RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College affiliated to University of Calcutta)

B.A./B.Sc. THIRD SEMESTER EXAMINATION, DECEMBER 2016

SECOND YEAR [BATCH 2015-18]

Date : 12/12/2016 **PHYSICS [Honours]**

Time : 11 am – 3 pm **Paper : III** Full Marks : 100

[Use a separate Answer Book for each Group]

Group – A

(*Answer any three questions*) [3×10]

1. a) How can you produce an electrical dipole? Final the natural potential energy of two dipoles separated in space by a distance $\vec{r}$. [1+5]

   b) One dipole $\vec{p} = p\hat{i}$ is placed at the origin but fixed in position, can not rotate. Another dipole $\vec{p}'$ is kept at $(a,a,0)$ but can rotate fully about its position. What orientation $\vec{p}'$ will take so that the system has minimum potential energy? If both of them are allowed to rotate fully what orientation $\vec{p}$ and $\vec{p}$ will take? Give reason. [3+1]

2. a) Show that the potential of a polarized object can be expressed as the sum of potentials produced by a volume charge density ρ_b and surface charge density σ_b. [4]

   b) A sphere of radius R carries a polarization $\vec{P} = K\vec{r}$, where K is a constant and $\vec{r}$ is a vector from the centre. Calculate the bound charge densities σ_b and ρ_b. Find also the field inside and outside the sphere. [1+1+2+2]

3. a) The total charge in a sphere of radius r about the centre of a spherical charge cloud of radius a is $\frac{qr^2}{a^2}\left(e^{-\frac{r}{a}} - e^{-\frac{2r}{a}}\right)$.

   Find the corresponding field and potential. Show that in the limit $r \to 0$, charge density $\rho \to \frac{3q}{4\pi a^3}$. [4]

   b) Calculate the energy of a solid sphere of radius R with total charge q distributed uniformly. [3]

   c) Suppose there is a small spherical cavity of radius r_1 within a large sphere of radius r_2 carrying uniform charge density ρ. Calculate the field and potential within the cavity. [2+1]

4. a) Show that Gauss's law in electrostatics leads to Laplace's equation in free space. Show that the solution to Laplace's equation is unique in charge free region. [1+3]

   b) An uncharged grounded sphere is placed in a uniform electric field. Calculate he field and potential at an arbitrary point $P(r,\theta,\varphi)$ outside the sphere.

   [Assume the solution of Laplace's equation if necessary.] [6]

5. a) What is an electrical image? Explain the method of electrical image for the solution of electrostatic problems. [1+2]

   b) A point charge is placed in front of an earthed conducting plane. Calculate the actual induced surface charge density on the plane. [3]

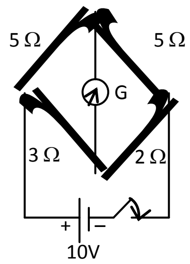
   c) A point charge q of mass m is released from rest at a distance d from an infinite grounded conducting plate. Find the time taken by the charge to hit the plate. [4]

Group – B

(*Answer <u>any four</u> questions*) [4×10]

6. a) Show that Kirchhoff's current law and Kirchhoff's voltage law lead to the conservation of charge and energy respectively. [2+2]

   b) State and explain Thenemin's theorem. Use the Thenemin's theorem to find the current through the galvanometer in Wheatstone Bridge circuit as shown in figure. G is the galvanometer resistance = 1.3 Ω. [2+4]



7. a) Staring form the expression $\vec{B}=\frac{\mu_0 I}{4\pi}\int\frac{d\vec{l}\times\vec{r}}{r^3}$. Show that $\vec{\nabla}\times\vec{B}=\mu_0\vec{J}$, which law does this expression represents. (where the symbols have their usual meanings) [4+1]

   b) A current sheets at planes $z = 0$ and $z = 5$ carry current $\vec{K}=+40\hat{x}A/m$ and $\vec{K}=-40\hat{x}A/m$ respectively. Determine B at (i) (2,2,2) (ii) (0,–5,10). [5]

8. a) What do you mean by magnetic vector potential? Show that the choice of vector potential is not unique. [2+2]

   b) Find the vector potential for a long straight wire carrying current I and length L at a point 'r' distance from the wire. Hence verify $\vec{\nabla}\cdot\vec{A}=0$. Also that the magnetic field $\bar{B}=\bar{\nabla}\times\vec{A}$ is consistent with Ampere's result. [3+1+2]

9. a) What is magnetization? 'A uniformly magnetized cell is equivalent to a current carrying loop' – explain. [1+2]

   b) Show that a uniform magnetisation $\vec{M}$ is equivalent to a bound current density $\vec{K}_m=\vec{M}\times\vec{n}$. Symbols have usual meaning. [4]

   c) An infinitely long cylinder a radius R carries a "frozen-in" magnetization parallel to the axis $\vec{M}=Cr\hat{z}$ where C is a constant and r is the distance from the axis. There is no free current any where. Find the magnetic field outside and inside of the cylinder. [3]

10. a) What is meant by hysteresis? Find an expression for the work done due to hysteresis. [1+3]

    b) Establish the boundary condition satisfied by $\vec{H}$ at the interface of two media of different permeabilities. Assume no free surface current. [4]

    c) Two magnetic media of relative permeability μ_1 and μ_2 are separated by a plane interface. If the fields $\vec{B}$ on either side make angles θ_1 and θ_2 with the normal to the interface. Show that field lines satisfy the relation $\mu_1\tan\theta_2=\mu_2\tan\theta_1$. [2]

11. a) State Faraday's law of induction and express it in differential form. [3]

    b) Two coils have self inductances L_1 and L_2 and mutual inductance M. Show that $M^2\le L_1L_2$. What is the significance of coefficient of coupling? [3+1]

    c) Two long parallel wires carrying the same current I in the opposite direction are separated by a distance d in air. The radius of each wire is assumed to be much less than d. Find the self-inductance per unit length. [3]

12. a) Find an expression for energy stored in an inductor. [2]

b) Show that in an RL circuit the total energy supplied by the source is equal to the sum of the energy dissipated by the R and energy stored in L. [4]

c) A circuit containing a cell of 2V, capacitor $C = 0.1\mu F$, inductor $L = 10mH$ and resistance R. Find the range of R for which the circuit would be oscillatory. [2]

d) A steady current of 2A in a coil of 400 turns causes a flux of 10^{-4} Wb to link (pass through) the loops of the coil. Find the average back *emf* induced in the coil if the current is stopped in 0.08s. [2]

Group – C

(*Answer <u>any three</u> questions*) [3×10]

13. a) What is Poisson's distribution? Show that it can be derived from Binomial distribution under certain restrictions. [1+3]

b) Consider the Gaussian distribution $P(x) = A\exp\{-\lambda(x-a)^2\}$ where A, a and λ are constants. Determine A. [2]

c) In a dilute gas, the probality that a molecule travels a path of length x without suffering collision with another molecule is given by

$$P(x,\lambda) = \frac{1}{\lambda}.e^{-\frac{x}{\lambda}};\ 0 \le x \le \alpha$$

Find the mean free path of the molecules. What is the area under the curve contained by plotting $P(x,\lambda)$ versus x? [3+1]

14. a) Find the critical constants of a real gas whose equation of state is given by $P = \frac{RT}{V-b} - \frac{a}{TV^2}$ where a and b are constant. [3]

b) The Berthelot's equation of state is given by

$$P = \frac{RT}{V-b} - \frac{a}{TV^2},$$

Where a and b are constants. Expand the above equation in the following virial form

$$\frac{PV}{RT} = 1 + \frac{B}{V} + \frac{C}{V^2} + \cdots$$

Find the expression of second virial coefficient 'B'. Depict the nature of variation of 'B' with temperature. Find also the value of Boyle temperature. [2+1+1]

c) The second virial coefficient of a real gas is 0.02 litre mol^{-1}. Calculate the volume of gram mole of the gas at 27^{0}C and 5 atm. pressure. [R = 0.082 lit. atm. Mol^{-1}K^{-1}]. [3]

15. a) Derive the one dimensional differential equation for heat conduction through a homogeneous and isotropic rod with radiation loss. [4]

b) What will be the modified form of the above differential equation if heat is generated at a rate of H per unit volume of the rod per sec. Assume that the bar is covered properly so that radiation loss may be ignored. [1]

Find the steady state solution of the modified equation assuming H as constant. Boundary conditions: both end of the rod are at room temperature (θ_0). [3]

c) Thermal conductivity of metals are appreciably large compared to insulators – give physical justification. [2]

16. a) (i) Interpret temperature form zeroth law of thermodynamics.

(ii) Define the terms macrostate and microstate.

(iii) 4 molecules are to be distributed in 2 cells. Find possible number of macrostates and corresponding number of molecules. [1+1+2]

b) State the condition for application of M-B statics. [3]

c) Using M-B speed distribution, find the energy distribution of molecule and comment on the most probable velocity. [2+1]

17. a) Derive an expression for thermal conductivity of gas (K) on the basis of Kinetic theory. How does it depend on temperature and pressure? (Explanation is essential). [4+3]

b) Determine the mean free path, collision frequency and molecular diameter at N.T.P. Given that the coefficient of viscosity n = 1.7 x 10^{-5} Ns/m^2, mean velocity, $\overline{c} = 4.5x10^2 m/s$ and density, $\rho = 1.29 kg/m^3$. You can use the relation between coefficient of thermal conductivity (K) and the coefficient of viscosity (n) directly. [3]

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