Unique Paper Code	:	32221201_OC	**Set B**
Name of the Paper	:	Electricity and Magnetism	
Name of the Course	:	B. Sc. (H) Physics – CBCS – (OC)	
Semester	:	II	
Duration	:	3 hours	
Maximum Marks	:	75	

Instructions for Candidates

Attempt any **four** questions.

All questions carry equal marks.

1. (a) A solid sphere of radius R carries volume charge density given by $\rho(r) = \rho_0 \left(1 - \frac{r}{R}\right)$ for $r \leq R$ and $\rho(r) = 0$ for $r>R$. Find the electric field inside and outside the sphere using Gauss's law. Can Gauss's law be used to find field if the charge distribution is not spherically symmetric? Identify the specific step(s) in the above derivation which cannot be carried out if the charge distribution is not spherically symmetric.

(b) If the earth were treated as an isolated insulated conductor situated in vacuum, what would be its capacitance? Take the radius of the earth as 6300 km.

(c) Using the case of a parallel plate capacitor derive an expression for the electrostatic energy density associated with an electric field. (8.75,5,5)

2. (a) Use Laplace's equation to prove that a point charge located in an electric field cannot exist in a state of stable equilibrium under the action of the electric field alone.

(b) Electric field in a given region of space is given by $\vec{E} = 5x\hat{\imath} + 6\frac{y}{z}\hat{\jmath} + 5z\hat{k}$, find the volume charge density and describe it physically.

(c) A point charge $+q$ is placed ad distance d in front of an infinite conducting plane connected to earth. Determine by the method of images the force of attraction between the charge and the plane. (6,6,6.75)

3. (a) Show that in electrostatics while the electric field is necessarily irrotational, this not the case with electric displacement.

(b) A point charge Q is placed at the centre of a dielectric sphere of radius R and dielectric constant K. Find bound surface and volume charge densities. What is the total bound charge on the surface of the sphere?

(c) A surface separates two dielectrics with dielectric constant ϵ_1 and ϵ_2. Electric field lines bend across the boundary due to bound polarisation charges (assume there are no free charges). Take the boundary normal **n** from medium 2 to medium 1. Field $\mathbf{E}_1$ in medium 1 makes angle θ_1 with the normal, $\mathbf{E}_2$ in medium 2 makes angel θ_2 with it. Show that (i) the planes defined by $\mathbf{E}_2$ and **n** and $\mathbf{E}_1$ and **n** are same (i.e. planes of 'incidence' and 'refraction' are same) , and (ii) $\frac{tan\theta_1}{tan\theta_2} = \epsilon_1/\epsilon_2$. (3,8,7.75)

4. (a) Write down the differential equation which shows that magnetic field lines do not have any sources and sinks. Draw field lines of an electric dipole and a magnet, including inside the magnet. Are the field lines of an electric dipole and magnet similar in shape in far field region? Are they similar in shape and direction inside the magnet and close to the dipole?

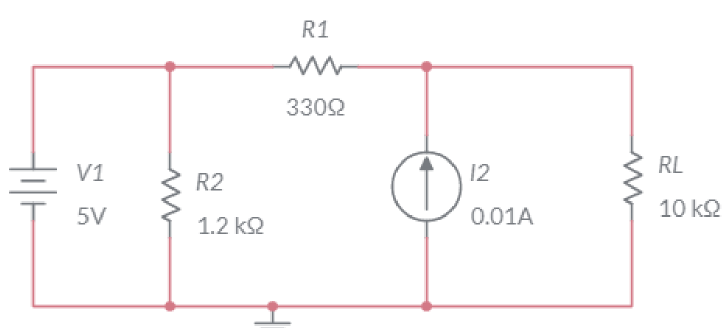
(b) Derive the relation $\oint_C \boldsymbol{A}.\boldsymbol{dl} = \Phi$, where $\boldsymbol{A}$ is vector potential and Φ is the magnetic flux crossing the surface bounded by *C*. Use it to find vector potential of a long solenoid carrying current *I*, and having radius *R* and *n* turns per unit length. In a diagram show directions of the vector potential both inside and outside the solenoid. Show that $\boldsymbol{\nabla}.\boldsymbol{A} = 0$ for the solution derived. (7, 11.75)

5. (a) Define self-inductance of a current carrying loop. Show that the work done in establishing current *I* in a loop with self-inductance *L* is $W = \frac{1}{2}LI^2$.

(b) Two solenoids have same axis and length have radii R_a and R_b , with $R_a > R_b$. The inner solenoid has current *I* flowing counter-clockwise through it, and the outer solenoid has no current. The outer solenoid has resistance *R*. The inner solenoid wire is cut by scissors, so that in a fairly small duration current in it drops to zero. What is the direction of induced current in the outer solenoid? How much total charge passes a point in the outer solenoid during the period this current flows? (8, 10.75)

6. (a) A series LCR circuit with L = 25nH, C = 70µF has a lagging phase angle of 20° at ω = 2 kHz. At what frequency will the phase angle be leading by 30°?

(b) Use the superposition theorem to find current through R_L for the given network.



(c) State Reciprocity theorem and explain using a suitable circuit diagram. (5,6 ,7.75)

Useful Constants

$\epsilon_0 = 8.85 \times 10^{-12} \mathrm{C^2 N^{-1} m^{-2}}$

$\mu_0 = 4\pi \times 10^{-7} \mathrm{NA^{-2}}$