PHYSICS

PAPER- I

SECTION - A

1. Answer any four of the following

(4 × 10 = 40)

(a) Using plane polar co-ordinates, obtain expressions for the generalized forces Q_r and Q_θ a particle of mass m moving in a plane.

(b) What is the speed of an electron moving relativistically with energy of 1 MeV?

What is the potential through which the electron must be accelerated to gain this speed?

(c) Five vibrations of equal amplitudes are superposed with all in phase and then with successive phase difference of δ. Calculate the ratio of the resultant intensities in the two cases.

(d) Compare Galilean and Lorentz transformations. Show that Galilean transformation is a special case of the Lorentz transformation.

(e) Derive expressions for acceptance angle and numerical apperture of an optical fibre.

2. (a) Discuss the properties of the moment of inertia tensor.

Four point masses, each equal to m, are placed at (b, 0, 0), (0, b, 0), (0, 0, b) and (b, b, b). Evaluate inertia tensor for this system.

(20)

(b) Deduce the Lagrange's equation of motion from Hamilton's principle.

(20)

3. (a) Consider two inertial frames of reference S_1 and S_2 with their axes parallel to each other and their origins coinciding at t = 0. If S_2 is moving with respect to S_1 with velocity $\vec{v} = \hat{k}\overline{v}$, where $\hat{k}$ is a unit vector along the z-axis, write down the Lorentz transformation relations between co-ordinates and time measured in S_1 and S_2. Generalise this result for the case = $\vec{v} = \hat{i}v_x + \hat{j}v_y$.

(20)

(b) Consider two waves given by

$$y_1 = a\sin\left(2\pi n_1 t - \frac{x}{\lambda_1}\right) \; and$$

$$y_2 = a\sin\left(2\pi n_2 t - \frac{x}{\lambda_2}\right)$$

with the same amplitude a and slightly different frequencies travelling in the same direction. Using the principle of superposition, show that minimum or maximum displacement at a given point repeats at regular intervals of time.

(20)

4. (a) Show that when light passes from air into a medium of refractive index μ, its wavelength λ in air changes to $\frac{\lambda}{\mu}$ in the medium. Hence prove that, if a drop of liquid is introduced between the lens and the glass plate in Newton's rings device, then

$$\mu = \frac{\left(D_{m+p}^2 - D_m^2\right)_{air}}{\left(D_{m+p}^2 - D_m^2\right)_{liq}}$$

given that $4R\mu\lambda = \left(D_{m+p}^2 - D_m^2\right)_{air}$

Here R is the radius of curvature of the lens. An equiconvex lens of focal length 80 cm (μ of material is equal to 1.55) is placed over a plane glass plate. Newton's rings are formed with green light (λ = 5.46 × 10^{-5} cm). Deduce the diameter of the first dark ring round the centre of the fringe system.

(20)

(b) Distinguish between single slit and double slit diffraction pattern. Discuss the missing orders in a double slit diffraction pattern when

(i) $a = b$

(ii) $a = b/2$ and

(iii) $a + b = a$

where a is slit width and b is double slit separation.

(20)

SECTION B

5. Answer any four of the following:

(4 × 10 = 40)

(a) Give the three dimensional relation between the electrostatic field $\vec{E}$ and the scalar potential ϕ. Show that the field is irrotational. What is the physical significance of $\vec{E}$ being irrotational? From the relation between $\vec{E}$ and ϕ obtain Poisson's and Laplace's equations.

(b) What is gauge transformation? Explain the Coulomb and Lorentz gauges.

(c) Using the first and second laws of thermodynamics, show that Tds = dH - VdP where symbols have their usual meanings. Using this, find the change in entropy for a constant pressure process.

(d) Mention the physical laws behind the four Maxwell's equations of electrodynamics. Give justification for the modification effected by Maxwell to Ampere's law.

(e) Explain the concept of negative temperature.

6. (a) Consider a discrete system of charge distribution $q_1, q_2, \ldots, q_i, \ldots$ placed at $\vec{\gamma}_1, \vec{\gamma}_2, \ldots, \vec{\gamma}_i, \ldots$ write the expression (without derivation) for the monopole and dipole moments.

Using the following expression, obtain all the components of the quadrupole moment tensor of the above charge distribution.

$$Q_{jk} = \sum_i q_i\left(3\gamma_j k_i - \gamma_i^2 \delta_{jk}\right)(j, k = x, y, z)$$

Here δ_{jk} is the Kronecker delta.

(20)

(b) Consider a rectangular loop having sides a and b lying in the yz plane of a Cartesian coordinate system, with the origin located at the centre of the loop. When the loop is rotating about z-axis so that the angle of rotation ϕ = ωt a magnetic field, $\vec{B} = \cos B_x \cos(\omega t + \alpha)$ is switched on. Find the emf induced in the loop.

(20)

7. (a) Consider the following components of $\vec{E}$ and $\vec{H}$ fields which are given by

$$E_y = -H_0\mu_0\omega\left(\frac{a}{\pi}\right)\sin\left(\frac{\pi x}{a}\right)\sin(kz - \omega t)$$

$$H_x = -H_0 k\left(\frac{a}{\pi}\right)\sin\left(\frac{\pi x}{a}\right)\sin(kz - \omega t)$$

$$H_z = -H_0\cos\left(\frac{\pi x}{a}\right)\cos(kz - \omega t)$$

Show that $\overline{E}$ and $\overline{H}$ are mutually perpendicular and also verify that $\overline{E}$ and $\overline{H}$ satisfy all the Maxwell's equations in vacuum.

(20)

(b) Derive Planck's law for black body radiation. Use it to obtain Wien's displacement law and Stefan Boltzmann law.

(20)

8. (a) Derive Clausius-Clapeyron equation. Explain where is it applicable?

(20)

(b) A liquid film is stretched through an area dA, the volume remaining fixed.

(20)

(i) Modify the equation $Tds = dU + PdV$ for the present case,

(ii) Write down the first Maxwell relation for this case, and

(iii) Show that the temperature falls when the film is adiabatically stretched.

PHYSICS

PAPER- II

SECTION - A

1. Answer any four of the following

(4 × 10 = 40)

(a) The lifetime of an excited state of an atom is 10^{-8} s. Calculate the energy width of such a state.

(10)

(b) Calculate the Fermi energy in eV for sodium whose atomic weight is 23 and density is 0.97×10^3 kg m.

(10)

(c) A radioactive element having mass number A = 216 emits α-particles of energy 4 MeV with a probability of 10^{-39}. Calculate the half life of the element making use of the relation for nuclear radius $R = 1.2\ A^{1/3}$ Fermi.

(10)

(d) Calculate the Lande g-factor for $3S_1$ and $3P_1$ levels. How many 'π' lines and 'σ' lines are observed for the transition $3P_1 \rightarrow 3S_1$?

(10)

(e) The potential energy for a diatomic molecule is given by

$$V(R) = D_0\left[1 - \exp\left\{-a(R - R_0)\right\}\right]^2.$$

where D_0, a and R_0 are constants. Show that V(R) is minimum at $R = R_0$. Obtain the expression for the frequency of oscillation for this potential.

(10)

2. (a) A wave packet is formed by using a wave function $Ae^{-\alpha|x|}$ where A is a constant.

Obtain an expression for 'A' from normalization condition and also calculate the value for the probability of the particle between 0 and 1/α.

(20)

(b) Determine the energy eigen values and the corresponding eigen functions for a particle of mass 'm' in an infinite one-dimensional potential well.

(20)

3. (a) Prove that the operators $\hat{\sigma}_x, \hat{\sigma}_y, \hat{\sigma}_z$ defined by

$$\hat{\sigma}_x\alpha = \beta\hat{\sigma}_y\alpha = i\beta, \hat{\sigma}_z\alpha = \alpha$$

$$\hat{\sigma}_x\alpha = \widehat{\alpha\sigma}_y\beta = -i\alpha, \hat{\sigma}_z\beta = -\beta$$

satisfy the same relationship as Paul spin matrices.

(20)

(b) Describe with the help of a diagram the Stern-Gerlach experiment. What is the significant of this experiment?

(20)

4. (a) What is the principle of Nuclear Magnetic Resonance?

(10)

(b) Outline the construction of an NMR spectrometer.

(10)

(c) Describe the origin of Raman lines due to pure rotational transitions.

(10)

(d) Classify the Raman and infra-red vibrational modes in the linear tri-atoraic molecule carbon dioxide.

(1[illegible])

SECTION B

5. Answer any four of the following

([illegible] x 10 = 40)

(a) Calculate the binding energy per nucleon for $^{87}_{38}Sr$ nucleus.

Given

mass of proton = 1.0078 amu

mass of neutron = 1.0087 amu

mass of ^{87}Sr = 86.9089 amu

(10)

(b) Calculate the Q-value of the reaction

$$p = {}^{208}Pb \rightarrow d + {}^{207}Pb$$

Given

mass of proton = 1.0078 amu

mass of deutron = 2.0141 amu

mass of ^{208}Pb = 207.[illegible]76[illegible] amu

mass of ^{207}Pb = [illegible]06.97[illegible]9 amu

(10)

(c) Determine which of the following decays/reactions is forbidden/allowed and explain why:

(10)

(i) $\bar{p} + n \rightarrow \bar{\Lambda} +$ [illegible]

(ii) $n \rightarrow$ [illegible] $+ e^- + \upsilon_e$

(iii) [illegible] $+ p \rightarrow \pi^- + \Sigma^+$

(iv) $\pi^+ \rightarrow \mu^+ + \upsilon_\mu$

(d) Lead in the superconducting state has critical temperature of 6.2 K at zero magnetic field and critical field of 0-64 MA m^{-1} at 0 K. Determine the critical field at 4 K.

(10)

(e) The datasheet for a certain enhancement type MOSFET reveals that I_D (ON) = 10 mA at V_{GS} = -12 V and V_{GS} (Th) = -3 V. Is the device P-channel or N-channel? Find the value of I_D when V_{GS} = -6 V.

(10)

6. (a) Write the semi-empirical mass formula and explain each term.

(15)

(b) What are the characteristics of nuclear forces? Name any four of them.

(5)

(c) What do you understand by parity violation in beta decay? Describe an experiment for its verification.

7. (a) Explain various conservation laws as encountered in particle physics. (20)

(b) What is Josephson's effect? (10)

(c) How are Josephson-junctions applied in squid type magnetometers? (10)

8. (a) Making use of operational amplifiers, set up an analog circuit to obtain the solution of the following differential equation : (20)

$$\frac{d^2v}{dt^2} + K_1 + \frac{dv}{dt} + K_2 v - v_1 = 0$$

(b) Draw a circuit diagram for a transistor push-pull amplifier. Explain its working. (15)

(c) Give salient features of a INTEL 8085 microprocessor. (5)

List of useful constant

Mass of proton : 1.637×10^{-27} kg

Mass of neutron : 1.675×10^{-27} kg

Mass of electron : 9.11×10^{-31} kg

Planck constant : 6.626×10^{-34} kg

Boltzmann constant : 1.380×10^{-23} JK^{-1}

Electronic charge: 1.602×10^{-19} C

Atomic mass unit (amu): 1.660×10^{-27} kg

: 931 MeV

Velocity of light in vacuum, $c = 3 \times 10^8$ ms^{-1} $m\left({}^4_2He\right) = 4.002603$ amu

Avogadro number : $m_0 = 6.023 \times 10^{23}$