[This question paper contains 8 printed pages.]

Your Roll No. ....

Sr. No. of Question Paper : 2989

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.

P.T.O.

1. Attempt all parts from the following : (5×3=15)

(a) Three identical boxes A, B, C are at same temperature T and have gases of equal number of classical particles, bosons and fermions respectively. Which gas will exert the greatest pressure and which gas will exert the least pressure? Why?

(b) Two isolated systems have thermodynamic probabilities $\frac{2}{3}e^{10}$ and $\frac{3}{2}e^{10}$ respectively. Calculate the total thermodynamic probability of the combination of these systems. Also, calculate the total entropy.

(c) For a system of N atoms, energy of each atom is given as

$$E = \frac{1}{2m}(p_x^2 + p_y^2) + \frac{1}{2}m\omega^2(x^2 + y^2) + \alpha(x + y)$$

where m, ω, α are constants.

Using equipartition theorem, find the average energy of this system.

(d) Why are electrons not ejected out spontaneously from a metal inspite of having tremendous zero point pressure?

(e) How is a Fermi gas different from a Bose gas at T = 0 K?

2. (a) Partition function is given by

$$Z = \sum_i g_i e^{-\beta\epsilon_i} ; \beta = 1/k_B T$$

Prove that

(i) mean energy, $\overline{E} = -\frac{1}{Z}\frac{\partial Z}{\partial \beta}$

(ii) mean pressure, $\overline{P} = \frac{1}{\beta Z}\left(\frac{\partial Z}{\partial V}\right)_{T, N}$

(iii) entropy, $S = k_B \ln Z + \frac{\overline{E}}{T}$. (3,4,5)

(b) Identify the regions in energy vs entropy diagram for two temperatures: −100 K and 100 K for a system with finite maximum energy. Which of the two is hotter? (3)

3. (a) Establish the relation between entropy and thermodynamic probability. (5)

(b) Consider a system of N magnetic dipoles in the presence of magnetic field B such that dipoles can be either parallel or anti-parallel to B.

(i) Find energy E of the system, enumerate the number of microstates, W(N, E) and hence find the expression for entropy. (2,2,3)

(ii) Show that the maximum entropy for this system is given by

$$S_{max} = Nk_B \ln 2$$ (3)

4. (a) In what ways Bose-Einstein Condensation (BEC) differ from ordinary condensation? (2)

(b) Derive the expression for temperature (T_c) at which BEC sets in. (5)

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

$$E(T_c) = 1.5\, N k_B T_c \frac{\zeta(5/2)}{\zeta(3/2)} \quad (8)$$

5. (a) Prove that the average energy of non-relativistic fermions (spin = 1/2) at T = 0 K is given by

$$\overline{E} = \frac{3}{5} \epsilon_F(0)$$

Why $\overline{E} \neq 0$ at T = 0 K? (6,2)

P.T.O.

(b) Show that for a strongly degenerate gas of fermions ($0 < T << T_F$), the chemical potential is

$$\mu(T) \approx \epsilon_F \left[1 - \frac{\pi^2}{12}\left(\frac{T}{T_F}\right)^2\right],$$ where $\epsilon_F = \mu(T = 0)$,

and $T_F = \epsilon_F / k_B$. (7)

6. (a) State Planck's postulates for blackbody radiation. Write Planck's law of blackbody radiation in terms of wavelength and hence deduce Wien's displacement law. (2,6)

(b) The entropy of a blackbody radiation is given as

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

Show that the pressure exerted by the radiation is given by

$$P = \frac{E}{3V}$$ (4)

(c) Consider a blackbody radiation inside a cavity maintained at temperature 400 K. Calculate the energy density of photons inside this cavity. (3)

7. In a hypothetical system, 3 particles are distributed over 4 degenerate energy levels (0, $\in$, $2\in$, $3\in$) such that the total energy of the system is $3\in$. Degeneracies of these energy levels are respectively (3, 4, 2, 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 :

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

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

$b = 2898$ μm K,

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

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

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

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

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

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

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

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 3077

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

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 any **five** questions in all.
3. Question No. **1** is compulsory.
4. Symbols have their usual meanings.

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

   (a) What do you understand by nanomaterials? Give one example each of 2D and ID nanomaterials.

P.T.O.

(b) Determine the surface area to volume ratio of spherical particles of radii 1 nm, 10 nm, 1 μm, and plot the variation of the ratio with radii.

(c) How do electrons interact with matter in electron microscopy?

(d) Draw the typical XRD curves obtained for crystalline, polycrystalline and amorphous materials.

(e) Sketch and label a schematic diagram of a single electron transfer device.

(f) How do optical properties of a material change with the size of nanoparticle?

(g) How nanomaterials can be used for cancer therapy?

(h) What are organic (dye synthesized) solar cells?

2. (a) Explain briefly the physical and chemical vapour deposition techniques. (8)

(b) Explain the nucleation and growth process for colloidal synthesis of nanomaterials. (7)

3. (a) Considering the free electron gas model, determine the density of state expression [ρ(E)] for a 3D material. Draw the corresponding E vs. K and E vs. ρ(E) diagram of 3D and 2D material for comparison and explain briefly the important features of the two. (12)

(b) Explain why the confinement results in the appearance of the zero-point energy in the E vs. K diagram. What is the physical significance of the zero-point energy? (3)

4. (a) Discuss the absorption, emission and luminescence radiative processes. (10)

(b) Why is vacuum required in all thin film deposition techniques? How is it achieved? (5)

5. Discuss the principle and fabrication technique of any **two** of the following used for the synthesis of nanomaterials?

(i) Sol-gel

(ii) Sputtering

(iii) Hydrothermal method

(iv) Molecular Beam Epitaxy (7.5×2=15)

P.T.O.

6. (a) How is ballistic transport different from diffusive transport? (5)

(b) Obtain an expression for the variation in electrostatic energy of a system for single electron charging. Name the effect associated with it. (10)

7. (a) What are silicon nanowires? Give its various applications. (8)

(b) What are quantum LASER devices? How are they formed? (7)

[This question paper contains 4 printed pages.] 04/6/24

Your Roll No. ....

H

Sr. No. of Question Paper : 3078

Unique Paper Code : 32227613

Name of the Paper : Communication System

Name of the Course : **B.Sc. Hons.–(Physics)_DSE Paper**

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. **All** questions carry equal marks.
4. Question No. **1** is compulsory.
5. Use of scientific calculator is allowed.

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

   (a) What are the different ways to increase the capacity of a cell in a cellular network?

P.T.O.

(b) A carrier wave is given by $V_c = 5.0 \times \text{Cos}(6 \times 10^6 \times t)$. This carrier is amplitude modulated by a base band signal given by $V_m = 3.0 \times \text{Cos}(100t)$. Find the value of modulation index.

(c) How PM signal is derived from FM?

(d) A broadcast radio transmitter radiates 5 kW power when the modulation percentage is 60 percent. How much is the carrier power?

(e) The noise level available at the output of a communication receiver is -10 dBm. What is the noise level in the absolute scale?

(f) What do you mean by bandwidth? Explain Shannon's limit for information capacity.

2. (a) Define the term SSB in amplitude modulation. Explain any one method of SSB signal generation using suitable block diagram. How much power is saved in SSB transmission over DSB-SC transmission?

(b) Explain amplitude demodulation using diode detector. What type of distortions can occur in the detection of AM signal using this method of detection? (8,7)

3. (a) Define Pulse amplitude modulation (PAM) and explain its generation with suitable diagrams.

(b) For the following bit sequence, draw the timing diagram for Unipolar Return to Zero (UPRZ), Unipolar Non Return to Zero (UPNRZ), Bipolar Return to Zero (BPRZ), Bipolar Non Return to Zero (BPNRZ) and Split Phase (Manchester) encoding :

Bit stream: 1 0 1 0 1 1 0 1 0 1 1 0 0 (10,5)

4. (a) Write the requirements of a FM detector circuit. Draw and explain the circuit diagram of slope detector for the demodulation of FM signal.

(b) An angle modulated signal has the form $s(t) = 100 \operatorname{Cos}[2\times10^{7}\pi t + 4\operatorname{Sin}(2\times10^{3}7\pi t)]$

(i) Determine the average transmitted power for a load resistance of 1kΩ.

(ii) Determine the peak phase deviation.

(iii) Determine the peak frequency deviation. (10,5)

5. (a) Draw the block diagram for a pulse code modulation (PCM) system and explain it's working.

(b) Determine (i) the peak frequency deviation, (ii) minimum bandwidth for a binary FSK signal with a mark frequency of 49 kHz, a space frequency of 51 kHz and an input bit rate of 2 kbps.

(10,5)

6. (a) Explain Global System for Mobile Communication with the help of a block diagram. Describe in detail about its different components and the interfaces between them.

(b) What do you understand by handoff and roaming?

(c) Determine the following :

(i) Channel capacity for a cellular telephone area comprised of seven macrocells with 16 channels per cell.

(ii) Channel capacity if each macrocell is split into four minicells. (8,4,3)

7. (a) What do you understand by satellite communication? Give a comparison between LEO (Low Earth Orbit), MEO (Medium Earth Orbit) and GSO (Geosynchronous Orbit). Explain why geostationary satellites are preferentially used for worldwide communications.

(b) Draw the block diagram of a satellite transponder and explain it's working. (8,7)

[This question paper contains 8 printed pages.] 04/6/24

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

Sr. No. of Question Paper : 3084 H

Unique Paper Code : 32227626

Name of the Paper : Classical Dynamics (DSE – Paper)

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 **four** questions in all including Question No. **1** which is compulsory.

1. Attempt any **four** of the following :

   (a) Explain time dilation phenomenon using space-time diagram.

P.T.O.

(b) With the help of diagram explain the difference between

(i) steady and unsteady flow

(ii) uniform and non-uniform flow.

(c) What do you mean by length contraction. The rest radius of the earth may be taken as 6400 km and its orbital speed about the sun as 30 km/sec. By how much would the earth's diameter appear to be shortened to an observer on the sun, due to earth's orbital motion?

(d) Show that motion of a charged particle in crossed electric and magnetic field is cycloid. Also determine the maximum height of a cycloid path.

(e) What do you mean by degrees of freedom. Determine degrees of freedom for the following systems :

(i) four particles moving freely in a space.

(ii) two particles falling under gravity in space.

(f) What is meant by stable, unstable and neutral equilibrium. For a particle moving under the influence of a potential, $V = \frac{1}{2}k\,x^2$ where k is a constant, determine the kind of equilibrium system holds. (4×6=24)

2. (a) Consider a particle of mass m moving in two dimensions, subject to a force $\vec{F} = -\alpha x\hat{x} + \beta\hat{y}$, where α and β are positive constants.

Using x and y as generalized coordinates, obtain the Lagrangian of this system and hence find the equation(s) of motion. (6,4)

(b) A particle of mass m is moving in three dimension close to the earth's surface, Lagrangian of this system is given as $L=\frac{1}{2}m\left(\dot{x}^2+\dot{y}^2+\dot{z}^2\right)-mgz$, where x, y, z are the generalized coordinates. Identify the cyclic coordinates and find the canonical momentum conjugate to the remaining generalized coordinate. (3,4)

3. A particle of mass m is moving in a central potential V(r), Lagrangian of the system is given by

$$L=T-V=\frac{1}{2}m\left(\dot{r}^2+r^2\dot{\phi}^2\right)-V(r)$$

where r and ϕ are the generalized coordinates. Obtain the Hamiltonian, H and using Hamilton's equations of motion, show that

(i) $\frac{d}{dt}\left(mr^2\dot{\phi}\right)=0$, i. e., angular momentum (l) is constant.

(ii) $\frac{d}{dt}\left(T+V\right)=0$, i. e., total energy (E) is constant.

(6,6,5)

4. (a) Derive 3-velocity transformation equations using 4-velocity transformation rule. (7)

(b) A car (rest mass m_0) is moving with the speed $2c/\sqrt{5}$ at 45° with x–axis in x – y plane. Find the

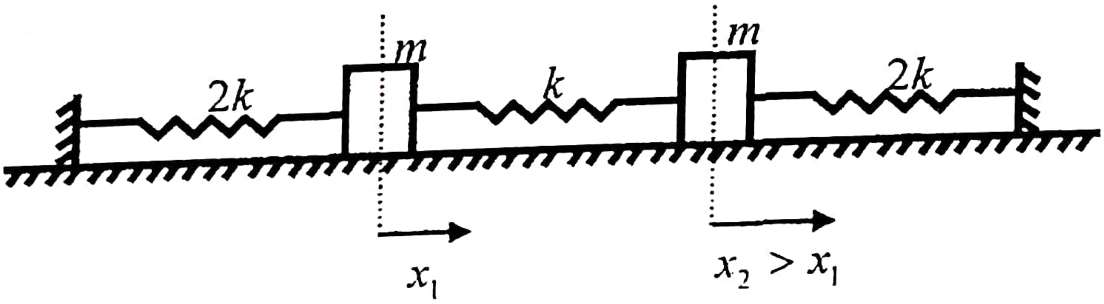
(i) 4-momenum of the car

(ii) norm of 4-momentum. (8,2)

5. (a) Using the invariance of the quantity $\omega t - \vec{k} \cdot \vec{r}$, obtain transformation rule for 4-wavevector, $k^{\mu} = \left(\omega/c, \vec{k}\right)$ and hence derive the expression for transverse Doppler effect. (6,3)

(b) An unstable atom at rest (rest mass M_0) decays into smaller atom (rest mass m_0) and photon. Using 4-vector approach or otherwise, prove that the speed of smaller atom is given by $u = c\dfrac{M_o^2 - m_o^2}{M_o^2 + m_o^2}$. (8)

6. Two blocks and three springs are configured as shown below. These blocks can execute longitudinal simple harmonic oscillations only. When the blocks are at rest, all springs are unstretched.



(a) Choosing the displacement of each block from its equilibrium position as generalized coordinates (x_1, x_2), obtain T (kinetic energy) and V (potential energy) matrices and hence find the angular frequencies of small oscillations. (2,2,2)

(b) Find the relations between (x_1, x_2) and normal coordinates (q_1, q_2) and hence obtain the expressions for T and V in terms of (q_1, q_2). (5,3,3)

7. (a) A charged particle (mass m, charge q) is at rest at origin and at t = 0, fields are applied such that $\vec{E} = E_0\hat{y}$ and $\vec{B} = B_0\hat{z}$. Find its position at time $t > 0$. (10)

P.T.O.

(b) If two capillaries of radii r_1, r_2 and length L_1, L_2 respectively are joined in series, derive the expression for the rate of flow of liquid through this arrangement using Poiseuille's formula. (7)

[This question paper contains 8 printed pages.] 04/6/24

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

Sr. No. of Question Paper : 3086 H

Unique Paper Code : 32227630

Name of the Paper : Advanced Quantum Mechanics

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

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 calculators are allowed.

P.T.O.

1. (a) Consider the vectors $|\psi> = 3i|\phi_1> - 7i|\phi_2>$ and $\chi> = |\phi_1> + 2|\phi_2>$, with $\{|\phi_i>\}$ an orthonormal basis. Calculate the inner product between $|\psi>$ and $\chi>$, and show that they satisfy the Cauchy-Schwarz inequality.

(b) Find the expectation value of the commutator relation $[\hat{j}_x, \hat{j}_y]$ in the state $|j = 1/2, m_j = 1/2>$, where $\hat{j}_x$ and $\hat{j}_y$ are total angular momentums.

(c) Consider the spin states $|+>$ and $|->$, basis states for a spin half system and suppose an operator $\hat{A}$ has the properties : $\hat{A}|+> = \frac{1}{2}i\hbar|->$ and $\hat{A}|-> = -\frac{1}{2}i\hbar|+>$. If a spin half system is in the state $|S> = \frac{1}{\sqrt{2}}[|+> + |->]$. Then find the value of $\hat{A}|S>$.

(d) Find the value of $\hat{J}_{-}\hat{J}_{+}|\frac{1}{2},\frac{1}{2}>$, where $\hat{J}_{+} = \hat{J}_x + i\hat{J}_y$.

(e) Show that the ground state energy of one-dimensional harmonic oscillator is

$E_0(\alpha) = \frac{\hbar^2}{2m}\alpha + \frac{m\omega^2}{8\alpha}$, where the symbols have their usual meanings. For calculating this, use the variational method and assume the trial function $\psi_0(x, \alpha) = Ae^{-\alpha x^2}$. (5×3=15)

2. (a) Consider a two dimensional space where a Hermitian operator $\hat{A}$ is defined by $\hat{A}|\phi_1> = |\phi_1>$ and $\hat{A}|\phi_2> = |\phi_2>$; $|\phi_1>$ and $|\phi_2>$ are orthonormal.

(i) Do the states the $|\phi_1>$ and $|\phi_2>$ form the basis?

(ii) Consider the operator $\hat{B} = |\phi_1><\phi_2|$. Is $\hat{B}$ Hermitian? Show that $\hat{B}^2 = 0$

P.T.O.

(iii) Show that the operator $\hat{B}\hat{B}^{\dagger} - \hat{B}^{\dagger}\hat{B}$ is unitary.

(b) If $\hat{A}$ and $\hat{B}$ commute, and if $|\psi_1>$ and $|\psi_2>$ are two eigenstates of $\hat{A}$ with different eigenvalues. ($\hat{A}$ is Hermitian), show that

(i) $<\psi_1|\hat{B}|\psi_2>$ is zero and

(ii) $\hat{B}|\psi_1>$ is also an eigenstate of $\hat{A}$ with the same eigenvalue as $|\psi_1>$; if $\hat{A}|\psi_1> = a_1|\psi_1>$ show that $\hat{A}(\hat{B}|\psi_1>) = a_1\hat{B}|\psi_1>$.

(9+6=15)

3. (a) Find the following commutation relations :

(i) $[\hat{x}, \hat{H}]$ where $\hat{H} = \frac{\hat{p}_x^2}{2m} + \frac{1}{2}m\omega^2\hat{x}^2$

(ii) $[\hat{L}_+, \hat{L}^2]$ where $\hat{L}_+ = \hat{L}_x + i\hat{L}_y$ and $\hat{L}^2 = \hat{L}_x^2 + \hat{L}_y^2 + \hat{L}_z^2$

(iii) $[\hat{S}^2, \hat{S}_Z]$

(b) If the expectation value of momentum is $<p>$ for the wave function ψ(x). Find the expectation value of momentum for the wave function $e^{ikx/\hbar}\psi(x)$. (9+6=15)

4. (a) Consider a particle of mass m which moves under the influence of gravity; the particles Hamiltonian is $\hat{H} = \frac{\hat{P}_z^{\ 2}}{2m} - mg\hat{Z}$, where g is the acceleration due to gravity. Calculate $\frac{d}{dt} < \hat{P}_z >$ and obtain $< \hat{Z} > (t)$, such that $< \hat{Z} > (0) = h$ and $< \hat{P}_Z > (0) = 0$.

P.T.O.

(b) If the state of a particle moving in one dimensional Harmonic oscillator is given by

$$|\psi> = \frac{1}{\sqrt{17}}|0> + \frac{3}{\sqrt{17}}|1> - \frac{2}{\sqrt{17}}|2> - \sqrt{\frac{3}{17}}|3>$$

where $|n>$ represents the normalised n^{th} energy eigenstate. Find the expectation value of number operator, $\hat{N}, \hat{N}^2$ and hence $\Delta\hat{N}$. (9+6=15)

5. (a) An electron is described by ha Hamiltonian that does not depend on spin. The electron's spin wave function is an eigenstate of S_z with eigenvalue $\pm\frac{\hbar}{2}$. The operator $\hat{n}.\vec{S}$ represents the spin projection along a direction $\hat{n}$, where $\hat{n} = \sin\theta(\cos\phi\hat{x} + \sin\phi\hat{y}) + \cos\theta\hat{z}$.

(i) Solve the eigenvalues problem of $\hat{n}.\vec{S}$. What is the probability of finding the electron in each $\hat{n}.\vec{S}$ eigenstate.

(ii) Assume now that the system is subjected to a homogeneous magnetic field $\vec{B} = \hat{n}B$. The Hamiltonian is $H = H_0 + \omega\hat{n} . \vec{S}$. The original state of the electron continues as an eigenstate of the modified system. Calculate the spin state of the system at later times $t > 0$. What is the probability of finding the system again in the initial state?

(b) Consider the operator $\hat{A} = \frac{1}{2}(\hat{J}_x\hat{J}_y + \hat{J}_y\hat{J}_x)$. Calculate the expectation value of $\hat{A}$ with respect to the state $|j, m>$. (9+6=15)

6. (a) Consider a system of three non-identical spin 1/2 particles whose hamiltonian is given as :

$H = -\frac{\epsilon_0}{\hbar^2}(\vec{S}_1 . \vec{S}_3 + \vec{S}_2 . \vec{S}_3)$, where ϵ_0 have the dimension of energy. Find the energy levels and their degeneracy.

P.T.O.

(b) Estimate the ground state energy of Hydrogen atom by means of the variational method using

trial wave function, $\phi_{\alpha}(r) = \begin{cases} 1 - \frac{r}{\alpha} & if r \leq \alpha \\ 0 & r > \alpha \end{cases}$,

where α is an adjustable parameter. Find a relation between α_{min} and the Bohr radius. Compare it with exact energy and find the fractional change in its value. Find a relation between α_{min} and the Bohr radius.

(6+9=15)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 3188

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

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 any **five** questions in all.

3. Question No. **1** is compulsory.

4. Symbols have their usual meanings.

P.T.O.

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

(a) What do you understand by nanomaterials? Give one example each of 2D and 1D nanomaterials.

(b) Determine the surface area to volume ratio of spherical particles of radii 1 nm, 10 nm, 1 μm, and plot the variation of the ratio with radii.

(c) How do electrons interact with matter in electron microscopy?

(d) Draw the typical XRD curves obtained for crystalline, polycrystalline and amorphous materials.

(e) Sketch and label a schematic diagram of a single electron transfer device.

(f) How do optical properties of a material change with the size of nanoparticle?

(g) How nanomaterials can be used for cancer therapy?

(h) What are organic (dye synthesized) solar cells?

2. (a) Explain briefly the physical and chemical vapour deposition techniques. (8)

(b) Explain the nucleation and growth process for colloidal synthesis of nanomaterials. (7)

3. (a) Considering the free electron gas model, determine the density of state expression [ρ(E)] for a 3D material. Draw the corresponding E vs. K and E vs. ρ (E) diagram of 3D and 2D material for comparison and explain briefly the important features of the two. (12)

(b) Explain why the confinement results in the appearance of the zero-pointa energy in the E vs. K diagram. What is the physical significance of the zero-point energy? (3)

4. (a) Discuss the absorption, emission and luminescence radiative processes. (10)

(b) Why is vacuum required in all thin film deposition techniques? How is it achieved? (5)

5. Discuss the principle and fabrication technique of any two of the following used for the synthesis of nanomaterials?

(i) Sol-gel

(ii) Sputtering

P.T.O.

(iii) Hydrothermal method

(iv) Molecular Beam Epitaxy (7.5×2=15)

6. (s) How is ballistic transport different from diffusive transport? (5)

(b) Obtain an expression for the variation in electrostatic energy of a system for single electron charging. Name the effect associated with it. (10)

7. (a) What are silicon nanowires? Give its various applications. (8)

(b) What are quantum LASER devices? How are they formed? (7)

(300)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 3189

Unique Paper Code : 32227613

Name of the Paper : Communication System

Name of the Course : **B.Sc. Hons.–(Physics)_DSE Paper**

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. **All** questions carry equal marks.
4. Question No. **1** is compulsory.
5. Use of scientific calculator is allowed.

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

(a) Briefly explain why a signal is required to be converted into passband region from baseband region for communication?

P.T.O.

(b) What is multiplexing? Define TDM and FDM.

(c) What is the function of *mixer* in a super heterodyne receiver?

(d) The maximum peak-to-peak value of an AM wave is 45 V. The peak-to-peak value of the modulating signal is 20 V. What is the percentage of modulation?

(e) Write the statement for sampling theorem. What is aliasing?

(f) Calculate the minimum bandwidth for a FSK signal with a bit rate of 200 kbps and S/N of 15dB.

2. (a) Show that there are infinite numbers of frequency bands accommodated in Frequency Modulated wave.

(b) Find out the carrier and modulating frequency, modulation index and the maximum deviation for a frequency modulated wave given as:

$E = 12 \sin (6 \times 10^8 t + 5 \sin 1250 t)$ (10,5)

3. (a) Draw the circuit diagram for the generation and detection of single side band amplitude modulated wave and explain it's working.

(b) Distinguish between amplitude and frequency modulation. Calculate the power developed by an AM wave in a load of 100 Ω when the peak voltage of the carrier is 100 V and the modulation factor is 0.4. (10,5)

4. (a) Enumerate the merits and demerits of digital communication system. What is the function of Encoder in PCM? Explain different Encoding schemes.

(b) For a PCM coding scheme for 3-bits, determine the quantization voltage, quantization error (e_q) and PCM code for the analog sample voltage of +1.07V. (10,5)

5. (a) Describe in detail the modulation techniques of Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM) and Pulse Position Modulation (PPM) with suitable proper diagrams. Explain the advantages and disadvantages of PCM over the Pulsed Modulation scheme.

(b) A FDM channel having total bandwidth of 100 MHz requires 20 kHz bandwidth for the transmission of single signal. How many signals can be transmitted simultaneously using a FDM scheme if the guard band frequency is 2 kHz? (10,5)

P.T.O.

6. (a) Draw a block diagram for a Transponder and explain its working. Discuss about the operating frequency of uplink and downlink in C-band.

(b) Define the term satellite visibility? Calculate the visibility of geostationary satellite for earth station located at the equator. (10,5)

7. (a) What is frequency reuse? Draw the frequency reuse patterns for the following cluster sizes: (i) N=4 (ii) N=7. Determine the frequency reuse distance for a mobile system of cluster size 10 and radius of each cell 5 kilometres.

(b) What do you understand by the SIM and IMEI numbers in mobile communication? (8,7)

[This question paper contains 8 printed pages.]

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

Sr. No. of Question Paper : 3194

Unique Paper Code : 32227625

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

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 including **Q. No. 1** which is compulsory.

3. Non-programmable **scientific calculator** is allowed.

P.T.O.

1. (a) Attempt all parts: (3×5=15)

Find the equation of shortest path between two points on the surface of right circular cylinder of radius 'a'.

(b) Lagrangian of some system is given as

$$L = \frac{1}{2}m(\dot{x}^2 + \dot{y}^2) + \alpha(x\,\dot{y} - y\,\dot{x})\,;$$ m, α are constants

Identify the generalized coordinates and hence find their corresponding momenta.

(c) Two sets are given along with their binary operations:

(i) W = {0, 1, 2, 3,... }; '+'
(additive set of whole numbers)

(ii) Z = {0, ± 1, ± 3,... }; '+'
(additive set of odd integers)

Does any of these sets form a group? Give at least one reason in each case.

(d) Consider a cyclic group $C = \langle a \rangle$ such that $a^8 = e$,

(i) write all generators of C.

(ii) find all non-trivial subgroups of C.

(e) Suppose a random variable X takes on the values

-3, 2, 4, 7

with respective probabilities

$$\frac{k+1}{10}, \quad \frac{2k-2}{10}, \quad \frac{3k-5}{10}, \quad \frac{k+2}{10}$$

Find the value of k and expected value of X.

2. (a) Find the Legendre transform $G(V_1, V_2)$ of the function

$$F(u_1, u_2) = 5u_1^2 + 4u_1u_2 + 5u_2^2$$

$[v_i = \partial F/\partial u_i, \quad u_i = \partial G/\partial v_i, \quad F + G = \Sigma\, u_i v_i]$ (7)

(b) A system with one degree of freedom has a Hamiltonian

P.T.O.

$$H(q, p) = \frac{p^2}{2m} + bp + cq^2; \qquad m, b, c \text{ are constants}$$

here q is the generalized coordinate and p is its corresponding momentum.

(i) Obtain the Lagrangian $L(q, \dot{q})$. (4)

(ii) Determine the Lagrangian equation of motion. (4)

3. (a) Using Euler-Lagrange equation, find the extremal of the following functional

$$I = \int_0^1 [y'^2 + 12xy]\, dx; \quad y' = \frac{dy}{dx}$$

such that y(0) = 0 and y (1) = 1. (7)

(b) Simple pendulum (ℓ, m) is executing SHM about its equilibrium position as shown in Fig. (1).

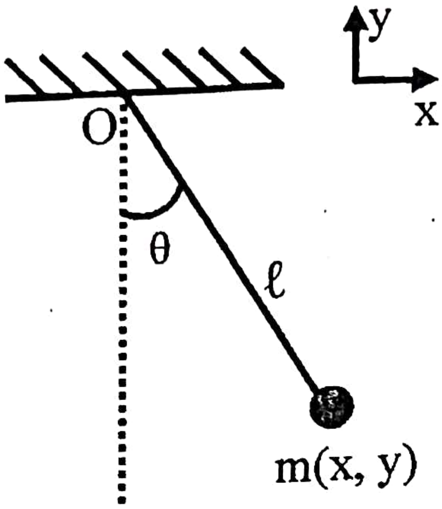


Fig. (1)

(i) Using the generalized co-ordinate and the generalized velocity, construct the Lagrangian and obtain the equation of motion.

(ii) Also, deduce the Hamiltonian. (5, 3)

4. (a) Consider the set K:

K = {e, a, b, ab}

where binary operation '*' is defined as a*a = b*b=e, a*b = b*a.

(i) Prepare the group multiplication table for K. (4)

(ii) Determine whether K is a cyclic group or not. (4)

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

$$\begin{bmatrix} a & b \\ -b & a \end{bmatrix}$$ (7)

5. Consider the set G with the binary operation '•':

G= {1, 2, 3, 4, 5, 6, 7, 8}

Group table of G is given as:

•	1	2	3	4	5	6	7	8
1	1	2	3	4	5	6	7	8
2	2	1	4	3	6	5	8	7
3	3	4	2	1	7	8	6	5
4	4	3	1	2	8	7	5	6
5	5	6	8	7	1	2	4	3
6	6	5	7	8	2	1	3	4
7	7	8	5	6	3	4	1	2
8	8	7	6	5	4	3	2	1

(a) Find Z(G), the centre of the group G. (1)

(b) H = {1, 2, 3, 4} is a subgroup of G, find left and right cosets of H in G and hence infer whether H is a normal subgroup or not. (8,2)

(c) Also, check if subgroup H is abelian / cyclic / both. (4)

6. (a) Two marbles are selected one after the other without replacement from a box containing 3 white marbles and 2 red marbles. Find the conditional probabilities:

P.T.O.

(i) P(2 white | first is white) (4)

(ii) P(2 red | second is red) (4)

(b) Using Binomial distribution, find the probability of guessing correctly at least 8 of the 10 answers in a true-false examination. (7)

7. (a) If X has a Poisson distribution such that

$P(X = 1) = P(X = 2)$,

find $P(X = 5)$. (3)

(b) Show that in a Normal distribution $N(\mu, \sigma)$

mean, $\bar{x} = \mu$ (4)

(c) Using multinomial distribution or otherwise, find the probability of throwing 11 in exactly one throw with 4 dice. (8)

June 2024

[This question paper contains 8 printed pages.]

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

Sr. No. of Question Paper : 3195

H

Unique Paper Code : 32227626 IC

Name of the Paper : Classical Dynamics

Name of the Course : **B.Sc. (Hons) Physics-DSE (Old Course)**

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. Question No. **1** which is compulsory.

3. Attempt any **four** questions from the remaining.

1. Attempt all of the following : (3×5=15)

   (a) Explain the concept of length contraction using the space-time diagram.

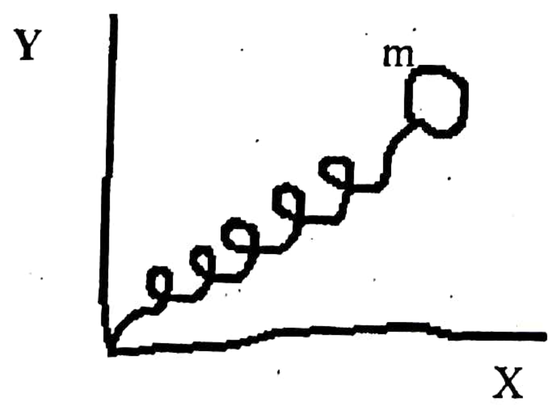
P.T.O.

(b) Show that motion of a charged particle in crossed electric and magnetic field is that of a cycloid.

(c) Given that the fluid velocity components to be :

$v_x = \frac{-ay}{x^2+y^2}, v_y = \frac{bx}{x^2+y^2}, v_z = 0.$ Find the equation of the stream lines.

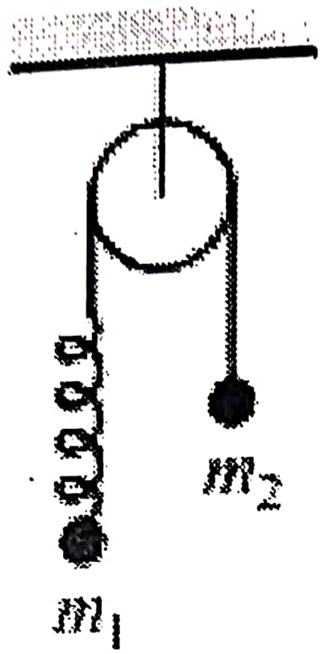
(d) As shown in the figure, a particle of mass m moves in a horizontal plane. The mass is connected to the origin by the spring with spring constant k and a relaxed length. Find the Lagrangian L. Verify that $E = \frac{\partial L}{\partial \dot{q}} \dot{q} - L$ represents the energy and is conserved.



(e) A rod of length L is inclined at an angle θ' to the x-axis in an inertial frame of reference S′ moving with velocity v in the x-direction w.r.t. another inertial frame 5. What will be the angle θ of the rod with respect to the x-axis in the frame S?

2. (a) What is Hamilton's Principle. Derive Euler-Lagrange equation using the Hamilton's Principle. Discuss the two main advantages of the Lagrangian approach over Newtonian approach. (2,4,2)

(b) A spring with spring constant k and relaxed length zero is inserted in a standard Atwood's machine to create the setup shown in the Figure.



Find the generalized coordinates and their conjugate generalized momenta of the system. Find the Hamiltonian in terms of these generalized coordinates and then write down the Hamilton's equations. (7)

3. (a) Define Hamiltonian, and derive Hamilton's equation of motion. Using Hamilton's equation of motion, show that the Hamiltonian,

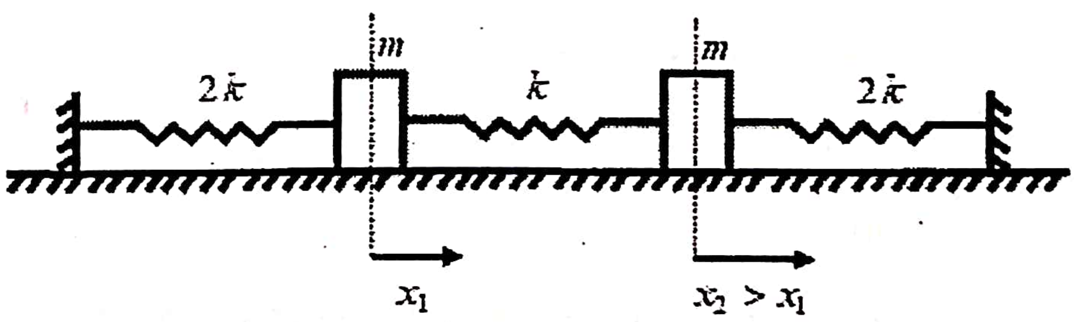
$H = \frac{p^2}{2m} e^{-rt} + \frac{1}{2} m\omega^2 x^2 e^{rt}$ leads to the equation of motion of a damped oscillator, $\ddot{x} + r\dot{x} + \omega^2 x = 0$.

(4,4)

(b) With the help of diagram explain the difference between (i) steady and unsteady flow (ii) uniform and non-uniform flow, (iii) Is it possible to have a uniform but unsteady flow? Give an example.

(7)

4. Two blocks and three springs are configured as shown in the Figure. When the blocks are at rest, all springs are unstretched. These blocks are constrained to move horizontally only.



P.T.O.

(a) Choosing the displacement of each block from its equilibrium position as generalized coordinates (x_1,x_2), obtain T (kinetic energy) and V (potential energy) matrices and hence find the angular frequencies of small oscillations. (8)

(b) Find the relations between (x_1,x_2) under normal mode of oscillation. Also, find the normal coordinates (q_1,q_2) and hence obtain the expressions for T and V in terms of (q_1,q_2). (7)

5. (a) Using the invariance of the quantity $\omega t - \vec{k}\cdot\vec{r}$, obtain transformation rule for 4-wavevector, $k^{\mu} = (\omega/c, \vec{k})$. Derive the expression for transverse Doppler effect. (7)

(b) An object moving in y-direction with a constant velocity travels a distance of 288 m in 1.2 microsecond in the S-frame. Find the proper time interval for crossing the distance. Verify that it remains unchanged in a frame S' which is moving in the positive x-direction with a speed 0.6c. Also find speed of S′ in the objects frame. (8)

6. (a) Using four vector approach prove that $E^2 = c^2p^2 + m_0^2c^4$ where the symbols have their usual meaning. (7)

(b) The speed of a particle of rest mass $135\frac{\text{MeV}}{c^2}$ is found to be 0.8c in a frame S′. The frame S′ is observed to move with a speed of 0.6c in another frame S. All the motions are collinear and are taken to be along x-axis. In S′, it is found that the particle decays into the two photons. Each of the photon makes an angle θ′ with the initial direction of the particle. Find the angle θ′ and the frequency of the photon in this frame. Also find the corresponding angle θ and frequency of photon in S frame. (8)

P.T.O.

7. (a) A charged particle (mass m, charge q) is at rest at the origin. At t = 0, an electric field $\vec{E} = E_0\hat{y}$ and a magnetic field $\vec{B} = B_0\hat{z}$ are switched on. Find the position of the particle at a later time t. (8)

(b) Two capillaries of radii r_1, r_2 and length l_1, l_2 are joined in a series. Using Poiseuille's formula, derive the expression for the rate of flow of liquid through this arrangement. (7)

[This question paper contains 8 printed pages.]

Your Roll No. ....

Sr. No. of Question Paper : 3197

Unique Paper Code : 32227630

Name of the Paper : Advanced Quantum Mechanics

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

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 calculators are allowed.

P.T.O.

3197

1. (a) Two state of a physical system are represented by $|\psi_1> = 6i|\phi_1> - 3i|\phi_2>$ and $|\psi_2> = -2|\phi_1> + 4i|\phi_2>$. $|\phi_1>$ and $|\phi_2>$ are orthonormal basis. Determine the scalar product $<\psi_1|\psi_2>$ and verify that

$$<\psi_1|\psi_2>^* = <\psi_2|\psi_1>.$$

(b) Evaluate the commutator for spin angular momentum operators $[\hat{S}_+, \hat{S}_z]$.

(c) Show that $\mathbf{a}^\dagger\mathbf{a}^\dagger\mathbf{a}\mathbf{a} = \hat{\mathbf{N}}^2 - \hat{\mathbf{N}}$, while $\mathbf{a}\mathbf{a}\mathbf{a}^\dagger\mathbf{a}^\dagger = 2 + 3\hat{\mathbf{N}} + \hat{\mathbf{N}}^2$; where $\mathbf{a}$, $\mathbf{a}^\dagger$ and $\hat{\mathbf{N}}$ are the annihilation, creation and number operators respectively.

(d) Compute the expression $<j\ m|\hat{J}_x^{\ 2}|j\ m>$ in the standard total angular momentum basis.

(e) Show that the ground state energy of one-dimensional harmonic oscillator is

$E_0(\alpha) = \frac{\hbar^2}{2m}\alpha + \frac{m\omega^2}{8\alpha}$, where the symbols have their usual meanings. For calculating this, use the variational method and assume the trial function

$\psi_0(x, \alpha) = Ae^{-\alpha x^2}$. (3×5=15)

2. (a) Consider two states

$|\psi_1> = 2i|\phi_1> + |\phi_2> - a|\phi_3> + 4|\phi_4>$ and

$|\psi_2> = 3|\phi_1> - i|\phi_2> + 5|\phi_3> - \phi_4>$, where

$\{|\phi_n>\}$ are orthonormal kets and 'a' is constant.

(i) Find the value of 'a' so that $|\psi_1>$ and $|\psi_2>$ are orthogonal.

(ii) Calculate the scalar products $<\psi_1|\psi_2>$ and $<\psi_2|\psi_1>$. Are they equal?

P.T.O.

(iii) Find the Hermitian conjugate of $|\psi_1>$ and $|\psi_1><\psi_2|$.

(b) (i) Show that the eigenvalues of a unitary operator are complex number of muduli equal to one and the eigenvectors of unitary operator that has no degenerate eigenvalues are mutually orthogonal.

(ii) Using the completeness condition show that $Tr(\hat{A}\hat{B}) = Tr(\hat{B}\hat{A})$. (9+6=15)

3. (a) Find the following commutation relations :

(i) $[\hat{p}^2, [\hat{H}, \hat{x}^2]$, where $\hat{H} = \frac{\hat{p}^2}{2m} + \frac{m\omega^2}{2}\hat{x}^2$

(ii) $[\hat{L}^2, \hat{S}.\hat{L}]$;

(iii) $[\hat{H}, \hat{a}^{\dagger}]$ where $\hat{H}$ is the hamiltonian of one dimensional harmonic oscillator and $\hat{a}^{\dagger}$ is the raising operator.

(b) Using Ehrenfest's Theorem find the value of $\frac{d}{dt} < \hat{x} . \hat{p} >$, where $\hat{x}$ and $\hat{p}$ are position and momentum operator respectively. (9+6=15)

4. (a) Find the eigenvalues and eigenvectors of spin operator $\hat{S}$ of an electron in the direction of $\hat{n}$ (unit vector) where $\hat{n} = (\sin\theta \cos\phi)\hat{x} + (\sin\theta \sin\phi)\hat{y} + \cos\theta\hat{z}$. Also find the probability of measuring $\hat{S}_z = -\hbar/2$.

P.T.O.

(b) The state of particle is represented as $|\psi> = A[2|0> + 5|2>]$, where $\{|n>\}$ are the eigenstate of hamiltonian of one dimensional harmonic oscillator. Find the expectation value of energy in the state $|\psi>$. (9+6=15)

5. (a) Consider a spin-half particle with a magnetic moment μ. At time t = 0, the state of particle is

$$|\psi(t=0)> = |+>_x = \frac{1}{\sqrt{2}}(|+> + |->)$$

The Pauli spin matrices are given by :

$$S_x = \frac{\hbar}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, S_y = \frac{\hbar}{2}\begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, S_z = \frac{\hbar}{2}\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}.$$

(i) If the particle evolves in a uniform magnetic field parallel to the z=direction, $\vec{B} = B_0\hat{z}$, calculate $|\psi(t)>$, the state of the particle (in the $|+>, |->$ basis) at some later time t.

(ii). At time t, the observable S_x is measured. What is the probability that the value $+\hbar/2$ will occur.

(b) A polar representation of the creation and annihilation operators for a simple harmonic oscillator can be introduced as : $\hat{a} = \sqrt{\hat{N}+1}e^{i\hat{\phi}}$, and $\hat{a}^\dagger = e^{-i\hat{\phi}}\sqrt{\hat{N}+1}$; where the operators $\hat{N}$ and $\hat{\phi}$ are assumed to be hermitian. The commutator relation still holds $[\hat{a}, \hat{a}^\dagger] = 1$. Show that $\cos\hat{\phi}|n>$ is the eigenstate of $\hat{N}$ with eigenvalue $(n-1)$. (9+6=15)

6. (a) A system of three (non-identical) spin-half particles whose spin operators are $\hat{S}_1, \hat{S}_2$ and $\hat{S}_3$ is governed by the Hamiltonian

$$\hat{H} = \frac{\alpha}{\hbar^2}\hat{S}_1 . \hat{S}_2 + \frac{\beta}{\hbar^2}(\hat{S}_1 + \hat{S}_2) . \hat{S}_3,$$

where α and β have the unit of energy. Find the energy eigenvalues and their degeneracy.

P.T.O.

(b) For a particle of mass m moving in one-dimensional rigid box with walls at $x = 0$ and $x = a$. Use the trial function of the form $\psi(x) = x(a - x)$ estimate its ground state energy using the variational method. (6+9=15)

(100)