# PHYSICS

## PAPER - I

***Useful Constants***

Electron charge : $e = 1.602 \times 10^{-19}$ C
Electron rest 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 in free space : $c = 3 \times 10^8$ m/s
Boltzmann constant : $k = 1.38 \times 10^{-23}$ J/
Electron volt : $eV = 1.602 \times 10^{-19}$ J
Planck's constant : $h = 6.62 \times 10$ Js
Stefan's constant : $\sigma = 5.67 \times 10$ Wm$^{-2}$

## SECTION-A

1. Answer any four questions from the following: (4 × 10= 40)

(a) Find the moment of inertia of a slab of length $l$, breadth $b$ and mass M about an axis perpendicular to the plane of $l$ and $b$ and passing through the centre.

(b) A $\pi$ it-meson has a lifetime of $2.6 \times 10^{-8}$ sec. It is moving with a velocity 0.99 c, where $c$ is the velocity of light in free space. How far will it move in the laboratory before it decays?

(c) What is spherical aberration? Obtain the condition for minimum spherical aberration for a combination of two thin lenses.

(d) How does the phenomenon of double refraction occur in a calcite crystal? Explain in brief the meanings of positive and negative crystals.

(e) What is holography? How does it differ from conventional photography? Mention the applications of holography in modern optics.

2. (a) Equation for simple harmonic motion of a simple pendulum is

$$\ddot{\theta} + \omega^2\theta = 0$$

Establish it from lagrangian formulation. (20)

(b) (i) Obtain an expression for effective force experienced by a body in a rotating frame and identify the centrifugal force from it. (14)

(ii) The angular velocity of the earth relative to the fixed star is $7.3 \times 10^{-5}$ sec$^{-1}$. The velocity of earth is $10^3$ m/sec. Find out the magnitude of the Carioles acceleration. (6)

3. (a) (i) How does the special theory of relativity govern the lengths of object and time ? Derive the expressions for the same. (14)

(ii) Explain the phenomenon of twin paradox. (6)

(b) What is Huygens principle ? Using this principle and suitable diagram, show that this principle could also lead to Snell's law of refraction. (20)

4 (a) How do Einstein's A and B coefficients take care of spontaneous and stimulated emission of light, respectively? Assuming the correctness of Planck's law for the radiation energy density, establish the relation between Einstein's A and B coefficients. Why is it that the ordinary sources emit spontaneous radiation?

(20)

(b) Show that the intensity distribution in single slit Fraunhofer diffraction is given by $I = I_0 \sin^2 \beta/\beta^2$.

Where $\beta = \pi b \sin\theta / \lambda$ with $b$ as the slit width. $\lambda$ is the radiation wavelength and the parallel rays make angle $\theta$ with the normal to the slit. Prove that the conditions for maxima are obtained from the relation $\beta = \tan\beta$.

(20)

## SECTION B

5 Answer any four of the following :

(4 × 10 = 40)

(a) A point charge + q is placed in front of a grounded conducting sphere of radius $r_0$ at a distance a from its centre. Find the potential at an external point due to the induced charge on the sphere using the method of electrical images.

(b) Write down the Lorentz gauge condition, and hence derive the in homogeneous wave equations for the scalar and vector potentials.

(c) The four arms of a Wheatstone bridge have the following resistances:
$R_{AB} = 100\Omega, R_{BC} = 10\Omega, R_{CD} = 5\Omega$ *and* $R_{DA} = 60\Omega$.
A galvanometer of 15 Ω resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10 V is maintained across AC.

(d) Write a short note on Chandrasekhar limit and discuss its observational consequences.

(e) The mean energy of molecules of helium is $\langle E \rangle = 3.92 \times 10^{-21}$ j. Determine the mean speed v of the helium molecules under the same condition.

6 (a) Two infinite conducting plates are placed parallel to the yz-plane at $x = 0$ and $x = d$ respectively. The plate at $x = 0$ is earthed and that at $x = d$ is kept at a constant potential $\phi_0$. The space between the plates is filled with electric charge of volume density $\rho = \rho_0 x / d$. Determine the potential at $x$ where $0 \le x \le d$. Also obtain the surface charge density on each plate.

(20)

(b) (i) For a series LR circuit, show that the transient current is given by

$$I = \frac{E}{R} e^{-Rt/L},$$

where E is the battery emf.

What is the time constant of the LR circuit?

(14)

(ii) A 2-volt battery having a negligible resistance is applied to an iron-cored coil having a resistance of 1 Ω and inductance 1 henry. What will be the current after 1/5 second?

(6)

7 (a) Briefly outline the theory of scattering of electromagnetic radiation by a bound electron and hence derive the condition for Rayleigh scattering.

(20)

(b) (i) What is Wien's displacement law? How do you obtain it from Planek's law?

(12)

(ii) An incandescent lamp filament has an area of 50 $mm^2$ and operates at a temperature of 2 127 °C. Assume that all the energy furnished to the lamp is radiated from it. If the

filament acts like a blackbody. How much power must be furnished to the lamp when operating?

(8)

8. (a) State and prove the law of equipartition of energy. Apply it to find the specific heat at constant volume (Cv) of diatomic molecules like $H_2$, $N_2$ etc. Compare your result with experimental observations.

(20)

(b) Outline the Debye's theory of specific heat of solids. How does it compare with experim[illegible]

(20)

# PHYSICS

## PAPER - II

**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 contestant $= 6.626 \times 10^{-34} Js$

Boltzmann constant $= 1.380 \times 10^{-23} JK^{-1}$

Bohr Magneton $= 9.273 \times 10^{-24} A/m^2$

Electronic charge $= 1.602 \times 10^{-19} C$

Atomic mass unit (u) $= 1.660 \times 10^{-27} kg$

$= 931 MeV$

Velocity of light in vacuum, $c = 3 \times 10^8 ms^{-1}$

$m\left({}_1^1H\right) = 10.007825u$

$m\left({}_1^2H\right) = 2.014102u$

$m\left({}_1^3H\right) = 3.016049u$

$m\left({}_6^{12}C\right) = 12.00000u$

$m\left({}_{10}^{20}Ne\right) = 19.99244u$

$m\left({}_2^4He\right) = 4.00260u$

$m(\quad) = 1.008665u$

## SECTION-A

1. Answer any for of the following

(a) The mean lifetime of the eta meson is known to be $7 \times 10^{-19} s$. If the rest mass of this particle is 550 MeV, what is the uncertainty in its rest mass?

(10)

(b) Normalize the wave function $\psi = Ae^{-a|x|}$ Find the probability of the particle being between 0 and $\infty$.

(10)

(c) What do you understand by eigen values and eigenfunction of an operator? Find the eigenfunction of the momentum operator $\hat{p}_x$. Discuss the eigenvalues for this operator.

(10)

(d) The frequency of absorption line for HCl in the rotational spectra is $6.36 \times 10^{11} Hz$ for the transition L = 0 to L = 1. Calculate the bond length of HCl molecule (mass of chlorine = 35 u).

(10)

(e) A hydrogen atom in its ground state is placed in a magnetic field 0.05 T. Calculate $g$ factor and hence obtain splitting of energy level.

(10)

2. (a) Write down the general form of the Schrödinger equation for a particle. Discuss the physical significance of the wave function. Obtain an expression for the probability current density and calculate it for a particle moving with a constant velocity $\vec{v}$.

(15)

(b) Calculate an expression for the transmission coefficient for a particle enouncing a potential barrier of height $V_0$ and width $a$ such that its energy $E < V_0$. What is quantum tunneling? Explain qualitatively the phenomenon of $\alpha$ – decay.

(2[illegible])

3. (a) Write down the complete Schrödinger equation for a single electron atom in spherical coordinates. Separate the equation into radial part and angular part. Obtain the asymptotic solution of the radial equation.

(20)

(b) State and explain the Franck-Condon principle and discuss its role in the understanding of the intensity of vibrational-electronic spectra.

(20)

4. (a) What is meant by the term 'Polaris ability'? How is it related to Raman effect? Discuss briefly the quantum theory of Raman effect.

(20)

(b) Give an elementary theory of nuclear magnetic resonance. Briefly describe the essential parts of an NMR spectrometer.

(20)

## SECTION B

5. Answer any four of the following:

(a) Estimate the binding energy of deuteron in MeV. Why is it stable?

(10)

(b) $^{12}_{5}B$ decays via $\beta$-decay. The atomic mass of this isotope of boron is 12.014354u. Write down the reaction equation for this decay. What kinetic energy is given to the decay products?

(10)

(c) Which of the following reactions violate (s) one (or more) conservation law (s) ? Name the conservation law (s) violated in each case:

(10)

(i) $\nu_e \rightarrow n + e^-$

(ii) $p + p \rightarrow p + n + K^+$

(iii) $p + p \rightarrow p + p + \Lambda^0 + K^0$

(iv) $\pi^- + n \rightarrow K^- + \Lambda^0$

(v) $K^- + p \rightarrow n + \Lambda^0$

(d) What do you understand by Cooper pairs?
Explain d.c. and a.c. Joseph son effect.

(10)

(e) Show that the maximum proportion of the available volume which may be filled by hard spheres arranged on a simple cubic lattice is 0.52.

(10)

6. (a) Discuss the various factors that determine the stability of a nucleus and hence write down the semi- empirical mass formula. Apply it to explain the stability of a nucleus against alpha decay.

(20)

(b) Give a simple theoretical explanation of Moss Bauer Effect. Show how it is applied to study the hyperfine splitting of the nuclear energy levels taking a specific example.

(20)

7. (a) State and prove De Morgan's laws.

(10)

(b) Give the logic circuit for the Boolean expression $AB + AB\overline{C} + AB\overline{CD}$. Write down the truth table for this expression.

(20)

(c) Explain intrinsic and extrinsic semiconductors. Obtain an expression for intrinsic concentration and explain its temperature dependence.

(10)

8. (a) Discuss Kronig-Penney model for the motion of an electron in a periodic one-dimensional square well potential. Explain the origin of allowed and forbidden energy bands. Show from $E$-$k$ plot that the materials can be classified into conductors, insulators and semiconductors.

(20)

(b) Explain the basic conservation laws used to study the fundamental interactions involving elementary particles.

(10)

(c) Discuss the quark structure of mesons and baryons.

(10)