

PHYSICS

Paper—I

Time : Three Hours

Full Marks : 300

Note :— Candidates should attempt Question 1 from Section-A and Question 5 from Section-B which are compulsory, and any **THREE** of the remaining questions, selecting at least **ONE** from each Section. All questions carry equal marks.

SECTION—A

1. Answer any **THREE** of the following :—

- (a) Consider a reference frame S' rotating with uniform angular velocity ω with respect to an inertial frame S . Obtain equation of motion of a particle of mass m from the point of view of an observer who is at rest with respect to S' .

A mass of 30 gm is placed at a distance of 20 cm from the axis of a frame of reference rotating at the angular speed of 10 radian per second. Calculate the values of centrifugal and Coriolis forces. What are directions of the forces ?

$$10+10=20$$

- (b) The speed of light in still water is $\frac{c}{n}$, where n is the refractive index of water. If water moves with speed v in the same direction in which the light is travelling, show that the speed observed in laboratory is equal to :

$$\frac{c}{n} + v \left(1 - \frac{1}{n^2} \right). \quad 20$$

- (c) What do you mean by circularly polarized light ? How can elliptically polarized light be changed into circularly polarized light ? How will you distinguish between elliptically polarized light and mixture of plane polarized and unpolarized light ? 20
- (d) Define unit planes and nodal planes of an optical system. A spherical lens of radius 4.5 cm having the refractive index of material 1.5 is placed in air. Obtain the system matrix, focal length, position of unit planes and position of nodal planes. 20
2. (a) Show that acceleration is invariant to Galilean transformation whereas velocity is not.

A satellite of mass m_s is revolving round the earth in a circular orbit of radius r_s . Obtain angular momentum of satellite about centre of earth and hence total energy in terms of angular momentum.

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- (b) What do you mean by central force ? Construct the Lagrangian and hence equation of motion of a particle in a plane under a central force of potential $u(r)$. Use the polar coordinates (r, θ) .

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- (c) Define inertia tensor and principal moments of inertia. Find inertia tensor and principal moments of inertia for a homogenous cube of density ρ and mass M . 20
3. (a) (i) Define a 4-vector momentum and identify its components for a particle of rest mass m_0 . 15

- (ii) Show that the relation

$$E = \sqrt{p^2 c^2 + m_0^2 c^4}$$

is invariant under Lorentz transformation.

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- (b) (i) Distinguish between phase and group velocity of waves. Show that phase velocity and group velocity of a train of wave are same in a non-dispersive medium. 15
- (ii) A simple pendulum is oscillating in a viscous medium. Show that the amplitude will be affected whereas its time-period will remain the same. 15

4. (a) Write an expression for intensity distribution in fringes of a Fabry-Perot interferometer. Obtain the half fringe width and discuss the sharpness of fringes obtained. Compare the circular fringes obtained from Newton's ring experiment, Michelson's interferometer and F.P. interferometer. 20
- (b) Two diffraction gratings have the same width of the ruled surface but one has greater number of lines. Compare intensity, width of principal maxima and resolving power of gratings. 20
- (c) What do you mean by spatial and temporal coherence of light? Why laser radiation has a high degree of coherence? Obtain an expression for the lateral coherence width considering the Young's double slit experiment. What is its significance? 20

SECTION—B

5. Answer any **THREE** of the following :— $3 \times 20 = 60$
- (a) Show that the energy stored in an electric field, produced by charges kept in vacuum, is proportional to $|\vec{E}|^2$.
- (b) Describe how you can determine the internal resistance of a cell by using a Wheatstone bridge and applying Kirchhoff's laws.

- (c) Using Maxwell's distribution of velocities, show that the average value of $(v_x + av_y)^2$, a being a constant, is $(1 + a^2) \frac{KT}{m}$.
- (d) Two stars having temperatures T_1 and T_2 , and radii R_1 and R_2 are at distances d_1 and d_2 respectively from the earth. What will be the ratios of their total luminosities, of the fluxes received from them at the earth and of the wavelengths at which they emit maximum energy?
6. (a) Show that the dipole moment induced in a dielectric sphere of radius a and dielectric constant ϵ , kept in a uniform electric field $\vec{E}_0$ is proportional to $\frac{(\epsilon - 1)}{(\epsilon + 2)} a^3 \vec{E}_0$. 30
- (b) Two inductance L_1 and L_2 are connected in parallel. What is the equivalent inductance when they are :
- (i) close to and
- (ii) far away from, each other? 20
- (c) Show that the normal component of the displacement vector and the tangential component of the electric field is continuous across a charge-free interface between two dielectrics. 10



7. (a) Define the Poynting vector and using the conservation of energy of a system of charged particles and fields, show that it represents the amount of energy crossing unit area per unit time.

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- (b) Show that the Maxwell's equations can be written as two uncoupled, second order differential equations for scalar and vector potential using Lorentz gauge condition.

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- (c) Show that the work done by the magnetic field on a charged particle moving with velocity $\vec{v}$ is zero.

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8. (a) Describe the working of an Otto engine and show

that its efficiency is given by $1 - \left(\frac{1}{\rho}\right)^{\gamma-1}$, ρ and γ

being the compression ratio and the ratio of specific heats respectively.

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- (b) What are the limitations of Einstein's theory of specific heat of solids ? How were these eliminated by Debye ? Derive Debye's expression for specific heat for mono atomic solids and show that at low temperature it is proportional to T^3 .

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