2020

PHYSICS

[HONOURS]

Paper : V

Full Marks : 75 Time : 4 Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

1. Answer any **five** questions: 1×5=5

   a) Calculate the total electric flux from a stationary charge of +q coulomb placed in free space.

   b) Find the work in moving a charge of IC through a distance of 1m on an equipotential conductor.

   c) Find the unit of CR.

   d) No transient is produced in a pure resistive circuit. Why?

   e) An ideal transformer with 1000 turns in its primary coil converts 240v(peak value) a.c. into 12v(peak value) a.c. Find the number of turns in the secondary coil of the transformer.

   f) State Kirchhoff's voltage law.

   g) A series a.c. circuit has a resistance of $10\,\Omega$ and a reactance of $5\,\Omega$. What is the impedance of the circuit?

   h) In what respect, the electric field inside a current carrying conductor differs from an electrostatic field?

2. Answer any **six** questions: 2×6=12

   a) Electric field at a distance r from a point charge q placed in a dielectric is less than the electric field produced by the same charge q in free space. Explain.

   b) State Earnshaw's theorem.

   c) Two resistance R and 4R are connected in parallel in an electrical circuit. Find the ratio of power dissipations in R and 4R.

   d) Obtain the potential energy of an electric dipole of dipole moment $\vec{p}$ placed in a non-uniform electric field $\vec{E}(\vec{r})$.

   e) Find $\vec{B}$ for a given magnetic vector potential $\vec{A}=\frac{1}{2}\vec{C}\times\vec{r}$ where $\vec{C}$ is a constant vector.

   f) Find the frequency of an oscillator circuit where L=0.1H and C=$0.047\,\mu F$.

g) Find the force on a magnetic dipole of moment $\vec{m} = m\hat{j}$ when it is placed in a magnetic field of $\vec{B} = 2\left(x^2 + y^2\right)\hat{i} - 4xy\hat{j}$.

h) In an ideal a.c circuit show that potential across an inductor leads the current by 90^o.

i) Explain with a diagram what is meant by non-inductive coil.

j) A magnetic field $\vec{B} = B_0 \cos wt\,\hat{k}$ points straight up from the plane of a circular ring of radius a placed in the xy plane. Find the induced electric field.

3. Answer any **three** questions: 6×3=18

a) i) Check if the electric field given by $\vec{E} = \dfrac{x\hat{i} + y\hat{j} + z\hat{k}}{\left(x^2 + y^2 + z^2\right)^3}$ is a conservative one.

ii) Calculate the potential at a non-axial point $(\vec{r})$ due to an electric dipole of dipole moment $\vec{p}$. 2+4

b) Electric potential at a point (r, θ) is given by

$$v(r,\theta) = \sum_{l=0}^{\infty}\left(A_l r^l + \frac{B_l}{r^{l+1}}\right)P_L(\cos\theta)$$

where A_l, B_l are constants and $P_L(\cos\theta)$ is the Legendre Polynomial. Potential on its surface of a hollow sphere is defined as $v(R,\theta) = v_0(\theta)$.

i) Express $v_0(\theta)$ in terms of $P_l(\cos\theta)$ and r.

ii) Evaluate A_1 when $v_0(\theta) = k\sin^2\dfrac{\theta}{2}$, k=constant

iii) Evaluate A_1 and write down $v(r,\theta)$ when $v_0(\theta) = \phi_0$. 2+2+2

c) i) For a magnetic circuit establish a relationship between megnetomotive force, the reluctance and the magnetic flux.

ii) Use Biot-Savart law to determine the magnetic field at an axial point of a circular-coil carrying a steady current. 3+3

d) i) Express conservation of charge in the form of a differential equation. What is the form of this equation for a steady current?

ii) Calculate the total current through the wire of radius a, carrying current density

$\vec{y} = \left(\frac{r^2}{a}\right)\vec{y}_0$, where $\vec{y}_0$ is parallel to the axis. 3+3

e) i) What do you mean by Seebeck, Peltier and Thompson effects? Differentiate between Peltier effect and Joule heating effect.

ii) The thermo-emf in a thermocouple with one junction at 0^oC and the other at t^oC is given by $E=at+bt^L$ where a and b are constants. Find the Peltier coefficient at t^oC. 4+2

4. Answer any **four** questions: 10×4=40

a) i) A point charge q is placed at a distance d from the centre of a grounded sphere of radius a(a<d). Calculate the location and magnitude of the image charge. Find the potential and electric field at an external point. Calculate the induced surface charge density.

ii) A dipole moment $\vec{p}$ is placed with its axis vertical at a distance d from an infinite conducting horizontal grounded plane. Calculate the force exerted on the plane by the dipole. 7+3

b) i) Establish Clausius-Mossotti relation for a nonpolar dielectric.

ii) Show that the mutual interaction energy of two dipole moments $\vec{P}_1$ and $\vec{P}_2$ is given by

$$u = \frac{1}{4\pi t_0}\left[\frac{\vec{p}_1.\vec{p}_2}{r_3} - \frac{3(\vec{p}_1.\vec{r})(\vec{p}_2.\vec{r})}{r^5}\right].$$ 5+5

c) i) Obtain an expression for the growth of current in a series L-R circuit connected to a battery of emf. E. Define time constant of the circuit. Express your result graphically.

ii) A coil of induction 10H and resistance 10Ω is connected to a steady voltage of 100V at time t = 0. Find the value of current at t = 0.1s. What is the time taken for the current to reach one half of its steady value? 6+4

d) i) Establish the boundary conditions satisfied by $\vec{B}$ and $\vec{H}$ at the interface of two media of different permeabilities. Assume no free surface current.

ii) In a magnetic medium having relative permeability $\mu_r = 4$ the magnetic field is given by $\vec{B} = 0.01e^{-y}\hat{z}$ T. Calculate susceptibility and magnetization. 6+4

e) i) Using the concept of magnetic vector potential $\vec{A}$, establish Biot-Savart law and Ampere's circuital law.

ii) Find the magnetic field at the centre of a square loop of wire of edge a, lying in the xy-plane carrying current I in anticlockwise direction. 6+4

f) i) What is meant by resonance in a series LCR circuit? What are current and voltage resonances? Find the corresponding resonant frequencies.

ii) A series circuit consisting of L=0.3H, C=4 μF and R=60 Ω is connected to 220V, 50Hz. Find the r.m.s value of current and power dissipation in the circuit. 6+4

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