PHYSICS

PAPER - I

SECTION - A

Useful Constants

Electron charge : $e = 1.602 \times 10^{-19}$ C
Electron mass : $m_e = 9.109 \times 10^{-31}$ kg
Proton mass : $m_p = 1.672 \times 10^{-27}$ kg
Vacuum permittivity : $\varepsilon_0 = 8.854 \times 10^{-12}$ farad/m
Vacuum permeability : $\mu_0 = 1.257 \times 10^{-6}$ henry/m
Velocity of light : $c = 3 \times 10^{8}$ m/s
Boltzman constant : $k = 1.38 \times 10^{-23}$ J/K
Electron volt : eV $= 1.602 \times 10^{-19}$ J

1. Answer any four of the following

$(4 \times 10 = 40)$

(a) The coordinates of a particle of mass m are given by $x = x_0 \cos \omega_1 t$ *and* $y = y_0 \sin \omega_2 t$.

(i) Find the x, y components of force acting on the particle. Under what conditions will this be a central force?

(ii) Find the potential energy and show that the total energy is conserved.

(b) Discuss Michelson – Morley experiment. Show as to how it led to the rejection of the ether hypothesis.

(c) A quartz quarter-wave plate is to be used with the sodium light (λ = 5896 Å). What should be its thickness?

(The refractive indices for the ordinary and the extraordinary rays are given respectively by $n_0 = 1.54425$ and $n_e = 1.55336$)

(d) What are the progressive waves and standing waves? How will you distinguish between the two? The equation of a standing wave in a metal rod is given by $y = 0.002 \sin\left(\frac{\pi}{3}x\right)\sin(100t)$.

Obtain the value of the maximum tensile stress at a point x = 1.00 cm. Young's modulus for the material of the rod = 8×10^{11} dynes/cm^2.

(e) A grating has 315 rulings per mm. For what wavelengths in the visible spectrum can one observe the fifth order diffraction?

2. (a) Explain what is coriolis force. Show that the deflection of a freely falling particle under the earth's gravity due to coriolis force is,

$$x = \frac{\omega}{3}\sqrt{\frac{8h^3}{g}}\sin\theta,$$

where θ is the colatitude, h is the height through which the particle falls and w is the angular velocity of the earth.

(20)

(b) Derive the Euler equations for the motion of a rigid body.

(20)

3. (a) Write all the four components of the 4-momentum in special theory of relativity. Consider a frame S' moving with respect to the inertial frame S with a velocity $\vec{v} = v\hat{e}_x$, where $\hat{e}_x$ is a unit vector along X-axis. Apply Lorentz transformation to transform the components of the 4-momentum from S to S'.

(20)

(b) Consider a particle of mass m performing oscillations along the X-axis under the influence of the forces $-kx, -r\frac{dx}{dt}, and\ F = F_0 \sin pt$. Here k, and F_0, p are all constants. Write the equation of motion for this particle (do not solve this equation). Calculate the amplitude of oscillation and the phase difference between the driven oscillator and the applied force.

(20)

4. (a) Find the intensity expression for the Fraunhofer diffraction pattern of the double slit. Deduce the conditions for maxima and minima.

Discuss the missing orders ma double slit pattern

(20)

(b) Derive the expression for the intensity of interference fringes formed by transmission in a Fabry — Perot interferometer and its chromatic resolving power.

Explain why it is suitable to study the hyperfine structure.

(20)

SECTION B

5. Answer any four of the following:

(4 × 10 = 40)

(a) A point dipole $\vec{p}$ at $\vec{r}$ is in the field of a point charge q located at the origin. Find the energy of the dipole and the force experienced by it.

(b) What is the displacement current? Explain clearly the reasons for which Maxwell had to introduce this current to generalize one of the electromagnetic equations to a non-stationary case.

(c) In the case of water at 0°C, the latent heat of fusion is 3.35 × J/kg, the volume of one gm of ice is 1.09070 cc, and the volume of one gm of water is 1.00013 cc. Find the change in melting point of ice for 1 atm increase in pressure.

(d) Distinguish between mean value, peak value, and the root mean square value of an alternating current.

(e) Calculate the number of molecules in 0.1 kg of oxygen, whose velocities lie between 195 and [illegible] m/s at 00 C.

6. (a) Write the Poisson equation in electrostatics in the spherical polar coordinates for potential $\Phi\left(\vec{r}\right)$ and the volume charge density $\rho\left(\vec{r}\right)$. Specialise it to the case of a sphere of radius r_0 with $\rho\left(\vec{r}\right)$ = constant (say ρ_0) for $r \le r_0$, $\rho\left(\vec{r}\right) = 0$ for $r > r_0$. Find $\Phi\left(\vec{r}\right)$, both inside and outside the sphere. Now apply the following boundary conditions:

(i) $\Phi_{out} \to 0$ for $r \to \infty$;

(ii) Φ_{in} finite for $r = 0$;

(iii) Φ and the component of $\vec{E}$ normal to the surface of the sphere are continuous at r = r_0. Then show that

$$\Phi_{out}\left(\vec{r}\right) = \frac{\rho_0 r_0^3}{3\varepsilon_0 r}$$

$$\Phi_{in}\left(\vec{r}\right) = \frac{\rho_0}{6\varepsilon_0}\left(3r_0^2 - r^2\right)$$

Here, Φ_{out} and Φ_{in} are the potentials outside and inside the sphere, respectively.

(20)

(b) Draw the diagrams for LCR circuits equivalent to a damped oscillator without any external force and to a driven oscillator (with damping). Write, but do not solve, differential equations for each of them.

Draw diagrams for a series resonance circuit and a parallel resonance circuit. Show that resonance frequency for both of these circuits is same.

(20)

7\. (a) Consider the propagation of a plane electromagnetic wave along the z-axis in a homogeneous, isotropic, linear and stationary medium. Show from Maxwell's equations that if is along the x-axis then $\vec{H}$ is along the y-axis and $\left(\vec{E} \times \vec{H}\right)$ points in the direction of propagation. Show further

$$\frac{E_x}{H_y} = \frac{\omega\mu}{k},$$

where ω is the angular frequency, k is the wave number and $\vec{B} = \mu\vec{H}$.

(20)

(b) What do you understand by a black body? Can it be realized in practice?

Explain the terms 'emissive power' and 'absorptive power'.

Deduce at any temperature for radiation of the same wavelength the ratio of emissive power to the absorptive power of a substance is constant and is equal to the emissive power of a perfectly black body.

(20)

8\. (a) What are isothermal, adiabatic, isobaric and isochoric processes? Obtain expressions for the work done in each of these processes.

(20)

(b) Derive all the Maxwell's thermo dynamical relations and hence explain Joule—Kelvin effect.

(20)

PHYSICS

PAPER - II

SECTION - A

List of Useful Constants

Mass of proton	$= 1.673 \times 10^{-27}$ kg
Mass of neutron	$= 1.675 \times 10^{-27}$ kg
Mass of electron	$= 9.11 \times 10^{-31}$ kg
Planck constant	$= 6.626 \times 10^{-34}$ J s
Boltzmann constant	$= 1.380 \times 10^{-23}$ J K^{-1}
Bohr magneton	$= 9.273 \times 10^{-24}$ A/m^2
Electronic charge	$= 1.602 \times 10^{-19}$ C
Atomic mass unit (amu)	$= 1.660 \times 10^{-27}$ kg
	$= 931$ MeV
Velocity of light in vacuum,	$c = 3 \times 10^{8}$ m s^{-1}

$m\left({}^{1}_{1}\mathrm{H}\right) = 1.007825$ amu

$m\left({}^{2}_{1}\mathrm{H}\right) = 2.014102$ amu

$m\left({}^{3}_{1}\mathrm{H}\right) = 3.016049$ amu

$m\left({}^{12}_{6}\mathrm{C}\right) = 12.00000$ amu

$m\left({}^{20}_{10}\mathrm{Ne}\right) = 19.992439$ amu

$m\left({}^{4}_{2}\mathrm{He}\right) = 4.002603$ amu

1. Answer any four of the following:

(a) Calculate the de Broglie wavelength of a thermal neutron at the temperature of 27° C.

(10)

(b) Calculate the minimum energy of a proton confined within a nucleus of radius two fermi using Heisenberg uncertainty relation.

(10)

(c) Using Gaussian function shows that expectation value $\langle x^n \rangle = 0$ for odd values of n.

(10)

(d) State elementary ideas about Lamb shift and point out its significance.

(10)

(e) Explain spin multiplicity and deduce the term symbols for the singlet and triplet states of singly ionized lithium atom.

(10)

2. (a) Estimate the ground state energy of

(i) simple harmonic oscillator and

(ii) hydrogen atom, using uncertainty principle.

(20)

(b) Define reflection and transmission coefficients. Deduce expressions for them considering one-dimensional potential step of rectangular barrier and show that their sum is unity.

(20)

3. (a) Derive expressions for Fermi vector and Fermi energy on the basis of free electron theory of metals.

(20)

(b) Distinguish between normal and anomalous Zee man effect. Obtain an expression for the splitting of energy levels.

(20)

4. (a) Explain fluorescence and phosphorescence with suitable examples. Discuss two applications in each case.

(20)

(b) Give the elementary theory of Nuclear Magnetic Resonance (NMR) and describe any three applications.

(20)

SECTION B

5. Answer any four of the following:-

(a) Explain the characteristics of nuclear fusion.

Discuss the mechanism of energy production in stars.

(10)

(b) State the coordination number of simple cubic, body centered cubic and face-centered cubic lattices. Also determine the number of atoms per unit cell of all the three cubic lattices.

(10)

(c) Which of the following reactions can occur ? State the conservation principles violated by others:

(10)

(i) $K^0 \longrightarrow \pi^+ + \pi^-$
(ii) $\pi^- + p \longrightarrow n + \pi^0$
(iii) $\pi^+ + p \longrightarrow \pi^+ + p + \pi^- + n$
(iv) $\gamma + n \longrightarrow \pi^- + \dots$

(d) A member of Σ group of particles consists of two u quarks and one s quark. What is its charge? Which quarks make up the Ξ hyperon?

(10)

(e) Describe the basic construction and working of a JFET. Describe how the characteristics of a FET are obtained.

(10)

6. (a) Give a simple theory of the deuteron. Obtain and plot the wave function for the deuteron ground state taken as an s state.

(20)

(b) Discuss in detail the shell model of the nucleus with its successes and limitations.

(20)

7. (a) Explain the fundamental forces in nature and their unification.

(20)

(b) Distinguish between superconductivity and high temperature superconductivity. Describe the properties of cuprates and fulleres.

(20)

8. (a) What is a microprocessor? Sketch the evolution of a present-day computer. Explain with a block diagram the structure and working of a digital computer.

(20)

(b) NAND is universal gate. Explain with suitable logic diagrams and truth tables

(20)