PHYSICS

Time Allowed: 3 Hours ***Maximum Marks: 300***

Candidates should attempt Question 1 and 5 which are compulsory, and any three of the remaining questions selecting at least one question from each Section. All questions carry equal marks.

PAPER - I

SECTION A

1. Attempt any three of the following:

(a) A satellite moves round the earth at a distance of 3.884 x 10^5 km from its centre. Find its period of revolution in days. Proceed dto deduce the distance for a geostationary satellite.

(b) Write down Lorentz transformation relations and prove that

$$x^2 + y^2 + z^2 - c^2t^2$$

is invariant under this transformation.

An event occurs at x^1=60 m at t^1=8x10^{-8} sin a reference frame S' which is moving along the common x or x' axis with a speed 3c/5 with reference to a stationary from S. The origins of the two frames coincide at t=0, t' = 0. Deduce the space time coordinates of the event in the frame S.

(c) A neutron of energy 1.00 MeV collides with a stationary helium nucleus and is scattered. Deduce the momentum of the neutron and the helium nucleus in their centre of mass system.

(d) Calculate the mean free path of molecules of H_2 gas at 20^0 C at atmospheric pressure. Assume the molecular diameter to be 2.00 x 10^{-10} m.

2.(a) A thin uniform rod of length l and mass m is hinged to the floor at its lower end. It begins to fall from a vertical position. Deduce an expression for the angular speed of the road when it hits the floor. How would you explain that the rod would suffer less damage if the floor is soft than if the floor is hard?

(b) Define differential, scattering cross-section. Write down the dependence of Rutherford scattering cross-section σ(θ), on the scattering angle θ and sketch this dependence graphically.

In the present case, the total scattering cross-section, $\sigma = \int \sigma(\theta) d\Omega$ turns out to be infinite. Comment on this result.

(c) Prove the addition theorem of velocities in Special Theory of Relativity.

Two bodies A and B are moving away in opposite directions each with a speed of 0.70 c with respect to a stationary observer. Deduce the speed or B as measured by A.

3(a) Slate Kepler's laws of planetary motion. Assume the law of gravitation to be of the form F=mMG/r^m where n is some number. Find the value n which will be consistent with Kepler's third law. For this you may assume planetary orbits to be circular.

(b) Define solar constant and say which of the values 1.34 W/m^2 , 1.34 x 10^3 W/m^2, 1.34 x 10^5 W/m^2 is valid for it.

Calculate the total energy radiated by the sun in one second and hence the decrease in its mass per second.

(c) Thermal energy of a solid is given by the relation

$$E = \int_0^{vm} \frac{hvg(v)dv}{e^{hvk}B^T - 1}$$

where vm=k_B Θ_D/h.Θ_D being the Debye temperature. Given g(v)=6Nh^2 v(k_B)$_D$)^2, deduce the expression for E for T << Θ_D and discuss the temperature variation of specific heat for T << Θ_D.

$$\left(\int_0^{\infty} \frac{x^2 dx}{e^x - 1} = 2.404 \right)$$

4.(a) A pipe of varying diameter is used to lift water by 7 m the area of cross-section of the pipe at the base is 125 cm^2 and the pressure here is 2.5 x 10^5 N/m^2. The area of cross-section of the pipe at the top is 25 cm^2. The rate of flow of water is 3 x 10^{-2} m^3/s. Calculate the pressure of water at the top neglecting energy losses.

(b) Write down the Maxwell-Bolzmann law for the distribution of speeds c of molecules in a gas. Show the distribution graphically for the temperatures T and 2T; also write down the expression for average value of c^3.

(c) Discuss how stars arc classified on the basis of their spectra. Briefly mention what different informations about stars can be obtained from the study of their spectra.

SECTION B

5. Answer any three of the following:

(a) A system is composed of two-level atoms, the excited state 1, being 0.10 eV above the ground state 0. Find the fraction of all atoms which will be in state. 1 if the system is in thermal equilibrium at temperature 300 K.

(b) For a certain wave, system the angular velocity θ and the wave vector k arc related as follows:

$$\omega = \omega_0 \quad | \sin \frac{ka}{2} | \quad for \; \frac{\pi}{a} \quad < k < \frac{\pi}{a}$$

Determine and plot the phase velocity and the group velocity for this system.

(c) Two transverse sine waves each of amplitude 4 mm wavelength 2m and time period 1 s and in-phase at x=O, t=O arc travelling along the x-axis in Opposite directions, Obtain the equation of the resultant wave and comment on its nature. Calculate the maximum displacement at x=2.3 m. Also locate the antinodes and nodes.

(d) A single, slit of width 0.14 mm is illuminated normally by monochromatic light and diffraction bands are observed on a screen 2 m away. If the centre of the second dark band is 1.6 cm from the middle of the central bright band deduce the wavelength of light.

6.(a) Calculate the work done in compressing adiabatically 10^{-3} kg of air initially at STP to one-half its original volume. (Give density of air at STP=1.293 kg/m^3 and γ = 1.4.

(b) Nine Kilograms of mercury is poured into a glass U-tube of uniform internal diameter of 1.2cm. It oscillates freely about its equilibrium position. Calculate the period of oscillation.

(c) What is hologram? Explain how the image of the object is formed when one looks through it.

7.(a) Explain mathematically how left and right circularly polarized light is produced by combining two linearly polarized beams.

Given a beam of light, how can one experimentally test whether it is unpolarized or circularly polarized?

(b) Write down the differential equation for a damped simple harmonic oscillator. Solve it and discuss the characteristics of dead-beat motion.

(c) Show schematically the intensity distribution for a 2-slit Fraunhofer diffraction-interference, if slit-widths are 2λ each and centres of slits have separation 6λ. Assume incident light falling normally, and limit the discussion to the central diffraction band range.

8. Write notes one any three of the following:

(a) Gyroscope and its applications.

(b) Experimental verification of variation of mass with velocity.

(c) Dilution refrigeration.

(d) Enthalpy as a thermodynamic potential.

(e) Ruby laser

(f) Rayleighs criterion and resolving power of a telescope.

PHYSICS

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PAPER - II

SECTION A

1. Answer any three of the following:

(a) A charged particle moving horizontally towards the east with a velocity of 10^5 m/s enters into a region where there is a horizontal electric field E intensity 100 volt/cm directed towards the north as also a magnetic field B. The particle continues to move in the same direction as before. What can you san about the field B? Is it completely determined? What will be the path, of particle if the magnetic Field be switched off?

(b) State de Brogue hpot1iesis and use it to deduce the energy levels of a particle in a one-dimensional box. Calculate the mean energy per electron at O K if electrons arc enclosed in a long-chain molecule of length 50 A.

(c) Starting from Biot-Savart law, calculate the magnetic field at the centre of a solenoid of length 1 meter, radius 2 cm and having 25 turns per centimeter, the current through the solenoid being 1 ampere.

(d) State the important points in Bohr's theory of the hydrogen atom winch depart from classical ideas. Flow is the idea of Bohr orbits changed in Schrodinger's wave mechanics?

2.(a) The components of an electrostatic field in vacuo are given as

$$E_x = \frac{a}{r^3} + \frac{bx^2}{r^5}$$

$$E_y = \frac{cxy}{r^5}$$

$$E_z = \frac{fxz}{r^5}$$

where a,b,c, and f are constants x,y,z, the rectangular cartesian coordinates and $r^2=x^2+y^2+z^2$. Using the basic equations obeyed by the electrostatic field in vacuo, find he relations between a,b,c and f and determine the charge density at a general point in space. Would that explain the observed field?

(b) A circular coil of wire having 100 turns and radius 10 cm is rotating about a vertical axis in its own plane uniformly at rate of 480 revolutions per minute. There is a horizontal magnetic field of intensity 0.01 Wb/m^2. The terminals of the coil are connected to the ends of an inductor having inductance 0.01 henry. Assuming that the resistance in the circuit can be neglected, find the current in the circuit at the instant the plane of the rotating coil is perpendicular to the magnetic field.

3. Write brief scientific notes on any three of following:

(a) Ferrimagnetism and ferrites.

(b) Elementary particles and their classification.

(c) Linear particle accelerators.

(d) Logic gates and their applications.

(e) Transistor as an amplifier.

4. What are the transitions leading to the emission of the D lines of Sodium? Deduce the expression for the Lande splitting factor. g and calculate its values for the states involved in the emission of D lines. Hence find the change of energies of these levels when a sodium source is placed in a magnetic field which is not too high.

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SECTION B

5. Answer any three of the following:

(a) What are anti-Stokes lines? Do they occur in both Raman and Compton scatterings? Explain how they arise and how temperature affects their intensities.

(b) Give an example of nuclear fusion and explain how energy is released in the process. In nature fusion reactions are often brought about by height temperatures. Explain the role of high temperature and the relevance of quantum effect in this.

(c) What is superconductivity? In what kind of materials is it found to occur? Name some parameters which characterise a superconductor. Cite any two major use if we succeed in making superconductors with T_c not far atmospheric temperatures.

(d) Two isotopes of oxygen have nuclear masses 15.990523 a.m.u. and 17994768 a.m.u. Calculate the binding energy per nucleon in the two cases in MeV. What do you expect about the relative abundances of the two isotopes?

6. Set up Schrodinger's equation for a one-dimensional harmonic oscillator. Assuming that the solution is of the from $\psi = Ae^{-\alpha x^2} f(X)$ where α is a constant and f(x) is a polynomial in x, find the energy eigen values and the ground state eigenfunction. Comment on the relation between the ground slate energy and Heisenberg's uncertainty principle.

7.(a) State the laws followed in α-decay by different radioactive nuclei and outline the theory which explained α-decay.

(b) Radium has a half life of 1600 years and the daughter nucleus Radon also decays with a half-life of 3.82 days. In an enclosure containing radium and radon gas, the amount of radon appears to be constant for observations extending over a week. Explain this and calculate the ratio of the numbers of radium nuclei. Will the amount of radon remain the same even after 400 years?

8. How is a p-n junction prepared? Explain the charge and potential distributions in such a junction in open circuit. Explain how a p-n junction can be used to build a solar cell.

Describe the mechanism of the increase of conductivity of Germanium by doping it with Arsenic.