2022

PHYSICS — HONOURS

[Syllabus : 2018-19 and 2019-20]

Paper : CC-3

(Electricity and Magnetism)

Full Marks : 50

The figures in the margin indicate full marks.

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

Answer ***question no.* 1** and ***any four*** from the rest.

1. Answer ***any five*** questions : 2×5

(a) Determine the electric field due to potential $\phi(r) = \left(\frac{A}{r}\right)e^{-\lambda r}$.

(b) For $\delta_n(x) = \frac{n}{\pi}\left(\frac{1}{1+n^2x^2}\right)$, show that $\int_{-\alpha}^{\alpha} \delta_n(x)dx = 1$.

(c) Which one of the following expression is not valid for an electrostatic field :

(i) $\vec{E} = k[xy\hat{x} + 2yz\hat{y} + 3xz\hat{z}]$

(ii) $\vec{E} = k\left[y^2\hat{x} + \left(2xy + z^2\right)\hat{y} + 2yz\hat{z}\right]$

(d) Show that in a magnetized material where there is no free current, $\vec{H}$ can be written as gradient of a scalar potential which satisfies Laplace's equation.

(e) A point charge $+q$ is placed in front of a conducting sphere of radius r_0 at a distance 'd' from the centre. Find the location and value of the image charge.

(f) An AC circuit connected to a 220V. 50 Hz supply contains a 20H coil of resistance 100Ω connected in series with a $1\mu F$ capacitor. Calculate the power factor of the circuit.

(g) Plot the hysteresis loops for soft iron and steel on the same graph. Comment on :he effect of temperature on the area of the loops.

Or,

(Only for 2018-19 Syllabus)

State Thevenin's theorem.

2. (a) In a region of space the electrostatic field is everywhere directed parallel to x-axis. Show that the field in this region is independent of y- and z-coordinates. Further if there is no charge in this region, prove that the field is also independent of x.

(b) Twelve equal charges, q, are situated on each numeral of a clock face. What is the net force on a test charge Q at the center?

(c) Use Gauss's theorem to prove the following statement :

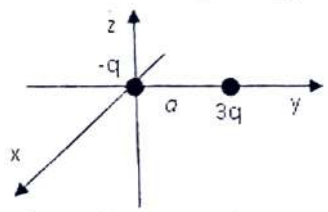
A closed, hollow conductor shields its interior from fields due to charges outside, but does not shield its exterior from the fields due to charges placed inside it. (2+1)+3+4

3. (a) An electric dipole formed by two equal and opposite charges each of magnitude 1 μC separated by a distance of 1 m is placed in a uniform electric field of strength 10^5V/m such that the axis of the dipole is parallel to the field. Calculate the amount of work to be done to rotate the dipole end to end i.e. by an angle 180°.

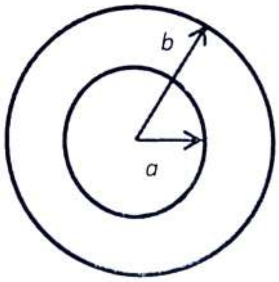
(b) The dielectric constant of a mono-atomic gas at N.T.P. is 1.000538. Calculate the dipole moment induced in each atom when the gas is placed in an external electric field of 30 kV/m.

(c) A dielectric sphere of radius a carries a (frozen-in) polarization $\vec{P} = k\vec{r}$, where k is a constant and r is the distance from the centre. Use Gauss theorem in dielectrics to find the electric field inside $(r < a)$ and outside $(r > a)$ the sphere. 2+4+4

4. (a) Two point chages, $3q$ and $-q$, are separated by a distance a. Find the dipole moment and the approximate potential (in spherical coordinates) at large r.



(b) A metal sphere of radius 'a' carries a chage Q. It is surrounded, out to radius b, by linear dielectric material of permittivity ε. Find the potential at the center (relative to infinity).



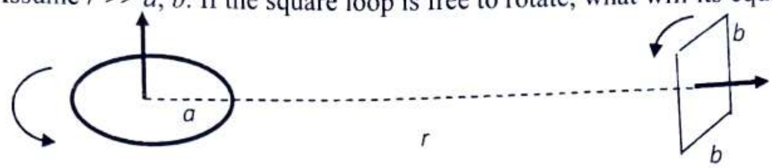
(c) Starting from Maxwell's equation, derive $\nabla^2 V = -\dfrac{\rho}{\varepsilon}$ for a homogeneous medium. The symbols have their usual meanings. (3+1)+4+2

5. (a) A circular loop of wire, with radius R, lies in xy-plane, centered at the origin and carries a current I running counterclockwise as viewed from the positive z axis.

(i) What is the magnetic dipole moment?

(ii) What is its (approximate) magnetic field at points far from the origin?

(b) Calculate the torque exerted on the square loop shown in the adjacent figure, due to the circular loop a radius a. Assume $r >> a$, b. If the square loop is free to rotate, what will its equalibrium orientation be?



(c) Show that the energy of a magnetic dipole in a magnetic field $\vec{B}$ is given by $U = -\vec{m}.\vec{B}$.

(1+2)+4+3

6. (a) What is reciprocity theorem in connection with mutual inductance between a pair of circuits close to each other?

(b) Two coils with self inductances L_1 and L_2 have mutual inductance M. Find an expression for their coefficient of coupling, k. Determine the range of its value by reasoning.

(c) A magnetic field $\vec{B} = 3\left(\hat{i} + 2\hat{j} - 4\hat{k}\right)$ Tesla and an unknown electric field exist in a region. If an electron moving within that region with a velocity $\vec{v} = 2\left(3\hat{i} - \hat{j} + 2\hat{k}\right)$ m/sec experiences no force, calculate the unknown electric field.

(d) Find the inductance of an ideal solenoid of length 0.50 m with 300 turns and circular cross section of radius 0.02 m.

2+(3+1)+2+2

7. (a) Explain why and how Ampere's circuital law for steady current was generalised by Maxwell.

(b) Write the condition of resonance in a series LCR circuit. Show that the average power dissipation in a series LCR circuit reaches its maximum at resonance Explain why such a circuit is called an *acceptor circuit.*

(c) What is *power factor* in an ac circuit? A series LR circuit has complex impedance $\left(\sqrt{3} + j\right)\Omega$. If an alternating source of emf of 10V is applied across it, calculate the power consumed by the circuit.

Or,

(Only for 2018-19 syllabus)

(c) Using Thevenin's theorem, find the value of current passing'through the 6Ω (connecting across AB) resistor in the circuit shown in figure below.

2+(1+2+1)+(1+3)