3 Yr. Degree/4 Yr. Honours 3rd Semester Examination, 2024 (CCFUP)

Subject : Physics

Course : PHYS3011 (MAJOR)

(Electricity and Magnetism)

Time: 2 Hours **Full Marks: 40**

The figures in the margin indicate full marks.

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

1. Answer *any five* questions from the following: 2×5=10

(a) A pure electric dipole (dipole moment p) is situated at the origin, pointing in the z-direction. What is the force on a point charge q at $(a, 0, 0)$ (Cartesian coordinates)?

(b) Find the capacitance of two concentric spherical metal shells with radii a and b $(a < b)$.

(c) A sphere of radius R carries a polarization $\vec{P}(r) = k\vec{r}$, where k is a constant and $\vec{r}$ is a vector from the center. Calculate the bound charge densities σ_b and ρ_b.

(d) Show that magnetic forces do no work.

(e) Find the mathematical relation between magnetic permeability and magnetic susceptibility for a linear medium.

(f) State the Thevenin's theorem for two-terminal linear networks.

(g) Plot the time variation of charging current and voltage across the capacitor of a series CR circuit when it is connected to a source of constant voltage V.

(h) Write down two major differences between a dead beat galvanometer and a ballistic galvanometer.

2. Answer *any two* questions from the following: 5×2=10

(a) Find the energy stored in a uniformly charged solid sphere of radius R and charge Q.

(b) State the Ampere's circuital law. Consider two long straight parallel wires separated by distance of 1 cm, each carrying a current of 1 Amp in the same direction. Find the magnitude and the direction of the force per unit length acting on each wire. What would the results be if the directions of the current flow were opposite? 1+(3+1)

(c) Using the Biot-Savart law determine the magnetic field at an axial point of a circular loop of radius R, carrying a current I.

(d) Imagine a small sphere cut out of a dielectric specimen which has uniform polarization $\vec{P}$. What is the polarization charge density on the surface of the cavity left out by the sphere? Find the electric field at the center of the cavity due to these polarization charges. 1+4

3. Answer *any two* questions from the following: 10×2=20

(a) (i) Find the electric potential at a distance z above the center of a thin circular disc of radius R, which carries a uniform surface charge density σ. Hence, find the electric field at the same point and comment on your result when $z \gg R$. 3+1+2

(ii) State the Gauss' law in electrostatics. Find the electric field at a distance r from an infinitely long straight wire, which carries a uniform line charge density λ. 1+3

(b) State the uniqueness theorem related to electrostatic potential. A point charge $+q$ is held at a distance d above an infinite grounded conducting plane. Using the method of images find-

(i) the potential $V(x, y, z)$ in the region above the conducting plane.

(ii) the induced surface charge density on the conducting plane and show that the total induced charge on the plane is $-q$.

(iii) the total work required to remove the point charge slowly to an infinite distance from the plane. 2+(2+4+2)

(c) (i) A series circuit consisting of $L = 0.1\ H$, $C = 15\ \mu F$ and $R = 200\Omega$ is connected to 220V, 50 Hz main. Calculate the current (r.m.s) in the circuit. Calculate the voltage (r.m.s.) across the inductor, capacitor and the resistor. Is the algebric sum of these voltages is more than the source voltage? If yes, justify the answer. Calculate the power factor and the power dissipation in the circuit. 3+(1+2)+2

(ii) Write down the physical significances of 'electrical resonance' in a series LCR circuit. 2

(d) (i) A metal bar of mass m slides frictionlessly on two horizontal parallel conducting rails, at a distance l apart. A resistor R is connected across the rails and a uniform magnetic field $\vec{B}$, pointing into the page, fills the entire region. If the bar moves to the right at speed v, what is the current in the resistor? In what direction does it flow? What is the magnetic force on the bar and in what direction? If the bar starts out with speed v_0 at time $t = 0$ and is allowed to slide, what will be its speed at a later time t ?

(ii) A long coaxial cable carries current I (the current flows down the surface of the inner cylinder, radius a and back along the outer cylinder, radius b). Find the magnetic energy stored in a section of length l. Hence, find the self-inductance of the cable.
