Total number of printed pages–7

3 (Sem–2/CBCS) PHY HC 1

2023

PHYSICS

(Honours Core)

Paper : PHY–HC–2016

(Electricity and Magnetism)

Full Marks : 60

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×7=7

   (a) What is the significance of electric susceptibility for a dielectric ?

   (b) How much electrostatic energy is stored by a solid sphere of radius R and total charge Q ?

   (c) Write Faraday's second law in differential form.

   (d) What is the capacitance of earth ? Given the radius of earth is 6400 *km*.

Contd.

(e) If there is no damping in an L-C-R circuit with A.C, what will be the *Q*-factor ?

(f) Under what condition, a cell can act as a constant current source ?

(g) In a ballistic galvanometer :

(i) inertia of the coil is small and damping is also small

(ii) inertia of the coil is large and damping is critical

(iii) inertia of the coil is large and damping is small

(iv) both inertia of the coil and damping are large.

(Choose the correct option)

2. Answer the following questions : 2×4=8

(a) In a region of space the electric field is given by $\vec{E} = 8\hat{i} + 4\hat{j} + 3\hat{k}$. Calculate the electric flux through a surface of area 100 units in $x-y$ plane.

(b) Write down Poisson's and Laplace's equation in electrostatics.

(c) Which one of the following will experience a maximum magnetic force, when projected with the same velocity (V) perpendicular to the magnetic field (B) ?

(i) α-particle

(ii) β-particle

(d) An electric dipole of moment $2\times10^{-8}\,Cm$ is placed in a uniform field of intensity $1.5\times10^{5}\,NC^{-1}$. How much work is done on turning the dipole end to end ?

3. Answer ***any three*** questions : 5×3=15

(a) (i) Using Gauss' law, find the electric field outside a uniformly charged spherical shell of radius R and total charge q. 3

(ii) The potential of a certain charge configuration is expressed by $v = 2x + 3xy + y^2$ volts. Find the electric intensity at point (5,2). What acceleration does an electron experience in the x-direction ? Distances are in metre.

Contd.

(b) What is meant by dielectric polarisation? Show how $\vec{E}, \vec{D}$ and $\vec{P}$ are related for an isotropic dielectric medium. Is water molecule a polar molecule ? If so, why ?
[Where the symbols have got their usual meaning.] 1+3+1=5

(c) State Ampere's circuital law of magnetic field. A toroid has a core made up of non-ferromagnetic material. The inner radius of the core is 19 *cm* and outer radius is 21 *cm*. Around this core 5000 turns of copper wire are wound. If the current in the wire is 10 A, what is the strength of the magnetic field

(i) outside the toroid;

(ii) inside the core of the toroid;

(iii) in the empty space surrounded by the toroid ? 1+4=5

(d) Two inductors of self inductances L_1 and L_2 with mutual inductances M are connected in series. Derive an expression for the equivalent inductance of the combination.

(e) Define charge sensitivity and current sensitivity of a ballistic galvanometer. Obtain an expression for charge sensitivity of a ballistic gavanometer. How is it related to the current sensitivity ? 2+2+1=5

4. Answer ***any three*** questions : 10×3=30

(a) (i) What is the principle of 'method of electrical images' ? A point charge *(Q)* is placed in front of an earthed conducting sphere of radius *(R)*. Calculate the potential and field at an external point $P(r, \theta)$. 1+4=5

(ii) What is electric dipole ? Derive an expression for electric potential at a point due to an electric dipole. 1+4=5

(b) Derive Gauss' law in a dielectric medium. Establish the boundary conditions satisfied by electric field $\vec{E}$ and electric displacement vector $\vec{D}$ at the boundary between the two dielectrics. 4+6=10

(c) (i) Derive an expression for magnetic field at a point on the axis of a circular current loop. Use it to prove that magnetic field at the ends of a long solenoid is one-half of that at the centre. 5+3=8

(ii) An electron circulates around a nucleus in an orbit of radius 5.1×10^{-1} metre at a frequency ν of 6.8×10^{15} rev./sec. Calculate magnetic field strength at the centre of the orbit. 2

(d) An instantaneous e.m.f $E = E_0 \sin\omega t$ is applied to LCR circuit due to which the instaneous circuit is $I = I_0 \sin(\omega t - \phi)$. What is the average power consumed during one complete cycle ? If the circuit contains only capacitor, then what will be the average power ? 8+2=10

(e) (i) State and prove maximum power transfer theorem. 5

(ii) An AC source of internal resistance R_s is used to drive a load consisting of a capacitor (C) in parallel with a series combination of an inductor (L) and a resistor (R) Find the condition for maximum power transfer. 5

(f) What is hysteresis ? Derive an expression for work done per unit volume during cycles of magnetisation. What are the factors on which hysteresis loss depends ? Draw hysteresis curves for the material suitable for its use *(i)* in a transformer, and *(ii)* as a permanent magnet. 2+4+2+2=10
