'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 2nd Semester Examination, 2022

CC3-PHYSICS

ELECTRICITY AND MAGNETISM

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
All symbols are of usual significance.

GROUP-A

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

   (a) Check whether the following represent an electrostatic field or not:

   $$\vec{E} = 4y\hat{i} - 2x\hat{j} - \hat{k}$$

   (b) A point charge q is kept at one corner of a cube. Calculate the total flux through the other three surfaces that do not meet at q.

   (c) Define volume charge density $\rho(\vec{r}')$ for a point charge q situated at the position $\vec{r}$.

   (d) State uniqueness theorem.

   (e) What do you mean by reactance of an AC circuit?

   (f) Give physical reason behind the fact that impedance of an inductor increases with frequency.

   (g) What is power factor in A.C. circuit?

   (h) A uniform electric field 2 V/m exists in a medium of dielectric constant 3. What is the electrostatic energy density stored in the field?

GROUP-B

Answer any *three* questions from the following 5×3 = 15

2. (a) Find an expression for electric field at a point close to the surface of a charged solid conductor of semi-infinite dimensions having a surface charge density of σ. 2

   (b) A dipole of moment $\vec{p}_1$ is fixed at the origin. Another coplanar dipole of moment $\vec{p}_2$ is placed at the position $\vec{r}$ and is free to rotate. Show that for equilibrium, 3

   $$\tan\theta_1 = -2\tan\theta_2$$

   where θ_1 and θ_2 are the angles that $\vec{r}$ makes with $\vec{p}_1$ and $\vec{p}_2$ respectively.

3. (a) Establish the following relation for a dielectric medium, where symbols have their usual meaning. 3

$$\oint \vec{D} \cdot d\vec{s} = Q_{\text{free}}$$

(b) A battery of 50 V emf is used to charge a 200 μF capacitor, after which the battery is disconnected. The capacitor is then connected in parallel with another capacitor. If the potential drops to 20 V, find the capacitance of the second capacitor. 2

4. (a) Show that the energy of a spherical charge distribution of uniform charge density is given by $2\frac{1}{2}$

$$U = \frac{3}{5}\frac{Q^2}{4\pi\varepsilon_0 a}$$

where Q is the total charge and a is the radius of the sphere.

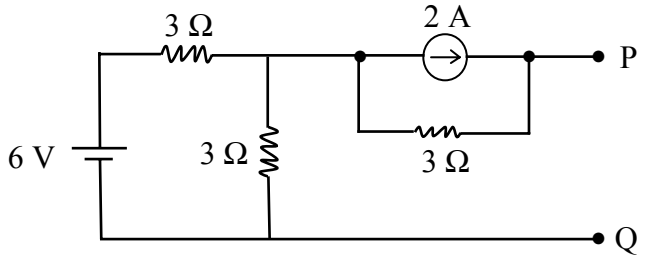
(b) Determine by solving Laplace's equation, the potential at a distance x from an infinite conducting plane carrying a surface charge density σ. Given that the potential at a distance x_0 from the plane is ϕ_0. $2\frac{1}{2}$

5. (a) Distinguish between $\vec{B}$ and $\vec{H}$ fields. 2

(b) A magnetic field of 1.6×10^3 A/m produces a flux of 2.4×10^{-5} Wb in a bar of cross-section 0.2 cm^2. Find the permeability and susceptibility of the specimen. 3

6. (a) State and explain Norton's theorem. 2

(b) Determine the Norton equivalent source current and resistance with respect to the terminals P, Q for the circuit diagram given below: 3



GROUP-C

Answer any *two* questions from the following $10\times2 = 20$

7. (a) Show that for N point charges q_i $(i = 1, 2, ... , N)$, the energy of interaction is given by 3

$$U = \frac{1}{2}\sum_{i=1}^{N} q_i \phi_i$$

where ϕ_i is the potential of the field established by all charges except q_i at the point where q_i is located.

(b) A parallel plate capacitor has two square plates of edge a, separated by distance d. The space between the plates is filled with a dielectric of linearly increasing dielectric constant k as given below: 4

$$k = k_0 + \alpha x$$

where α and k_0 are constants and x is the distance from any one of the edges. Show that the capacitance is given by

$$c = \frac{\varepsilon_0 a^2}{d}\left(k_0 + \frac{\alpha a}{2}\right)$$

(c) Three equal point charges $+q$ are located at the vertices of an equilateral triangle of side a. Calculate the electrostatic energy of the system. 3

8. (a) A dielectric sphere of radius a and permittivity ε_1 is placed in a uniform electric field $\vec{E}_0$ in a medium of permittivity ε_2. Using Laplace's equation, show that the polarization induced on the surface is given by 6

$$\vec{P} = 3\varepsilon_2 \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + 2\varepsilon_2}\vec{E}_0$$

(b) Calculate the potential and field due to a short dipole of moment 2×10^{-27} cm at a distance 1 cm from it on its axis. 4

9. (a) State Biot-Savart law and use it to calculate the magnetic field due to a current passing through a conducting wire of finite length at a distance 'a' from it. How is the result modified when the wire is of infinite length? 1+3+1

(b) From fundamental principle, establish the relation $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$. 2

(c) A coil of self inductance 100 mH is connected in series with another coil of self inductance 169 mH. The effective inductance of the combination is found to be 70 mH. Determine the coefficient of coupling. 3

10.(a) Obtain an expression for the average power in a series LCR circuit and show that the power is dissipated only in R. 4

(b) Derive an expression for the bandwidth of a series LCR circuit. 3

(c) Determine the values of L, C and R of a series LCR circuit which has a resonance frequency of 10 kHz, a bandwidth of 1000 Hz and draws 15.3 W from a 200 V generator operating at resonance frequency of the circuit. 3

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