PHYSICS

PAPER – I

SECTION A

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

(a) Moon revolves around Earth making a complete revolution in 27.3 days. Assume that the orbit is circular and has a radius of 4,00,000 kms. What is the magnitude of acceleration of Moon towards Earth?

(b) Does the frequency of sound emitted by one moving frame of reference and heard on the other frame of reference depend on the velocities of the moving frames?

Discuss this aspect when both the frames are moving in opposite directions to each other with uniform velocities V_1 and V_2 respectively. The first frame emits the sound and the other receives it.

(c) A vertically suspended 2 m length of string is given a tension equal to the weight of a 0.80 kg mass. The string is found to resonate in four equal segments to a frequency of 520 Hz. What is the mass per unit length of the string? Take the value of acceleration due to gravity of Earth to be 9.8 ms^{-2}.

(d) What do you understand by the terms Spatial coherence and Temporal coherence? Illustrate by giving one example for each.

Deduce the relationship between coherence time and coherence length.

(e) What is double refraction? Taking a calcite crystal as an example, explain the phenomenon of double refraction.

2. (a) What is a Foucault's pendulum? Show that the plane of vibration of the pendulum at north pole executes one complete rotation in one day but it does not rotate at all at the Equator.

(13)

(b) Derive an expression for the Rutherford scattering cross-section and show that it varies as the square of the K.E. of the particle.

(13)

(c) A mass M kg is placed on a smooth horizontal plane and attached by a string to another mass M kg hanging over a mass less and frictionless pulley. Find the acceleration of the system and tension in the string.

(14)

3. (a) Bring out clearly how the Lorentz transformation equations explain Time dilation and Length contraction.

(13)

(b) State Huygens' principle. How does Huygens theory explain the laws of refraction of light in a transparent medium? Deduce the path difference between two waves of wave lengths λ_1 and λ_2, traveling in a transparent medium.

(14)

(c) If s is the minimum distance between an object and its real image formed by a thin converging lens of focal length f, then show that $s = 4f$

(13)

4. (a) Distinguish between Fraunhofer and Fresnel diffractions. What is a Cornu's spiral? With the help of a neat diagram, explain its significance.

(13)

(b) Explain the operation of a He-Ne laser with the help of relevant energy level diagram. What is the role of Ne atoms in the laser?

(13)

(c) In a Young's experiment, light of two wavelengths, 520 nm and 650 nm, are used to form the interference fringes. The distance between the plane of the slits and the screen is 120 cm. Find the

(i) Distance of 5th brigth fringe from the central maximum for the wavelength 650 nm;

(ii) Least distance from the central maximum at which the bright fringes due to both the wavelengths coincide.

(14)

SECTION B

5. Answer any four of the following: (10 × 4 = 40)

(a) State Biot-Savart's law. Explain how the magnetic field produced at the centre of a current-carrying circular wire can be obtained.

(b) A quarter-wave plate is made of thin sheets of mica whose birefringence for sodium light (λ = 589 nm) is 0.0041. What is the thickness of the quarter-wave plate?

(c) Deduce Maxwell's fourth equation in the differential form, i.e.,

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

(d) Show that the efficiency of a Cannot engine using an ideal gas as the working substance and operating between T_1K and T_2K is given by

$$\eta = \frac{T_1 - T_2}{T_1}$$

(e) A 50 gm block of copper taken from a furnace is dropped into a 200 gm glass beaker containing 100 gm of water. The temperature of water rises from 15°C to 30°C. What was the temperature of the furnace?

6. (a) A thin plastic rod of length L has positive charge of uniform linear density λ. Find the electric potential due to it at P at a perpendicular distanced from one end of the rod.

(13)

(b) (i) In a single-loop circuit containing a battery of e.m.f. E and a resistance R, find the value of the current, by applying the energy principle.

(5)

(ii) Three resistors R_1, R_2 and R_3, are connected in parallel. One battery of e.m.f. E_1 is connoted between R_1 and R_2 such that the current in the battery flows anti-clockwise. Another between having e.m.f. E_2, is connected between R_2 and R_3, on the same line as E_1,. The current through E_2, flows clockwise. Calculate the currents through R_1, R_2, and R_3. Assume $R_1 = R_2 = R_3 = 2\Omega; E_1 = 4V$ and $E_2 = 2v$.

(9)

(c) What is an ideal transformer? Explain the theory of a transformer taking into account the requirements of energy transmission.

(13)

7. (a) Explain the technique of holography. Mention some of its important applications. (13)

(b) Deduce Maxwell's second equation in the differential form, i.e. $\Delta - \vec{B} = 0$ (13)

(c) A magnetic field of 2.6×10^{5} Am^{-1} is applied to an optically active medium whose Verdet's constant for Sodium-D light is 0.104 are mm/A. If the light traverses a path 10cm long, through which angle will the plane of oscillation turn? (14)

8. (a) Write brief but comprehensive notes on the following: (20)

(i) Saha ionisation formula

(ii) Bose-Einstein condensation

(b) Show that for an ideal gas undergoing an adiabatic process pv^{γ} = constant.

Calculate the change in entropy when 1 kg of ice at 0^0C melts to water at the same temperature. The latent heat of melting of ice is 79.6 cal. gm^{-1}.

(20)

PHYSICS

PAPER – II

SECTION A

LIST OF USEFUL CONSTANTS

Mass of proton	= 1.673×10^{-27} kg	Atomic mass unit (amu)	= 1.660×10^{-27} kg
Mass of neutron	= 1.675×10^{-27} kg		931 MeV
Mass of electron	= 9.11×10^{-31} kg	Mass of ^{14}N	= 14.007550 amu
Mass of constant	= 6.626×10^{-34} Js	Mass of ^{11}B	= 11.01281 amu
Boltzmann constant	= 1.380×10^{-23} JK^{-1}	Mass of Alpha particle	= 4.03879 amu
Bohr Magneton	= 9.273×10^{-24} A/m^2	Mass of ^{16}O	= 15.99 amu
Electronic charge	= 1.602×10^{-19} C	Velocity of light in vacuum	= 3×10^8 ms^{-1}

1. Answer any four of the following:

(a) Can an electron stay inside a nucleus? Justify your answer using quantum mechanical principles.

(10)

(b) Show that the density of states for a particle of mass μ, inside a cuboid of side L is

$$p(k) = \frac{\mu L^3}{8\pi^3 \hbar^2} k \sin\theta \, d\theta \, d\phi.$$

This particle has momentum $p = \hbar\bar{k}$ with spherical co-ordinates of $\bar{k}$ given by (k, θ, ϕ).

(10)

(c) What is the polarisability of a molecule? How does it lead to an explanation of Raman effect?

(10)

(d) Explain the meanings of the following in atomic spectroscopy:

Electron configuration, equivalent electron, term symbol, level symbol, degeneracy.

(10)

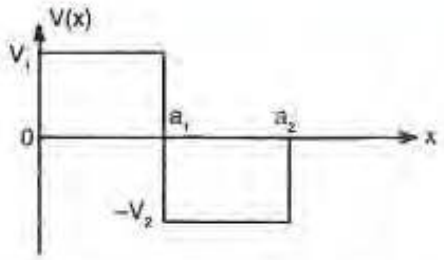
(e) What is Lamb shift? How much his it been measured for an atom with atomic number one? Can it be explained using Dirac's relativistic wave equation for an atom?

(10)

2. Consider the one-dimensional potential

$$V(x) = \begin{cases} 0 \text{ for } x < 0 \text{ (Region I)} \\ V_1 \text{ for } 0 \le x \le a_1 \text{ (Region II)} \\ -V_2 \text{ for } a_1 \le x \le a_2 \text{ (Region III)} \\ 0 \text{ for } x . a_2 \end{cases}$$

Here both V_1, $V_2 > 0$. Assume that a particle of mass μ and energy E is incident from left on this potential.



(a) Write time-independent Schrodinger equations and their respective solutions for each region taking $0< E <V_1$.

(13)

(b) Apply boundary conditions (do not solve the consequent equations).

(12)

(c) Obtain the normalization integral for the wave function in the whole region. Simplify it as much as you can without performing integration.

(15)

3. Let H_{fs} represent the interaction potential in the Hamiltonian of a hydrogen atom which gives rise to the fine structure spliting.

(a) Write the explicit from of H_{fs}.

(6)

(b) Show that is commutes neither with $\vec{L}$ nor with $\vec{S}$ (the total orbital and spin angular momenta, respectively).

(8)

(c) Define the angular momentum operator J that commutes with H_{fs} and prove your statement.

(6)

(d) Obtain an expression for H_{fs} in terms of L^2, S^2, and square of the new angular momentum operator J you have defined.

(6)

(e) Which degeneracy in the spectrum of an atom is removed by the presence of H_{fs}?

(6)

(f) Calculate H_{fs} for a 3d electron (leave your answer in terms of radial function).

(8)

4. (a) Explain the meanings of the terms (O, P, Q, R, S) branches, bands, and of progression in molecular spectroscopy. Which spectrum contains only branches, both branches and bands, branches and progression?

(25)

(b) High resolution laser spectroscopy can resolve lines that can not be resolved by conventional spectroscopy. Justify this statement.

(15)

SECTION B

5. Attempt any four of the following:

(a) Estimate the packing fraction of ^{16}O nucleus.

(10)

(b) Which of the fundamental interactions is present in the following nuclear process? Use the conservation laws to arrive at the conclusion:

$$\Sigma^0 \rightarrow \Lambda^0 + \gamma \ (life\text{-}time \leq 10^{-14} s).$$

(10)

(c) What is the structure of sodium chloride? How many unit cells of NaCl are th[illegible] each cube? What are the positions of Na and Cl ions in each cell?

(10)

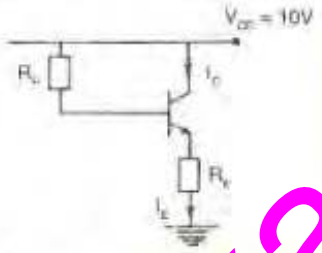
(d) Simplify the logic expression

$$Y = A\overline{B} + \overline{A}B$$

by drawing up truth tables.

(10)

(e) For the circuit designed as in diagram below:



Determine

(i) The type of BJT used,

(ii) The [illegible] value R_B,

(iii) The value of resistor R_E,

to set the emitter-earth voltage at 5 V when I_c is nominally 2 mA and β = 200.

Given, V_{BE} = 0.65 V

(10)

(a) What is Kurie plot? In what way it finds use in nuclear decay?

(10)

(b) (i) Differentiate between K-capture and inverse beta decay.

(5)

(ii) What are the properties of neutrino?

(5)

(iii) What is the principle used in the experiment conducted by Reines and Cowan?

(7)

(c) Explain why is it that a U-235 is fissile with a thermal neutron whereas U-238 requires a fast neutron to undergo fission. Given: Binding energies of the added neutrons for U-235 and U-

238 are 6.8 MeV and 5.9 MeV respectively. Estimate the critical energies for the two nuclei to support your answer (13)

7. (a) What are quarks? List the various types of them. Give the concept of coloured quarks. (20)

(b) Discuss the motion of electrons in a one dimensional crystalline lattice according to band theory. (6)

(c) On the basis of answer to (b), plot schematically, the energy, velocity and effective mass of electrons as a function of wave vector k. (6)

(d) How does band theory leads to distinction between metals, insulators and intrinsic semiconductors? (6)

(e) 'What is the concept of 'hole'? (2)

8. (a) Referring to the circuit diagram given below, the following data hold good:

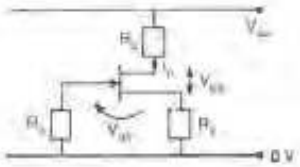
$I_{DSS} = 8mA$

$V_P = -4V$

$R_D = 2.2k\Omega$

$R_S = 1k\Omega$

$V_{DD} = 10V$



V_{GS} (V)	I_D (mA)
0	8.0
−1	4.5
−2	2.0
−3	0.5
−4	0.0

(i) What is the type of device used? (2)

(ii) Draw the transfer characteristic. (2)

(iii) Draw the load line. (2)

(iv) Obtain an approx. value for I_D. (2)

(v) Obtain an approx. value for V_{DS} (2)

(b) What are the characteristics of a practical OP-AMP?

How does the open loop gain of a 741 OP AMP vary with frequency? Use graphical illustration. What is CMRR? (15)

(c) (i) What is the principle used in "half adder"? (5)

(ii) Draw the truth table for a half-adder. (5)

(iii) What are the Boolean expressions for 'sum' and 'carry' outputs of a half-adder? (5)