RAMAKRISHNA MISSION VIDYAMANDIRA

(Residential Autonomous College under University of Calcutta)

B.A./B.SC. THIRD SEMESTER EXAMINATION, DECEMBER 2011

SECOND YEAR

PHYSICS (Honours)

Date : 16/12/2011

Time : 11am – 2pm

Paper : III

Full Marks : 75

[Use separate answer-books for each group]

Group–A

Answer **any two** questions from questions no. 1 – 4: 10x2

1. a) Starting from a general definition of electric field $\vec{E}(\vec{r})$ at an observational point $\vec{r}$, show that $\vec{\nabla}\times\vec{E}(\vec{r})=0$. 2

   b) State and explain Gauss' theorem in electrostatics. Obtain Poisson's equation from the differential form of Gauss' theorem. 2+2

   c) Given a spherical charge distribution of volume charge density

   $$\rho(r)=\rho_0 \text{ (a constant) for } 0\le r\le R$$
   $$= 0 \text{ for } r > R$$

   Obtain an expression for the electrostatic potential $\phi(\vec{r})$ due to this charge distribution assuming $\phi(r=\infty)=0$. 4

2. a) Show that if the total charge of a charge distribution is zero, then the total dipole moment of the charge distribution is independent on the choice of origin. 3

   b) Derive expression for the (i) potential and (ii) field at a point $\vec{r}$ due to a dipole $\vec{p}$ at $\vec{r}'$. 5

   c) Using the results in (b) obtain the an expression for the interaction energy of two dipole $\vec{p}_1$ and $\vec{p}_2$ located at $\vec{r}_1$ and $\vec{r}_2$ respectively. 2

3. a) Deduce an expression for the electrostatic energy in a dielectric media. 4

   b) A metal sphere of radius 'a' is surround out to a radius 'b' by a linear dielectric material of permittivity '$\in$'. Determine the capacitance of the sphere. 3

   c) A uniformly charged sphere of radius 'a' carries a total charge Q having a uniform volume density of charge. Show that the stored electrostatic energy is $U=\dfrac{3Q^2}{20\pi\in_0 a}$ 3

4. a) Explain briefly the principle used in solving the electrostatic problems by the method of image. 3

   b) What is a linear dielectric? 1

   c) Obtain the potential outside and inside a dielectric sphere placed in a uniform external electric field $\vec{E}$ by solving the Laplace's equation with appropriate boundary condition. 6

Answer **any three** questions from question No. 5 – 9: 10x3

5. a) How does the conductivity of semiconductors and metals vary with temperature? 2

b) If 10V is applied between the ends of a 1mm diameter copper wire 100 meter long find electron velocity.

Given $\sigma = 5.7 \times 107 mho/m,\ \mu_e = 0.0040 m^2/Vs, \rho = 1.4 \times 10^{10} C/m^3$ 3

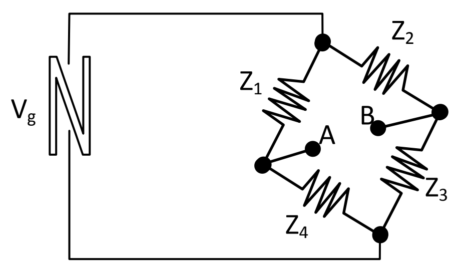
c) Two cells of e.m.f's E_1 and E_2 with internal resistances r_1 and r_2 respectively, connected in parallel. These combination is connected to an external resistance R in such way that the two cells send current in the same direction. Show that the current I through R can be written as $I = \dfrac{E_1 r_2 + E_2 r_1}{r_1 r_2 + R(r_1 + r_2)}$. 3

d) A current in a solenoid produces a magnetising field of 167 Amp/m. What is the magnetic induction inside it if it has an iron core of magnetic susceptibility 5000? 2

6. a) State Thevenin's theorem in electrical network. 2

b) Between the two terminals A, B in the bridge network, a load impedance Z is connected, find in what condition maximum power will delivered to the load. 5

c) In the diagram, if Z_1 = 30Ω, Z_2 = 20Ω, Z_3 = 30Ω, Z_4 = 10Ω and V_g = 10V, find the equivalent circuit parameters and at what value of load Z, maximum power will delivered. 2+1



7. a) Write down the Biot-Savart expression for the magnetic field due to a volume distribution of steady current. Show that the magnetic field can be expressed as the curl of a vector field $\vec{A}(\vec{r})$. Give the expression of $\vec{A}(\vec{r})$. 4

b) What will be the divergence of the magnetic field and what is its physical significance? Show that the flux of magnetic field due to a steady current distribution, through a closed surface is zero. 2

c) Find the magnetic field at a distance r from an infinitely long straight wire carrying a steady current I using Ampere's law. Express the magnetic field in a vectorial form. 2

d) Using the expression for $\vec{A}(\vec{r})$ obtained in the problem (a), find a vector potential for a straight wire carrying a steady current I and extending from $-\infty$ to $+\infty$. What is the direction of the vector potential? Does it matter to the magnetic field if you have an infinite additive constant to this potential? Give reasons. 2

8. a) State Faradays law of electromagnetic induction and express it in a differential form. 2

b) Two coils having self inductances L_1 and L_2 and their mutual conductance is M. Show that $M^2 \le L_1 L_2$.

Also, show that their equivalent inductance L_{eff} is given by $L_{eff} = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$

when the coils are connected in parallel.

Explain under what conditions the positive and negative signs apply. 3+5

9. a) What do you mean by 'Hysterisis'. Show that the loss of energy due to hysterisis per unit volume of the material per cycle of magnetization is given by the area of the $B-H$ loop. 1+3

b) Deduce the fundamental equation of a magnetic circuit. 3

c) Show that an inhomogeneous magnetisation gives rise to a volume current density $\vec{J}_b$ where $\vec{J}_b = \vec{\nabla} \times \vec{M}$ ($\vec{M}$ = Magnetisation in the matter). 3

Group – B

Answer **any one** question from the following: 10x1

10. a) "An infinitesimal amount of work can not be represented by an exact differential". Explain the meaning of the statement. 2+1

b) A system goes from initial state *i* to final state *f* (Fig. 1). Calculate work done when the system goes through paths *iaf*, *ibf* and *if*. 3

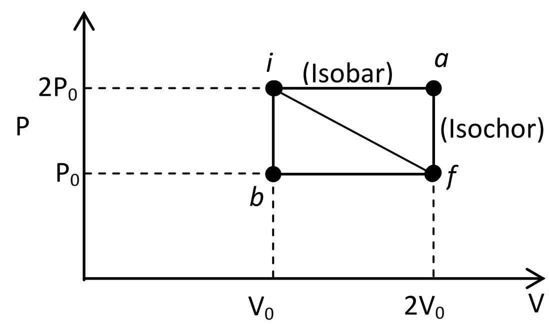


Fig. 1

c) Show that for a quasi-static adiabatic expansion of an ideal gas $PV^\gamma = \text{constant}$.

An adiabatic curve has a steeper negative slope than an isothermal curve at the same point — Explain. 3+1

11. a) Write down the Kelvin-Planck statement and the Clausius statement of the second law of thermodynamics. 2

b) Obtain the efficiency of a Carnot's engine. 4

c) An air conditioner, having power rating 2 KW, removes 6.3 KW heat from a large room. It's coefficient of performance is one tenth that of a Carnot's refrigerator operating in same temperature difference. The temperature outside is 37ºC. What is the temperature inside? 4

Answer **any one** question from the following: 10x1

12. a) State Clausius theorem. Show that in any irreversible process entropy change of the universe is always positive. 1+4

b) For an ideal gas with constant heat capacities, show that the entropy is given by $S = C_v \ln P + C_p \ln V + \text{constant}$. 2

c) The entropy of n moles of an ideal gas can be written as

$$S = (n/2)[5R\ln(U/n) + 2R\ln(V/n) + S_0],$$

where U is the total internal energy of the gas, V is the volume and S_0 is a constant. Calculate molar specific heats C_p and C_v.

Show also $PV = \frac{2}{5}U$, P is the pressure of the gas. 3

13. a) The Maxwell's law of distribution of molecular speed in three dimension can be expressed as $n(v)dv = CNV^2 e^{-\frac{mv^2}{2kT}} dv$; N is the total number of molecules. Other symbols are of usual meaning. Find the normalisation constant C. Using Maxwell's law of distribution of molecular speed find the mean square speed of the gas molecules. 2+2

b) Find out the expression for the most probable speed v_m and the number of molecules $n(v_m)$ having speed v_m. 2+2

c) Depict the nature of speed distribution for two different temperatures T and $4T$ on the same graph. 2

Answer **any one** question from the following: 5x1

14. a) With reference to a thermodynamic system define a state function. 1

b) State zeroth law of thermodynamics. Discuss its importance for developing the concept of temperature. 1+3

15. a) Show that the probability of a gas molecule traversing distance x without collision is $e^{-x/l}$, where l is the mean free path of the gas. 3

b) The mean free path in a certain gas is 4.0 cm. Consider 10000 free paths. How many are longer than 4 cm? 2

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