

CSM – 58/20

Physics

Paper – I

Time : 3 hours

Full Marks : 300

The figures in the right-hand margin indicate marks.

*Candidates should attempt Q. No. 1 from
Section – A and Q. No. 5 from Section – B
which are compulsory and any **three** of
the remaining questions, selecting
at least **one** from each Section.*

SECTION – A

1. Answer any **three** of the following :

- (a) Derive the expression for the acceleration of a particle in a non-inertial frame rotating with a constant angular velocity $\vec{\omega}$ about an axis \hat{n} relative to an inertial frame with the same origin.

20

- (b) Mention the reason for conducting the Michelson Morley experiment. Obtain the expression for the expected fringe shift in the experiment.

5+15 = 20

- (c) Define 'Phase Velocity' and 'Group Velocity'. Obtain the relation between them. Indicate them with a diagram of a wave packet.

6+10+4 = 20

- (d) Discuss the diffraction of light by a circular aperture and explain how the wavelength of light can be measured using this diffraction pattern.

15+5 = 20

2. (a) Apply the Lagrangian formalism for a particle moving under a central force $\vec{F} = f(r)\hat{r}$ and arrive at the equation of motion for the spherical polar coordinates r, θ of the particle.

20

- (b) Show that the relativistic formula for the kinetic energy of a free particle reduces to the non-relativistic form if the particle moves with non-relativistic speed. A particle of rest mass M decays at rest into two identical (c)

particles each of rest mass m which move at relativistic speed u in the rest frame of M . Find u . $5+15 = 20$

- (c) Using Fermat's principle arrive at the laws of reflection. Explain why the straight line path between point A in one medium and Point B in another medium is not always the actual path for light. $15+5 = 20$

3. (a) Describe the construction and working of Michelson Interferometer. Discuss, giving reasons, the nature of fringes when one mirror is nearly perpendicular to the other mirror. $15+5 = 20$

- (b) Discuss the application of Cornu's spiral for the analysis of diffraction at straight edge. Distinguish between the above diffraction and the diffraction due to a circular aperture. $15+5 = 20$

- (c) A circularly polarized beam of light and another unpolarized beam of light, both of same intensity, are given, What is the nature of polarization of light coming out if each is passed through a linear polarizer. Describe

the effect on the intensity of light as the polarizer is rotated in each case. Discuss how the combination of a quarter wave plate and a linear polarizer can be used to find out which of the input beam is unpolarized and which is circularly polarized. $5+5+10 = 20$

4. (a) Give the theory of multiple beam interference and use this to explain how Fabry-Perot interferometer can be used to find the wavelength of light. $10+10 = 20$

- (b) Obtain the formula for the resolving power of a diffraction grating. If a diffraction grating has 6×10^5 lines per metre, find the wavelength range that can be resolved by the grating at first order of diffraction for a light of mean wavelength 6000×10^{-10} m.

$10+10 = 20$

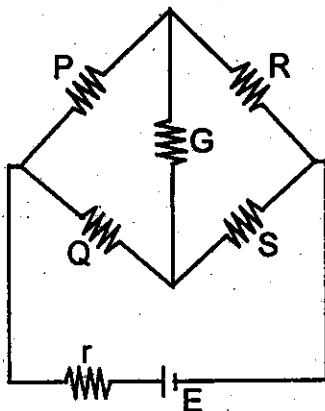
- (c) Explain the meaning of spatial coherence. How is it different from temporal coherence. Describe how both spatial and temporal coherence can be found out in the double-slit interference experiment. $5+5+10 = 20$

SECTION – B

5. Answer any **three** of the following :

- (a) Discuss the multipole expansion of the scalar potential at \vec{r} due to a static charge density $\rho(\vec{r}_0)$ at \vec{r}_0 . Hence obtain the formula for the electric field due to a dipole. 15+5 = 20
- (b) Obtain the formula for the current through the resistance G due to a battery of emf E, in the circuit shown below, using Kirchhoff's laws.

20



- (c) "Gauge transformations lead to reduction in the number of independent variables." Substantiate this statement in the case of

Electromagnetic field. Show that the scalar and vector potentials ϕ , \vec{A} of the electromagnetic field satisfy inhomogeneous wave equations, in the presence of charges and currents under Lorentz gauge condition.

5+15 = 20

- (d) Discuss Einstein's theory of specific heats of solids. Briefly mention how Debye's theory provided a better explanation of the behaviour of specific heat. 10+5+5 = 20

6. (a) Using the method of images, find the force on a point charge $+q$ kept at $(0, 0, 3d)$ due to a point charge $q' = -2q$ kept at $(0, 0, d)$ and an infinitely long and wide planar conductor occupying the xy -plane. 20

- (b) Describe how the hysteresis property of a magnetic material is studied experimentally. Explain the terms Retentivity, Coercivity and Energy loss associated with the notion of hysteresis. 14+6 = 20

Study the response of a circuit containing L, C, R all in series across a sinusoidal source and hence obtain an expression for the current. Obtain the condition for resonance in such a circuit. $15+5 = 20$

7. (a) Obtain Maxwell's equations from basic laws of electrodynamics. Explain the notion of Displacement current. $14+6 = 20$
- (b) Write down the form of Electromagnetic field tensor. Express any two of Maxwell's equations using this field tensor. $5+15 = 20$
- (c) Obtain Wien's displacement law and Stefan's law from Planck's radiation law. $10+10 = 20$
8. (a) Define the notion of Entropy of a thermodynamic system. Calculate the increase in entropy when 1 g of ice at $T_1 = 263$ K is converted in to steam at $T_2 = 373$ K. Specific heat of ice = 2092 J/kg/K , latent heat of ice = $3.36 \times 10^5 \text{ J/kg}$ and latent heat of vaporization of steam = $2092 \times 10^3 \text{ J/kg}$. $6+14 = 20$

- (b) Obtain all the Maxwell Thermodynamic relations. Calculate the pressure at which water boils at 448 K if the change in specific volume when 10^{-3} kg of water is converted into steam is $1676 \times 10^{-6} \text{ m}^3$. Latent heat of vapourization of steam = $2092 \times 10^3 \text{ J/kg}$.

16+4 = 20

- (c) Discuss the characteristic features of the three kinds of ensembles in Statistical Mechanics.

20

