

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

- State the integral form of Gauss's law. Write the mathematical expression explaining each term.
- 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.
- Obtain an expression for the integral form of Gauss's law for dielectric medium in terms of the electric displacement vector \vec{D} .
- Define the capacitance of an isolated conductor. What is its unit?
- What is the physical significance of the relation $\vec{\nabla} \cdot \vec{B} = 0$, where \vec{B} represents the magnetic field? Why is a field for which $\vec{\nabla} \cdot \vec{B} = 0$ called a solenoidal field?
- State the Ampere's circuital law. Express it mathematically.
- What is the 'ballistic' condition of a moving coil galvanometer? Define the charge sensitivity of a ballistic galvanometer.
- Write down and explain the reciprocity theorem for electrical circuits.

2. Answer any two questions:

5×2=10

- 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
- An infinite plane carries a uniform charge density σ 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
- 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
- State and prove the maximum power transfer theorem. 2+3

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3. Answer any two questions:

- (a) (i) A sinusoidal voltage is applied to a series LCR circuit. Calculate the amplitude $|Z|$ and phase angle θ 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 θ , (b) the current leads the applied voltage in the circuit by an angle θ , (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, $V(0) = \frac{k}{\epsilon_0} \ln \left[\frac{b}{a} \right]$, $k = \text{constant}$. (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)
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