates** if particles are
- (a) classical (identical and distinguishable)
- (b) bosons
- (c) fermions (5, 5, 5)

Some useful constants and integrals:

$$c = 3 \times 10^8 \text{ ms}^{-1},$$

$$m_e = 9.11 \times 10^{-31} \text{ kg},$$

$$b = 2898 \text{ } \mu\text{m K},$$

$$\sigma = 5.67 \times 10^{-8} \text{ Jm}^{-2}\text{s}^{-1}\text{K}^{-4},$$

$$h = 6.626 \times 10^{-34} \text{ J s} = 4.136 \times 10^{-15} \text{ eV s},$$

$$k_B = 1.38 \times 10^{-23} \text{ J/K} = 8.617 \times 10^{-5} \text{ eV/K},$$

$$\int_0^\infty \frac{x^{n-1} dx}{(z^{-1} e^x) - 1} = \Gamma(n) g_n(z); \quad g_n(1) = \zeta(n)$$

$$\int_0^\infty \frac{x^{n-1} dx}{(z^{-1} e^x) + 1} = \Gamma(n) f_n(z); \quad f_n(z) = g_n(z) - [2^{1-n} g_n(z^2)]$$

$$\zeta(3/2) = 2.612, \quad \zeta(5/2) = 1.341, \quad f_{3/2}(1) = 0.765,$$

$$\zeta(2) = \frac{\pi^2}{6}, \quad \zeta(4) = \frac{\pi^4}{90}, \quad \Gamma\left(\frac{1}{2}\right) = \sqrt{\pi}$$

Sr. No. of Question Paper : 1291

Roll No. 27/5/25 &

Unique Paper Code : **32227612**

Name of the Paper : **Nano Materials and Applications**

Name of the Course : **B.Sc. (Hons) Physics – CBCS-DSE- III**

Semester : **VI - Semester**

Duration : **3 Hours**

Maximum Marks : **75**



Instructions for candidates

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

Attempt any five questions in all.

Question No. 1 is compulsory.

Symbols have their usual meanings.

1. Attempt any five questions: (3x5=15)

- (a) Based on quantum confinement, classify the nanostructures and give one example for each.
- (b) Draw and differentiate clearly the powder XRD patterns of a single crystalline, polycrystalline and amorphous material.
- (c) Why is electron microscopy used to analyze nanomaterials rather than optical microscopes?
- (d) Write down the differences between PVD and CVD techniques.
- (e) What do you mean by quasi-particles? Give three examples.
- (f) What are carbon nanotubes? What are its various types?
- (g) Explain the process of Ball-milling for nanomaterial synthesis.

Q2. (i) What is Quantum confinement effect?

(ii) Describe the density of states (DOS) function for 3D, 2D, 1D and 0D materials with suitable diagrams and discuss characteristics features of each of them.

(iii) Consider a particle of mass 10^{-30} kg trapped in an infinitely deep potential well of width 0.5 nm. Find the value of the (a) wave number k in the ground state (b) How many states are there having value of k between 10 nm^{-1} and 100 nm^{-1} (c) What is the density of states at $E = 3 \text{ eV}$? (2+10+3)

Q3. (i) Explain the difference between optical and electronic band gaps with suitable diagrams?

(ii) Differentiate between the direct and indirect semiconductors with appropriate diagrams.

(iii) Discuss the phenomenon of absorption, emission and luminescence in a nanostructured material. (3+3+9)

Q4. (i) Describe the construction and working of single electron transistor (SET).

(ii) What are the conditions for observing the coulomb blockade and coulomb oscillations in such a device?

(iii) For a nanocapacitor of area $3 \times 3 \text{ nm}^2$ with an electrode separation of 2 nm and a tunnel resistance of 100 K Ω , calculate the quantum uncertainty in energy for electrons. (10+2+3)

Q5. (i) Explain the working of scanning tunneling microscopy (STM) Using the formula for the tunneling current between probe and the sample.

(ii) What type of sample can be studied using scanning tunneling microscopy?

(iii) Discuss constant current and constant height mode of sample imaging using STM. (10+2+3)

Q6. (i) Discuss the structure and working of a thin film based Solar cell.

(ii) Draw the IV characteristics of a Solar cell under different intensity of illumination.

(iii) How does the efficiency of a solar cell can be enhanced using quantum dots?

(iv) Discuss the principle of magnetic and optical data storage / memory devices. (8+2+2+3)

Your Roll No.

(27/5/25) 2

S. No. of Question Paper : 1303

Unique Paper Code : 32227625

Name of the Paper : Advanced Mathematical Physics II (DSE)

Name of the Course : B.Sc. (Hons.) Physics

Semester : VI

Duration: 3 Hours

Maximum Marks: 75



Instructions for Candidates

- Attempt five questions in all including Q. No. 1 which is compulsory.
- Non-programmable scientific calculator is allowed.

1. Attempt all parts:

(3 × 5)

- (a) Write Euler-Lagrange's equation for a function, $f(x, y, y')$ and hence prove that for the function $f = f(y, y')$ this equation becomes

$$f - y' \frac{\partial f}{\partial x} = \text{constant}$$

- (b) Prove the following Poisson brackets

$$[L_x, p_y] = p_z \text{ and } [L_x, L_y] = L_z$$

where L_x, L_y and L_z are the components of angular momentum and p_y and p_z are the components of linear momentum.

- (c) If $\langle b \rangle$ is a cyclic group of order 15, find the orders of the elements b^2, b^3 and b^5 .
- (d) Find the center of group $G = \{0, 1, 2, 3\}$ with the binary operation of addition modulo 4.
- (e) A fair coin is tossed 7 times. Find the probability of obtaining 3 and 5 heads inclusive by using Binomial distribution.

2.

- (a) Using Euler-Lagrange equation, determine the extremal of the functional

$$f(y, y', x) = \int_0^1 \frac{\sqrt{1 + y'^2}}{x} dx \quad \text{where } y' = \frac{dy}{dx}$$

subjected to the conditions $y(1) = 0$ and $y(2) = 1$. (7)

- (b) Determine the Lagrangian for a charge particle q of mass m moving under the influence of a Coulombic Force given by

$$F = -\frac{q}{4\pi\epsilon_0 r^2}$$

Also find the equations of motion. (8)

3.

- (a) The Lagrangian of a system is given by

$$L = \frac{m}{2}(a\dot{x}^2 + 2b\dot{x}\dot{y} + c\dot{y}^2) - \frac{k}{2}(ax^2 + 2bxy + cy^2)$$

where $\dot{x} = \frac{dx}{dt}$, $\dot{y} = \frac{dy}{dt}$ and a, b, c and k are constants and m is the mass of the system.

Determine the Generalized momenta, Hamiltonian of the system using Legendre transformation and equations of motion using Hamiltonian approach. (7)

- (b) Show that the path followed by a particle in a vertical plane in sliding from one point to another in the absence of friction in the shortest time is a cycloid. (8)

4.

- (a) Let $D = S_3$ be the group of permutations of 3 elements, that is

$$D = \{(1), (12), (13), (23), (123), (132)\}$$

Show that the cyclic subgroup of S_3 generated by (12) is not normal in S_3 . (7)

- (b) Show that the set of symmetry operations of an equilateral triangle form a dihedral group D_3 . (8)

5.

- (a) Show that the general form of the elements of $SO(2)$ group with respect to matrix multiplication is given by:

$$\begin{bmatrix} a & b \\ -b & a \end{bmatrix}$$

such that $a^2 + b^2 = 1$. (7)

- (b) Consider the set $G = \{I, A, B\}$ of matrices given below. Does the set form a group with respect to matrix multiplication?

$$I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, A = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}, B = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

If not, add a minimum no of elements to make it a group.

Determine whether the group G formed is isomorphic to the group $U: \{1, -1, i, -i\}$ with respect to multiplication. (8)

6. (a) If X is a Poisson distributed random variable, then find its mean and variance. (7)

- (b) Find the best values of a and b so that $y = ax^b$ fit the following data set (8)

x	2	4	7	10	20	40	60	80
y	43	25	18	13	8	5	3	2

7. (a) If X is a random variable such that

$$E[(X - 1)^2] = 10 \text{ and } E[(X - 2)^2] = 6$$

Find $E(X)$ and $Var(X)$. (7)

- (b) Bag I contains 3 red and 4 black balls and Bag II contains 4 red and 5 black balls. One ball is transferred from Bag I to Bag II and then a ball is drawn from Bag II.

i. The ball so drawn is found to be red in colour. Find the probability that the transferred ball is black.

ii. Find the probability that drawn ball is black. (8)

1304

[This question paper contains printed pages]

(26/5/25)

Your Roll No.

S.No. of Question Paper :
 Unique Paper Code : 32227626
 Name of the Paper : DSE Classical Dynamics
 Name of the Course : B. Sc. (Hons) Physics CBCS-LOCF
 Semester : VI



Duration: 3 Hours

Maximum Marks: 75

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

Question No. 1 which is compulsory.

Attempt any four questions from the remaining.

Q1) Attempt all of the following

[3×5 = 15]

- a) The Lagrangian L of a particle with mass m moving in one dimension is given by

$$L(x, \dot{x}, t) = \frac{1}{2}m\dot{x}^2 + \alpha\left(\frac{1}{2}x^2 + t\dot{x}\right) - \frac{1}{2}kx^2$$

where α and k are constants. Find the equation of motion of this particle.

- b) Determine the Hamiltonian of a free particle in (i) cylindrical coordinate system and (ii) spherical polar system.
- c) Let $A^\mu = (9, 4, 6, 6)$ be a four-vector. Determine whether this four-vector is time-like, space-like or light like vector.
- d) In an inertial frame S , a car is travelling in the xy -plane with constant speed of $u = 0.5c$ along a line which makes 45° with the x -axis. Find the components of its four-velocity.
- e) A particle moves along the x -axis under the influence of a force with potential $V(x) = 2(x^4 - x^2)$. Determine the positions of stable and unstable equilibria.

Q2)

- a) Using Hamilton's principle, derive the Euler-Lagrange equation for a system with N degrees of freedom. [8]
- b) Let $L_1(q, \dot{q})$ and $L_2(q, \dot{q})$ be two Lagrangian which are related like this:

$$L_2(q, \dot{q}) = L_1(q, \dot{q}) + \frac{d}{dt}[f(q, t)]$$

where $\dot{q} = \frac{dq}{dt}$ and $f(q, t)$ arbitrary function of the generalized coordinate q and time t .

Using the Euler-Lagrangian equation, show that both these Lagrangian leads to the same equation of motion. [7]

Q3)

- a) A simple pendulum of mass m and length L is attached to another mass M at the point of support. Mass M can move in a horizontal line lying in the plane in which mass m moves. Assume that there is no friction in the movement of mass m and M . Find the Lagrangian and the corresponding equations of motion. Identify cyclic coordinates and the corresponding conserved conjugate momentum. [8]
- b) If the Lagrangian of the system does not explicitly depend on time, then prove that the Hamiltonian is conserved. [7]

Q4)

- a) Two identical simple pendulums of length l and point mass m are coupled by a massless spring of constant k . The unstretched length of the spring is equal to the distance between the two supports of the pendulums. Write the Lagrangian of the system in appropriate generalized coordinates. Find the normal coordinates and normal frequencies of small oscillations about the equilibrium. [8]
- b) A particle moving along the x -axis under the influence of force with potential $V(x) = bx^2 + \frac{a}{x^4}$ where a and b are positive constants. Determine the frequency of oscillation about the stable equilibrium point under small oscillations. [7]

Q5)

- a) Starting from the displacement 4-vector, determine the components of (i) 4-velocity η^μ and (ii) the 4-acceleration a^μ . Using this determine the value of $\eta^\mu \eta_\mu$ and $a^\mu a_\mu$. [8]

- b) In an inertial frame S , the space-time coordinates of event A are $(t_A, x_A, 0, 0)$ and coordinates of event B are $(t_B, x_B, 0, 0)$. Assuming the invariant space-time interval between them is space-like show that there exists an inertial frame S' in which the two events are simultaneous. Find the velocity of frame S' with respect to S . [7]

Q6)

- a) For a particle with rest mass m , how is four-moment p^μ defined? If $\vec{u}$ is a 3-velocity vector of the particle, derive the components of the four-momentum p^μ and prove that $E^2 + p^2 c^2 = m^2 c^4$ where the symbols have their usual meaning. [8]
- b) In an inertial frame S two particles with four-momentum p_1^μ and p_2^μ collide with each other. After getting scattered the resulting particles have four-momentum p_3^μ and p_4^μ . If the total 4-momentum is conserved in the inertial frame S , using the Lorentz transformation, show that it is also conserved in inertial frame S' . Consider the frame S' to be moving along x -axis with respect frame S with constant velocity v . [7]

Q7)

- a) What is Reynolds number? Discuss its significance with respect to flow of fluids. Water is observed to flow through a capillary of diameter 1.0 mm with a speed of 3 m/s . Viscosity of water in CGS units is 0.018 at 0°C , 0.008 at 30°C and 0.004 at 70°C . Calculate the Reynolds number and test at which of these three temperatures is the flow likely to be streamlined. Assume that for Reynolds number $R < 2200$ flow is steady. [8]
- b) Derive the continuity equation in 3-dimensions for incompressible fluid. [7]

Roll No. 37/5/25

Sr. No. of Question Paper : 1305
Unique Paper Code : 32227626
Name of Paper : Classical Dynamics
Name of Course : B.Sc. (Hons.) Physics-DSE(repeat paper)
Semester : VI

Duration: 3 Hours

Maximum Marks: 75

Instructions for Candidates

- Write your Roll No. on the top immediately on receipt of this question paper
- Attempt five questions in all including question 1 which is compulsory.

1. Attempt any five of the following.

(3x5=15)

- A particle is constrained to move inside a sphere. Explain whether the constraints on motion is holonomic or non-holonomic.
- What is equilibrium state of a system? Describe the stable and unstable equilibrium of a system
- What is length contraction? How fast would a rocket have to go relative to an observer for its length to be contracted to 99% of its length at rest?
- Show that the time rate of change of the fluid mass inside a fixed volume V is equal (opposite in sign) to the mass of the fluid flowing out of the volume V across the bounding surfaces.
- Define cyclic coordinate and show that generalized momentum conjugate to a cyclic coordinate is conserved.
- Differentiate between laminar flow, streamline flow and turbulent flow in terms of Reynolds number.

(g) Starting from the position 4-vector, $\tilde{x} = (c t, \vec{r})$ prove that 4-velocity is given by

$$\tilde{\eta} = \gamma_u(c, \vec{u}); \gamma_u = \left(1 - \frac{u^2}{c^2}\right)^{-1/2}$$

2. (a) State Hamilton's principle. Derive Lagrange's equation of motion for a conservative system using the Hamilton's principle (8)

(b) Two equal masses 'm' are connected by springs having equal spring constant k, so that the masses are free to slide on a frictionless table. The ends of springs are attached with the fixed walls. Using the Lagrangian formalism, write the equations of motion for the vibrating masses. (7)

3. (a) Define normal modes of vibration and normal coordinates. For a system of parallel pendulum, find the normal frequencies of vibration and normal coordinates at the vicinity of point of stable equilibrium. (10)

(b) Derive the Hamilton's equation of motion for a particle moving under the influence of a central force $F = -k/r^2$, for $k > 0$. (5)

4. (a) Calculate the gyro-radius, gyro-frequency and velocity of a negatively charged particle '-q' of mass 'm' in a uniform electric field $E = E_0 \hat{x}$ and uniform magnetic field $B = B_0 \hat{z}$, which are perpendicular to each other, with proper diagram showing the trajectory of the particle. (8)

(b) Define Reynold's number along with the significances of dynamic viscosity and kinematic viscosity. In a certain situation, the Reynolds number is 3000, the pipe diameter is 10 mm, and the kinematic viscosity of water is $1.01 \times 10^{-6} \text{ m}^2/\text{s}$. Calculate the mean velocity of water flow in the pipe. (7)

5. (a) Derive Hamilton's canonical equations of motion? A particle moves in the XY plane under the influence of a central force depending only on its distance from the origin. Write the Hamiltonian for the system and write Hamilton's equation of motion. (8)

(b) Considering steady flow of an incompressible viscous fluid in an axially symmetric pipe of radius 'r', find the volume flow rate of the fluid through the pipe. Two capillary tubes A and B of equal length are arranged in parallel. A liquid flows through these tubes under the same pressure. Both the tubes have the radius 'r' and 'r/2' respectively. If the rate of flow of the liquid through A is $10 \text{ cm}^3/\text{s}$ then calculate the total rate of flow through their parallel combination. (7)

6. (a) Show that Lagrange's equations are invariant when

(i) a constant is added to the Lagrangian e.g. $(L \rightarrow L + C)$

(ii) a constant is multiplied to the Lagrangian $(L \rightarrow C L)$ (5)

(b) Obtain the most general form of the equations of motion of a viscous fluid and hence write the Navier-Stokes equation. (10)

7. (a) Two photons (each with energy E) collide at an angle θ and create a particle of rest mass m_0 . Using 4-vectors or otherwise, show that

$$m_0 = \frac{E}{c^2} \sqrt{2(1 - \cos \theta)} \quad (7)$$

(b) Show that 4-vector scalar product $x_\mu x^\mu$ and $x'_\mu x'^\mu$ are Lorentz invariant and further prove that the velocity of a particle of zero rest mass is always equal to the velocity of light (8)

[This question paper contains 4 printed pages.]

27/5/25 n
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?

P.T.O.

- (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

$$f_{XY}(x, y) = \begin{cases} x + Cy^2 & 0 \leq x \leq 1, 0 \leq y \leq 1 \\ = 0 & \text{otherwise} \end{cases}$$

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

- (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 $\theta \sim \text{Beta}(2, 2)$ 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 λ . 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 λ .
- (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 (θ) 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 θ . (8)

[This question paper contains 4 printed pages.]

Your Roll No.....

22/425

Sr. No. of Question Paper : 5557

J

Unique Paper Code : 2222013602

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

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. Attempt **four** questions from the rest of the paper
5. Use of non-programmable scientific calculator is allowed.

1. Attempt any **six** questions from the following:

(6 x 3 = 18)

- a) Briefly explain the modes of relaxation of an excited atomic state.
- b) The effective potential (in arbitrary units) when solving a one-electron atom problem is

$$V_{\{eff\}}(r) = -\frac{2}{r} + \frac{l(l+1)}{r^2}$$

Plot $V_{\{eff\}}$ Vs r for hydrogen atom for $l = 0$ and $l = 1$.

- c) What is the consequence of breaking of the Born-Oppenheimer approximation on the ro-vibrational spectrum of a diatomic molecule?

P.T.O.

- d) Show that the Darwin term results in a shift of 0.7305 cm^{-1} for $S_{1/2}$ state in H atom. Given $1 \text{ eV} = 8065.54 \text{ cm}^{-1}$; $\alpha^2 \approx (1/137)^2 = 1/18769$; Rydberg constant $= 1.097 \times 10^5 \text{ cm}^{-1}$.
- e) Differentiate between σ and π bonds.
- f) State the Geiger-Nuttall law and represent it graphically.
- g) What conclusions can be drawn from Weisskopf estimates about transition probabilities in terms of multipole order and the type of radiation?
2. a) Calculate the change in energy due to spin orbit interaction responsible for the fine structure of hydrogenic atoms.
- b) The D_1 line of Sodium is due to the transition $^2P_{1/2} \rightarrow ^2S_{1/2}$. Draw and discuss the shifts in the spectral line caused by a strong magnetic field. What is the name of this effect?
- c) For the hydrogen atom at the $n = 2$ energy level, demonstrate that the spin-orbit interaction causes no energy shift for $S_{1/2}$ state. **(9+6+3)**
3. a) State the differences between the spectra of rigid rotator and non-rigid rotator. Support with a diagram.
- b) What are the dipole selection rules for one-electron atoms?
- c) A free neutron decays into a proton by the emission of β^- particles of maximum kinetic energy 0.782 MeV . Find the mass of proton and hydrogen atom. Given the rest mass of electron $= 0.0005486 \text{ u}$, rest mass of neutron $= 1.008665 \text{ u}$. **(6+6+6)**

4. a) Derive the following expression for the wave number for energy level(s) (cm^{-1}) in case of Raman spectra $\bar{\nu} = (\bar{\nu}_0 \pm B(4J + 6)) \text{ cm}^{-1}$ where $\bar{\nu}$ and $\bar{\nu}_0$ are the wave numbers of energy levels of Raman Spectra and the exciting lines respectively, B is the rotational constant and J is the rotational quantum number. What do the positive and negative signs in the above equation, refer to?
- b) The first rotational absorption of $^{12}\text{C}^{16}\text{O}$ occurs at 3.84235 cm^{-1} while that of $^{13}\text{C}^{16}\text{O}$ is at 3.67337 cm^{-1} . Find the atomic weight of ^{13}C . Given mass of $^{16}\text{O} = 16.00 \text{ u}$ and mass of $^{12}\text{C} = 12.00 \text{ u}$.
- c) State the Franck-Condon principle. Draw electronic transitions illustrating the principle. (9+6+3)
5. a) A radioactive substance A with decay constant λ_A transforms into another radioactive substance B with decay constant λ_B which further decays into a stable end-product C ($A \rightarrow B \rightarrow C$). Assume at $t = 0$ only substance A with N_{A0} atoms is present. The number of atoms of substances A and B present at any instant t are $N_A(t)$ and $N_B(t)$ respectively. Discuss the equilibrium conditions for (i) longer lived parent nucleus compared to the daughter nucleus (ii) longer lived daughter nucleus than the parent nucleus. In each case represent graphically the variation of activity with time.
- b) Using the nuclear Shell model, explain how does the spin orbit interaction explain the existence of magic number 28. Why are the low-lying excited states assigned $(1/2)^+$ and $(1/2)^-$? (6+12)

- 6.a) Explain the fine structure splitting of spectral lines in H-atom due to the transition from the first excited state to the ground state. Identify the allowed transitions according to the selection rules. Why does each line from the first excited state to the ground state, split into a doublet in the fine structure of the hydrogen atom?
- b) Show that the laws of conservation of energy and angular momentum are not violated if a neutrino or an anti-neutrino is emitted in beta decay.
- c) Explain the origin of P and R branches in the vibration rotation spectra of diatomic molecules. (6+6+6)

Useful information:

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

a_0 is the Bohr radius

Z is the nuclear charge, l is the orbital quantum number

n is the principal quantum number

[This question paper contains 2 printed pages.]

02/6/25 A

Your Roll No.....

Sr. No. of Question Paper : 5650

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



J

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 $IO/\bar{M}$ 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 0111 (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)

[This question paper contains 4 printed pages.]



Your Roll No.....

02/6/25a

Sr. No. of Question Paper : 5651

J

Unique Paper Code : 2223010023

Name of the Paper : Research Methodology

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

Semester : VI- Semester (DSE 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. Q1 is compulsory. Answer any SIX parts from Q1 and FIVE questions in ALL.
3. Use of a non-programmable calculator is allowed.
4. Attempt all the parts of questions together.
5. Z- and T- tables are permitted.

1. Attempt any six parts of the following:

(3×6=18)

- (a) Explain three types of biases that may occur in research.
- (b) Discuss any two methods of data collection for qualitative research highlighting one of their merits.
- (c) What is Source-Normalized Impact Per Paper (SNIP)? If SNIP is A/B, explain the terms A and B.

P.T.O.

- (d) Name any two databases used in Physics/Astrophysics and also mention one of their capabilities.
- (e) What is gnuplot? Write a code to plot $\sin(x)$ between -5 and 5. Include a title as "Fig.1" with font size 20.
- (f) A person wishes to apply for a patent. Mention any three prerequisites which should be considered before filing a patent application.
- (g) Discuss any fellowship scheme for students by the Council of Scientific & Industrial Research. What is its eligibility criterion and mention one benefit it provides?
2. (a) What is the purpose of a literature review? Smita does not know how to conduct a literature review. Give three reasons why she should conduct a literature review for her research. (4)
- (b) You are given the following dataset taken during an experiment in their usual units.

x	2	5	7	9	10
y	5	12	20	24	30

- (i) Compute the sample means $\bar{x}$ and $\bar{y}$
- (ii) Use the least square fitting (for linear regression) formulas to compute β_1 and β_0

$$\beta_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$$

$$\beta_0 = \bar{y} - \beta_1 \bar{x}$$

(iii) Write the final linear regression equation.

(iv) The instrument should have a reading (0,0). How can this data be used to indicate that the instrument was not set properly and needed calibration? (8)

(c) What are the important requirements for using the Z-test? Use the Z-test for the following data. A school wants to compare the average test scores of male and female students:

Male: $n_1 = 50$, Mean, $\bar{X}_1 = 78$; Standard Deviation, $\sigma_1 = 10$;

Female: $n_2 = 50$, Mean, $\bar{X}_2 = 74$; Standard Deviation, $\sigma_2 = 9$. Show that we fail to reject the null hypothesis at the 1% significance level. (6)

3. (a) What are the key features of a good research problem? (5)

(b) Consider the function: $f(\theta) = (\theta - 4)^2$. . Use the gradient descent method to minimise this function starting from an initial value of $\theta_0 = 0$. . Using a learning rate of $\beta = 0.1$, perform two iterations to obtain the updated values of θ using the rule: $5\theta_{n+1} = \theta_n - \beta \cdot \nabla f(\theta_n)$ after computing the gradient $\nabla f(\theta)$. Discuss one advantage and disadvantage of this method. (7)

(c) What is the difference between linear and multilinear regression? Explain with the help of a mathematical expression and when are these used? (6)

4. (a) A scientist is looking for a journal for the publication of their work. Below are three journals with various parameters. Based on this data, discuss five factors which will help to decide their choice to be a non-predatory journal. Which journal is likely to be a predatory journal in this list? (6)

Journal	Peer Review Time	Indexing	APC (Dollars)	Impact Factor	Editorial Board Information
X	3 Weeks	Indexed in reputed database	2000	Not Calculated	Available
Y	3 Days	Not Indexed	1500	Not Calculated	Not Available
Z	4 Weeks	Indexed in reputed database	2500	5.2	Available

- (b) What is the NASA/IPAC Extragalactic database (NED)? Explain the purpose and input fields of the Coordinate Calculator in this database. (5)
- (c) Explain three ways in which errors can be communicated for a published article. Describe their differences. (7)
5. (a) Discuss any four features of scientific conduct. Specify two reasons why it is needed. (6)
- (b) Explain the difference between redundant and duplicate publications. What is meant by salami slicing and why should it be discouraged? (5)
- (c) Mention five different types of work which can be copyrighted. Explain the concept of "fair use" in copyright law with the help of an example. (7)
6. (a) What is a trademark? Mention three different types of trademarks. What is a symbol for a registered and unregistered trademark? (6)
- (b) What is a control parameter in any experiment? Why is it needed? Explain it with the help of any physics experiment. What are the objectives of background setting of an experiment? (7)
- (c) What is the peer-review process? Differentiate between single-blind and double-blind peer review. (5)