2019

Time Allowed- 3 Hours | PHYSICS– PAPER-I | MSC ( O ) PS-I/19

Full Marks – 200

If the questions attempted are in excess of the prescribed number, only the questions attempted first up to the prescribed number shall be valued and the remaining ones ignored.

Answers may be given either in English or in Bengali but all answers must be in one and same language.

## GROUP – A

Answer any three questions :-

1. (a) Differentiate between inertial and non-inertial frames of reference. Explain with examples.

(b) Show that in the northern hemisphere the Coriolis force deflects a freely falling body of man m towards the east and has the magnitude $2m\upsilon\omega\cos\lambda$ where $\upsilon$ is the magnitude of the downward velocity at latitude $\lambda$ and $\omega$ is the angular velocity of earth.

(c) Show that the gravitational potential at an external point P, distant $r$ from the centre of a homogeneous spherical shell of man M and radius R is given by

$$V = -\frac{GM}{r} \qquad (r > R)$$

where G is the Universal Gravitational constant.

(d) If a body is to be projected vertically upwards from earth's surface to reach a height of 10 R, (R being the radius of the earth), how much velocity should it be given ? [$R = 6.4 \times 10^6$ m]

(e) State and explain parallel axis theorem.

(f) Define cyclic coordinates with suitable example. 6+8+8+8+5+5

2. (a) Describe briefly Michelson-Morley experiment with a suitable schematic diagram and comment on the significance of the negative results obtained.

(b) Write down the expressions of length contraction and time dilation explaining the relevant symbols.

(c) A vector in a reference frame S′ is represented by $8\hat{i} + 6\hat{j}$. How can the vector be represented in a reference frame S with respect to which S′ is moving with a velocity $0.8c\hat{i}$ . Assume $\hat{i}$ and $\hat{j}$ are unit vectors in the direction of relative motion between S and S′ and perpendicular to it, respectively.

(d) Show that the relati istic kinetic energy (T) of a particle of rest man ($m_o$) moving with velocity $\upsilon$ is

$$T = m_o c^2\left[\frac{1}{\sqrt{1-\frac{\upsilon^2}{c^2}}} - 1\right]$$

where c is the velocity of light.

(e) Calculate the speed of an electron which has kinetic energy 2 MeV. (8+4)+6+6+10+6

3. (a) State Gauss' law and apply it to determine the electric field '$\vec{E}$' at a perpendicular distance 'r' from a straight infinitely long wire with a charge $\lambda$ per unit length.

(b) What is an electrical image ? Comment on its usefulness in solving electrostatic problems.

(c) A conducting sphere carrying a charge 'q' is placed inside a linear, homogeneous, isotropic dielectric of relative permittivity 'K'. Determine the polarization of the dielectric. Hence determine the volume and surface charge (polarization) densities.

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(d) Explain the phenomenon of hysteresis in a fenomagnetic material with a suitable diagram.

(e) A thin circular disc of radius R lies in the xy plane with its centre at the origin. The disc has a surface charge density $\sigma(r,\theta) = \sigma_0 r\cos\theta$ where $\theta$ is the angle made by the position rector $\vec{r}$ with the diameter chosen as the X-axis. Calculate the dipole moment of the disc.

(f) State & prove Poynting's theorem.

6+4+7+7+6+10

4. (a) Write down the first and second TdS equations in thermodynamics. Hence show that for an isentropic transformation

(i) $\left(\frac{\partial V}{\partial T}\right)_S = -\frac{C_V}{C_p - C_V}\left(\frac{\partial V}{\partial T}\right)_P$

(ii) $\left(\frac{\partial p}{\partial T}\right)_S = \frac{C_p}{C_p - C_V}\left(\frac{\partial p}{\partial T}\right)_V$

(b) 10 gm. of water at $60^\circ$C is mixed with 30 gm. of water at $20^\circ$C. Calculate the change in entropy of the system.

(c) Obtain the Clausius-Clapeyron equation and mention its significance.

(d) Explain why the Joule-Thomson expansion is often regarded as "quasi-static isenthalpic process".

(e) Show that the Joule-Thomson coefficient '$\mu$' is given by

$$\mu = \left(\frac{\partial T}{\partial p}\right)_H = \frac{1}{C_p}\left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right]$$

where symbols have usual meaning.

(4+4+4)+8+8+4+8

5. (a) Write down the system matrix for a thin lens of focal length 'f'. A thin convex lens of focal length $f_1$ = 10 cm. is separated by 5 cm. from a thin concave lens of focal length $f_2$ = -10 cm. Calculate the system matrix and the equivalent focal length of the combination.

(b) Explain what do you mean by spatial and temporal coherence.

(c) Draw a schematic diagram for Newton's ring apparatus and obtain an expression for radius of $n^{th}$ dark ring.

(d) What is Brewster's angle ? Explain the phenomenon of double refraction.

(e) A diffraction grating used at normal incidence gives a green line (5400 Å) in a certain order superimposed on the violet line (4050 Å) of the next higher order. If the angle of diffraction is $30^\circ$, how many lines/cm. are there in the grating ?

(5+3)+(4+4)+10+(3+3)+8

6. (a) It is known that the magnetic field $\vec{B}$ is derivable from a vector potential $\vec{A}$, according to the relation $\vec{B} = \vec{\nabla} \times \vec{A}$ Hence calculate $\vec{B}$ if $\vec{A} = e^{-x}\sin y\,\hat{i} - (1+\cos y)e^{-x}\,\hat{j}$

(b) Show that the force $\vec{F}$ acting between two infinitely long parallel conductors carrying currents $i_1$ and $i_2$, separated by a distance 'd' is given by $F = \mu_0 \frac{i_1 i_2}{2\pi d}$ where $\mu_0$ is the permeability of free space.

(c) A dc voltage of 80V is switched on to a circuit containing a resistance of 5Ω in series with an inductor of inductance 20 H. Calculate the rate of growth of current at the instant when the current is (i) 6 A and (ii) 16 A.

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(d) Obtain an expression for instantaneous current in a series L-C-R circuit with an alternating current source. Hence obtain the condition of resonance.

(e) Define mutual inductance and define its SI unit. Calculate the mutual inductance between the primary and secondary coil of a solenoid.

5+7+8+(8+2)+(4+6)

## GROUP - B

Answer any two questions :-

7. (a) A bead slides without friction on a frictionless wire in the shape of a cycloid with equations $x = a(\theta - \sin\theta)$, $y = a(1+\cos\theta)$ where $0 \leq \theta \leq 2\pi$. Find the lagrangian of the system and the lagrange's equation of motion.

(b) Consider two identical simple harmonic oscillators which are coupled together. Their kinetic and potential energies are given by

$$T = \frac{1}{2}m(\dot{q}_1^2 + \dot{q}_2^2)$$

$$V = \frac{1}{2}k(q_1^2 + q_2^2) - hq_1q_2$$

Calculate the Hamiltonian of the system.

(c) Define moment of inertia and radius of gyration. Calculate the moment of inertia of a circular disc of radius "R" about an axis passing through its centre and perpendicular to its plane.

(d) Show that a shearing stress is equivalent to an extensional stress and a compressional stress at right angles to each other.

(e) Deduce Poiseuille's formula for the streamline flow of a liquid through a capillary tube. Hence calculate the rate at which water flows through a capillary tube of length 0.5 m with an internal diameter of 1 mm. Coefficient of viscosity is $1.3 \times 10^{-3}$ kg/m-sec. The pressure head is 20 cm. of water.

7+7+(4+4)+6+(10+2)

8. (a) Differentiate between stimulated and spontaneous emissions.

(b) Define phase velocity and group velocity. Show that

$$v_g = v_p - \lambda \frac{dv_p}{d\lambda}$$

where $v_g$ is group velocity and $v_p$ is phase velocity, $\lambda$ is the wavelength.

(c) Calculate the wavelength shift in the relativistic Doppler effect for the $H_\alpha$ (6563 Å) line emitted by a star receding from the earth with a relative velocity 0.1c, where c is the velocity of light.

(d) State and explain what is meant by Gibb's phase rule. Explain why entropy increases in all natural processes.

(e) The density of iodine at the boiling point (458.3 K) is 3.71 gm/cc and latent heat of vapourisation is 40.9 cal/gm. If the boiling point changes by 1°C for a change of pressure of 17 mm of Hg, use Clapeyron's eqn to calculate the specific volume of the vapour.

6+(4+4)+8+(5+5)+8

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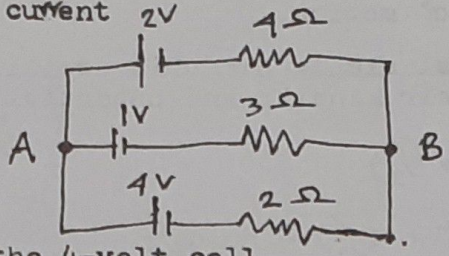
9. (a) In a frame S, the following two events occur :-

Event 1 : $X_1 = X_o$ ; $t_1 = \frac{X_o}{c}$ and $y_1 = Z_1 = 0$

Event 2 : $X_2 = 2X_o$ ; $t_2 = \frac{X_o}{2c}$ and $y_2 = Z_2 = 0$

Find the velocity of the frame S' (tort S) in which these two events occur at the same time. What is the value of t in S' at which these events are simultaneous ?

(b) Three cells are connected in parallel with similar poles connected together with wires of negligible resistances. The emfs of the cells are 2, 1 and 4 volts respectively and the corresponding internal resistances are 4Ω, 3Ω and 2Ω. Find the current




through the 4-volt cell.

(c) Define Q-factor of an ac circuit. How is it related to sharpness of resonance ?

(d) Apply Ampere's circuital law to find the magnetic field inside a toroid (endless solenoid).

(e) Explain how the concept of displacement current was introduced by Maxwell. What is its physical significance ?

10+6+(4+4)+8+(4+4)

10. (a) State and explain Fermat's principle. Hence obtain the laws of refraction.

(b) Show that for a system of particles the total kinetic energy is

$$T = \frac{1}{2} MV^2 + \frac{1}{2} \sum_i m_i \vec{v}_i'^2$$

where symbols have usual meaning.

(c) Derive the equation of continuity for fluid motion.

(d) What would be the pressure inside a small air bubble of 0.1 mm radius situated just below the surface of water. (Surface tension of water is 0.072 N/m and atmospheric pressure=1.013 x $10^5$ N/$m^2$)

(e) Calculate the work done in twisting a steel wire of radius 1 mm and length 0.25 m through 45°. Given, modulus of rigidity for steel $\eta = 8 \times 10^{10}$ N/$m^2$.

(4+8)+8+8+6+6

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