RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College under University of Calcutta)

B.A./B.SC. THIRD SEMESTER EXAMINATION, DECEMBER 2012

SECOND YEAR

Date : 14/12/2012 **PHYSICS (Honours)**

Time : 11 am – 2 pm Paper : III Full Marks : 75

Group-A

Section-I

Answer any two questions

1. a) State the integral and differential forms of Gauss' law in electrostatics. [2]

   b) Find the electric field inside a sphere of radius 'a' which carries a charge density proportional to the distance (r) from the origin, $\rho = kr (k = \text{constant})$. [4]

   c) Consider a spherical capacitor consisting of an inner metal sphere of radius 'a' and outer metal spherical shell of radius 'b'. The inner sphere is charged to a potential 'V_0' and the outer spherical shell is earthed. Using Laplace's equation, find an expression for the potential 'V' in the space between inner and outer spheres in terms of V_0, a and b. [4]

2. a. Using the expansion $\frac{1}{\left|\vec{r}-\vec{r'}\right|} = \sum_{l=0}^{\infty} \sum_{m=-l}^{+\ell} \frac{4\pi}{(2l+1)} \frac{r'^l}{r^{l+1}} Y_{lm}^*\left(\theta', \phi'\right) Y_{lm}\left(\theta, \phi\right)$ for r>r$'$, develop the multipole expansion of the potential $\Phi\left(\vec{r}\right)$ due to a localized charge distribution $\rho\left(\vec{r'}\right)$ in terms of the multipole moments $q_{\ell m}$. Discuss how and under what conditions this expansion can be used to simplify a problem. [3]

   b) Show that for a spherically symmetric charge distribution, all multipole moments beyond the monopole moment vanish. [3]

   c) For two point charges q and –q placed on the Z-axis at Z=a and Z=-a, compute the nonvanishing component of the dipole moment, $\left(\text{Given } Y_{lo}\left(\theta, \phi\right) = \sqrt{\frac{2l+1}{4\pi}} P_l\left(\cos\theta\right)\right)$. [4]

3. a) A uniformly charged sphere of radius 'a' carries a total charge Q . Show that the electrostatic field energy is u = $\frac{3Q^2}{20\pi\epsilon_o a}$. 4

   b) Write down the electrostatic boundary conditions at the interface of two dielectric media. The interface between dielectric media 1(dielectric constant=4) and dielectric media 2 (dielectric constant=3) is given by z=0. A uniform electric field, $\vec{E_1} = 5\hat{i} - 2j + 3k$ Kv/m exists in the media 1 $\left(z \le 0\right)$.

   Find (i) the electric field $\vec{E_2}$ in media 2

   (ii) the angles made by $\vec{E_1}$ and $\vec{E_2}$ with the interface. [2+(2+2)]

4. a) i) Briefly explain the image method of solving electrostatic problems in presence of conducting boundary surfaces with specific potential or charge density. [2]

   ii) Give reasons why the image charge should be located outside the 'region of interest'. [2]

   iii) Consider a conducting sphere raised to a potential V. For electric field outside the sphere what should be the image charge and where should it be located. [1]

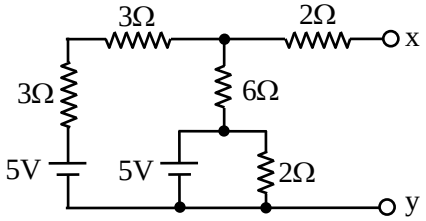
   b) An electric dipole of strength $\vec{p}$ is oriented perpendicular to and at a distance 'd' from an infinite conducting plane. Calculate the force exerted on the plane by the dipole. [5]

Section-II

Answer any three questions

5. a) State and prove maximum power transfer theorem. [1+4]

b) Find the Thevenin and the Norton equivalent circuits between the terminals x,y for the given network and determine the resistance to be connected across x,y to dissipate maximum power and calculate the maximum power. [2+2+1]



6. a) Find out $\vec{B}$ for a long straight wire carrying current $\vec{I}$. [5]

b) Deduce the equation satisfied by $\vec{A}$ using Coulomb gauge and find out the solution. (symbols have their usual meanings). [5]

7. a) Two parallel long wires of negligible resistance separated by a distance 'l' are connected to a source of e.m.f. 'E'. A metallic bar of resistance 'R' makes contact with the wires and can slide parallel to itself. A magnetic uniform field $\vec{B}$ is applied perpendicular to the plane of the wires. If the mass of the bar is 'm' find the velocity of the bar as a function of time 't' assuming that it starts from rest at t=0. [6]

b) Show that the equivalent inductance of two coils of self-inductances L_1, L_2 and mutual inductance M connected in parallel is given by $Leff = \frac{L_1L_2 - M^2}{L_1 + L_2 \pm 2M}$. Explain under what condition the positive and the negative sign apply. [4]

8. a) Two parallel wires of 1 m are separated by a distance of 0.2 cm. 5 A currents flow through each conductor in opposite directions. Calculate the mutual force between the conductors. Is it attractive or repulsive? 5

b) 100 V is applied between the ends of a 2 mm diameter straight copper wire of length 1000 m long find (i) its resistance, (ii) current through it and (iii) field inside it. Given conductivity

$\sigma = 5.7 \times 10^7$ mhos per meter $\left(\mho m^{-1}\right)$. 3

c) Consider a wire with a square cross section of area 1 mm x 1 mm, carrying a current of one amp. Current density in the wire is uniform and along the wire. Find the drift velocity of the carrier.

Given: $\rho = 1.6 \times 10^{-9} C, n = 10^{27}$ electron per cubic centimeter. 2

9. a) Deduce the boundary conditions satisfied by $\vec{B}$ and $\vec{H}$ respectively at the boundary of two media. [5]

b) Show that the continuity equations relating the charge density and current density in a conductor is given by $\vec{\nabla}.\vec{j} + \frac{\partial \rho}{\partial t} = 0$ where $\vec{j}$ is the current density and ρ is charge density. [5]

Group-B

Section-I

Answer any two questions

10. a) Find out an expression of number of molecules striking per unit area of an wall in unit time having speeds v to v+dv and making an angle $\theta \, to \, \theta + d\theta$ with the normal to the wall. Utilize this expression to derive an expression of pressure of an ideal gas in terms of the mean square speed of the gas molecules. 3+2

b) State the classical law of equipartition of energy. Comment on its validity criterion. 1+1

c) Find the total kinetic energy (K.E) associated with the chaotic motion of one mole of an ideal monatomic gas at absolute temperature T. How does this K.E. vary with temperature if pressure is maintained constant? 3

11. a) Explain the term mean free path in connection to the motion of gas molecules. What do you mean by 'collision frequency' and 'collision probability' of gas molecules? Prove that the distribution of

free path is $f(x)=\exp\left(\frac{-x}{\lambda}\right)$, λ is the mean free path. Draw the nature of distribution for high and low values of λ. [1+2+2+1]

b) A Carnot cycle operates as a heat engine between two identical bodies at initial temperature T_1 and $T_2, (T_1 < T_2)$. If the engine works until the temperatures are identical, show that final temperature is $\sqrt{T_1 T_2}$ and the work done is $W = C\left(T_1 + T_2 - 2\sqrt{T_1 T_2}\right)$

C is sp.heat of the source/sink. 4

12. a) Distinguish between quasi-static process and reversible process. 2

b) Prove that the efficiencies of all reversible engines working between the same two temperatures are same. 4

c) An electric current of 10A is maintained for 4 sec in a thermally insulated resistor of 25 ohm, whose initial temperature is 27^0C. The resistor has a mass of 0.01 kg and $C_p = 0.84 kJ.kg^{-1}.K^{-1}$.

(i) What is the entropy change of the resistor?

(ii) What is the entropy change of the universe? 4

13. a) What do you mean (physically) by the internal energy of an ideal monatomic gas? 2

b) Three moles of an ideal gas, being initially at a temperature 273 K, were isothermally expanded to five times its initial volume and then isochorically heated to initial pressure. The total amount of heat absorbed by the gas during the entire process is 80 KJ. Find the value of C_v for the gas. 4

c) A capacitor $(1\mu F)$ is connected to a reversible cell of 100 V at 0^0C. It is now disconnected and allowed to discharge through a resistance (10Ω) at 27^0C. Calculate the change in entropy. 4

Section-II

Answer any one question

14. Explain the 'green house' effect in the ecosystem. Does it violate the laws of thermodynamics? 3

A power plant generates 1000 MW using the water of a river nearby. If the waste heat is delivered to the river under the condition that temperature must not rise more than 5^0C. Find the amount of water necessary per minute. The efficiency of the power plant is 40%. 2

15 Show that the molar entropy of an ideal gas is given as $S(T,V) = C_v \ln T + R \ln V + S_0$. Give the significance of S_0. 4+1