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SH-II/PHSH/CC-III/23

# B.Sc. 2nd Semester (Honours) Examination, 2023 (CBCS)

## Subject : Physics

## Course : CC-III

## (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: 2×5=10

(a) State the integral form of Gauss's law. Write the mathematical expression explaining each term.

(b) Two charges $+q$ and $-q$ are separated by a distance $d$ in space devoid of any other charges or field. Draw a diagram depicting the lines of force for the system of charges $+q$ and $-q$ and also show the direction of the lines of force.

(c) Obtain an expression for the integral form of Gauss's law for dielectric medium in terms of the electric displacement vector $\vec{D}$.

(d) Define the capacitance of an isolated conductor. What is its unit?

(e) What is the physical significance of the relation $\vec{\nabla}.\vec{B} = 0$, where $\vec{B}$ represents the magnetic field? Why is a field for which $\vec{\nabla}.\vec{B} = 0$ called a solenoidal field?

(f) State the Ampere's circuital law. Express it mathematically.

(g) What is the 'ballistic' condition of a moving coil galvanometer? Define the charge sensitivity of a ballistic galvanometer.

(h) Write down and explain the reciprocity theorem for electrical circuits.

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

(a) Using Ampere's circuital law, calculate the magnetic field due to a long straight current-carrying conductor. Hence, calculate the force between two infinitely long parallel current-carrying conductor $X$ and $Y$, when currents $I_1$ and $I_2$ are flowing (in the same direction) through $X$ and $Y$, respectively. 3+2

(b) An infinite plane carries a uniform charge density $\sigma$ on its surface. Prove that the electric field, $\vec{E}$ (due to this infinite plane) at any point $P$ in space is independent of its distance from the infinite plane. How do you justify this result? 4+1

(c) For a point dipole of dipole moment $\vec{P}$ placed in a uniform external dielectric field $\vec{E}$, calculate the potential energy $U$ of the dipole. What will be the maximum and minimum value of this potential energy? Hence calculate the torque, $\vec{\tau}$ on the dipole. 2+1+1+1

(d) State and prove the maximum power transfer theorem. 2+3

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

(a) (i) A sinusoidal voltage is applied to a series LCR circuit. Calculate the amplitude $|Z|$ and phase angle $\theta$ of the impedance $Z$ of the circuit.

(ii) From the derived expression for $Z$, state under what condition, (a) the applied voltage leads the current in the circuit by an angle $\theta$, (b) the current leads the applied voltage in the circuit by an angle $\theta$, (c) the current and applied voltage are in phase.

(iii) Under what condition will this series LCR circuit act as purely resistive under the application of an external sinusoidal voltage? What is the phenomenon called? Calculate the linear frequency $f_0$ (in Hz) in the LCR circuit under this condition. Why is the circuit under this condition called an acceptor circuit? (2+1)+(1+1+1)+(1+1+1+1)

(b) (i) What is magnetic vector potential, $\vec{A}$? Show that $\nabla^2\vec{A} = -\mu_0\vec{J}$, where the symbols have their usual meaning.

(ii) State Biot-Savart's law. Using the Biot-Savart's law, determine the magnetic field at a point $P$ on the axis of a circular current carrying conductor having $N$ turns. (2+2)+(2+4)

(c) For a hollow spherical shell carrying charge density $\rho = \frac{k}{r^2}$, $k$ being a constant in the region $a \leq r \leq b$, find the electric field at — (i) centre of the shell ($r = 0$), (ii) $a < r < b$, (iii) $r > b$. Hence show that the potential at the centre, (using infinity as reference point) will be, $V(0) = \frac{k}{\varepsilon_0} \ln\left[\frac{b}{a}\right]$, $k$ = constant. (2+2+2)+4

(d) (i) State and illustrate Thevenin theorem.

(ii) What is a constant current source? Show that a voltage source acts as a constant current source when its internal resistance is much larger than the load resistance. What should be the internal resistance of an ideal current and voltage source? (2+2)+(2+2+1+1)