RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College under University of Calcutta)

B.A./B.Sc. THIRD SEMESTER EXAMINATION, DECEMBER 2014

SECOND YEAR

Date : 17/12/2014 **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*)

1. a) What do you mean by electrical dipole? Find the potential and field due to an electric dipole placed in free space. [1+2+3]

   b) Show that the average field produced inside a sphere by charges lying entirely outside is equal to that they produce at the centre of the sphere. [4]

2. a) In a region containing conductors and filled with a specified charge density ρ, show that electric field is uniquely determined if the total charge on each conductor is given. [4]

   b) For an infinite surface charge distribution in (X–Y) plane of uniform charge density ρ_S, show that the electric field intensity at any point (O, O, Z) on the z-axis is given by

   $$\vec{E} = \frac{\rho_S}{2\in_0}\hat{a}_z$$

   Hence find the electric field intensity at a point inside a parallel plate capacitor held perpendicular to z-axis. [4+2]

3. a) Show that the potential of a polarized object in the same as that produced by a volume density of charge ρ_b plus a surface density of charge σ_b. [4]

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

4. a) The surface of a spherical shell of radius R is charged by a density distribution $r(\theta) = K\cos\theta$. Find the resulting potential inside and outside the sphere. [6]

   b) The polarization with in a region having $\in_r = 2\cdot7$, has the uniform value $\vec{P} = (-0\cdot2\hat{a}_x + 0\cdot7\hat{a}_y + 0\cdot3\hat{a}_z)\,\mu c.m^{-2}$.

   Find (a) $\vec{E}$, (b) $\vec{D}$. [2+2]

5. a) Is x = 0, an ordinary point of the differential equation $2xy''(x) + 3y''(x) + xy(x) = 0$?

   Obtain the two linearly independent solutions by Frobenius method. [1+5]

   b) Prove the following relation for Legendre Polynomials $P'_{n+1}(x) + P'_{n-1}(x) = 2xP'_n(x) + P_n(x)$. [4]

Group – B

(*Answer **any four** questions*)

6. a) State and prove the maximum power transfer theorem. [4]

   b) What is a magnetic circuit? Establish the fundamental equation for magnetic circuit. [1+3]

   c) Calculate the current required in the toroid of iron having mean diameter 20 cm and cross-sectional area $\pi\,cm^2$ to produce a flux of $12\cdot57\times10^{-4}$ Wb in the ring. [2]

   [Given: The total number of turns of the wire is 800 and relative permeability of the material is $\mu_r = 5000$]

7. a) Establish the relation $\vec{E} = -\nabla V - \frac{\partial\vec{A}}{\partial t}$; where V and $\vec{A}$ are scaler and vector potential of magnetic field. [3]

b) Write down Biot-Savart's expression for $\vec{B}$ field in terms of volume current and hence show that $\vec{\nabla}.\vec{B}=0$. [1+2]

c) Determine the $\vec{B}$ field at the centre of radius R with uniform volume charge distribution ρ_v and rotating about one of its diameters with an angular velocity ω. [4]

8. a) Show that for uniform magnetization $\vec{K}=\vec{m}\times\hat{n}$, where $\vec{K}$ is the surface magnetization current density, $\hat{n}$ is the unit vector normal to the surface and $\vec{M}$ is the magnetization. [3]

b) If a current-carrying rectangular coil is immersed in a uniform magnetic field $\vec{B}$, show that
(i) Net force on the coil is zero (ii) Torque $T=\vec{m}\times\vec{B}$, where $\vec{m}$ is the magnetic dipole moment vector. [1+2]

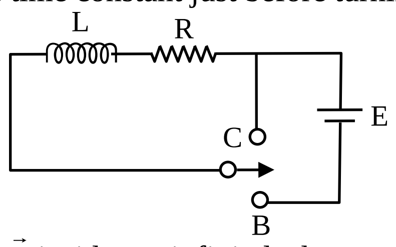
c) In a certain material $\chi=4\cdot 2$ and $\vec{H}=0{\cdot}2x\hat{y}A/m$. Determine— (i) $\vec{M}$ (ii) $\vec{B}$ (iii) volume current density (bound current) (iv) total current density. [4]

9. a) Find an expression for the differential form of Faraday's law of induction and explain its significance. [3+1]

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

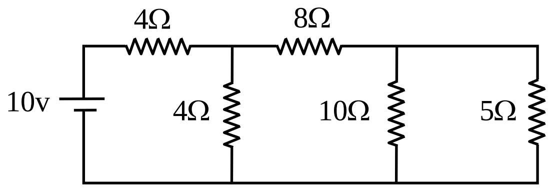
c) Two long parallel wires carrying the same current I in the opposite direction are separated by a distance d in air. The lengths of the wires are much larger than d. Find the self-inductance per unit length. [4]

10. a) Prove that the total energy dissipated in an LR circuit when switch is turned from B to C is equal to the energy stored during one time constant just before turning the switch. [4]



b) Show that the magnetic field $\vec{B}$ inside an infinitely long solenoid oriented along z-axis with n turns per unit length, radius R and carrying current I is $\vec{B}=\mu_0 nI\hat{a}_z$. [4]

c) Find the Norton's equivalent of the adjoining circuit. [2]



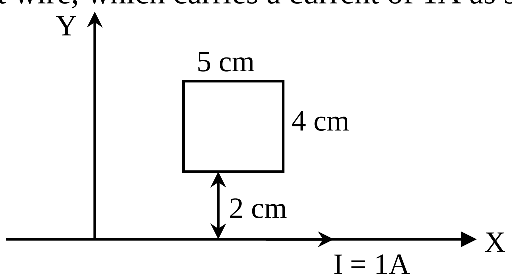
11. a) What do you mean by hysteresis in a ferromagnetic material? [2]

b) Show that hysteresis loss per unit volume per cycle of magnetization is equal to the area enclosed by the B-H loop. [3]

c) A sphere of linear magnetic material of permeability μ and radius R is placed in a region of permeability μ_0, where we have an initial uniform magnetic field $\vec{H}_0$. Find the magnetic scalar potential inside and outside the sphere (Assume the form of the solution of Laplace's equation). [5]

12. a) Two coils with self-inductances L_1 and L_2 respectively have mutual inductance M. Find an expression for their coefficient of coupling (K). [4]

b) A rectangular loop of sides 4 cm and 5 cm lies on a table at a distance 2 cm from a very long straight wire, which carries a current of 1A as shown in Fig.



i) Find the flux of B through the loop. [3]

ii) If some one now pulls the loop at velocity $2\hat{y}\,m/s$, what emf is generate in what direction does the current flow. [3]

Group – C

(*Answer **any three** questions*)

13. a) The Gaussian Probability distribution is given by :

$$P_G(x,\ \mu,\sigma)=\frac{1}{\sqrt{2\pi}\sigma}\exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right]$$

Sketch the graph of above distribution. Show that it has two points of inflexion at $x=\mu\pm\sigma$. [1+3]

b) Write down the expression of partition function Z of a system in thermal equilibrium at a temperature T. What is it's significance? [2]

c) A system has two non-degenerate energy levels $E_0 = 0$ and $E_1 = 0{\cdot}5$ eV. Estimate the temperature at which 1% of the total population occupy the higher level. [4]

[Boltzmann constant $k_B = 8{\cdot}625 \times 10^{-5}$ eV/K]

14. a) Write down the Maxwell's law of distribution of molecular speed in three dimension. Find out expressions for the most probable speed c_m and the number of molecules $n(c_m)$ having speed c_m.[2+2+2]

b) Calculate the fraction of molecules of a gas within 1% of the most probable speed at S.T.P. Will it be the same for all gases at all temperature? [3+1]

15. a) Write down an expression of mean free path. Comment on its dependence on pressure and temperature. [2]

b) Show that the probability of a gas molecule traversing a distance 'x' without collision is $\exp(-x/\ell)$, where 'ℓ' is the mean free path of the gas. [3]

c) A bar of length 30cm and uniform cross-section of 5cm^2 constants of two halves, AB of copper and BC of iron, welded together at B. The end A is maintained at 200°C and end c at 0°C, and the sides are thermally insulated. Find the rate of flow of heat along the bar when the steady state has been reached.

[Thermal conductivites are : copper = 0·9, iron = 0·12 in CGS unit] [5]

16. a) Plot isotherms according to van der Waals equation of state. What do you mean by metastable state? Identify those regions of the van der Waals isotherms which represent metastable states. [3]

b) Find the critical constants of the van der Waals gas. [4]

c) When the equation of state of a real gas is expressed as following virial expansion : $\frac{PV}{RT}=1+\frac{B}{V}+\dots,$

the second virial coefficient is found to be 0·02 litre-mol^{-1}.

Estimate the volume of a gram mole of the gas at 27°C and 5 atm pressure.

[R = 0·082 lit. atom. mol^{-1}K^{-1}] [3]

17. a) Find an expression for the coefficient of viscosity from the kinetic theory of gases. In gases coefficient of viscosity increases with increasing temperature, whereas in liquids, coefficient of viscosity decreases with increasing temperature. Explain briefly. [5+2]

b) A lake is covered with ice, 2 cm thick. The temperature of the outside atmosphere is –10°C. Find the rate of ice formation in cm/hour.

Given that the thermal conductivity of ice is 2·18 W.m^{-1}K^{-1}, The density of ice = 0·9 gm/cc.

Latent heat of melting of ice = 336 J/gm. [3]

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