Seminar 6: Lectures 11-12

Print and answer all questions found below.
Please bring your completed worksheet to the Seminar Class. [1]

Question 1

(a) Define electric flux and express it mathematically.

(b) Consider a uniform electric field $\vec{E} = 4 \times 10^4$ N/C directed along the positive x-axis. Calculate the electric flux through a rectangular surface of area $A = 2\,\text{m}^2$ when the surface is:

(i) perpendicular to the field,

(ii) parallel to the field, and

(iii) making a 30° angle with the field.

[1] It is assumed that you have access to the standard physical constants.

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Question 2

(a) Calculate the electric flux through a circular loop of radius $r = 5$ cm placed in a uniform electric field of magnitude $E = 300$ N/C, where the field is perpendicular to the plane of the loop.

(b) How would the electric flux change if the loop were tilted at an angle of 30 degrees with respect to the electric field direction?

(c) If the electric field is doubled, what is the new electric flux through the loop in both the perpendicular and tilted configurations?

Question 3

(a) State Gauss's Law

(b) A point charge $Q = 5 \times 10^{-6}$ C is placed at the center of a spherical surface of radius $r = 10$ cm. Calculate the electric flux through the surface.

(c) How would the electric flux change if the radius of the spherical surface were increased to 20 cm?

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Question 4

(a) Derive the expression for the electric field due to an infinite line of charge using Gauss's Law.

(b) If the line of charge has a linear charge density $\lambda = 2 \times 10^{-6}$ C/m, calculate the electric field at a distance $r = 5$ cm from the line.

Question 5

(a) Define electric potential energy and electric potential difference.
(b) Consider two charges $q_1 = 2 \times 10^{-6}$ C and $q_2 = -3 \times 10^{-6}$ C that are separated by a distance of 0.1 m. Calculate the electric potential energy of the system.
(c) Consider now just one charge $q = 2 \times 10^{-6}$ C. Calculate the potential difference between two points located 0.05 m and 0.2 m from this charge.

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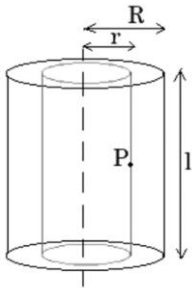
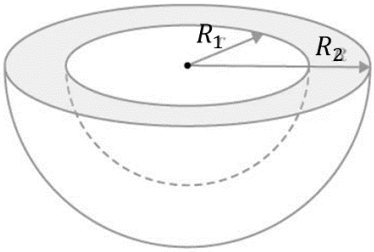
Question 6

(a) A long solid cylinder with radius R carries a uniform charge per unit length λ. Use Gauss's Law to find the electric field at a distance r from the axis for $r < R$ and $r > R$.



(b) Consider a spherical shell with inner radius R_1 and outer radius R_2, carrying a uniform charge density ρ within its volume. Using Gauss's Law, derive the expression for the electric field at a distance r from the center for $r < R_1$, $R_1 < r < R_2$, and $r > R_2$.

(c)



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Question 7

(a) Define electric potential energy and electric potential difference. Explain their relationship.

(b) Calculate the work done in moving a charge $q = 2 \times 10^{-6}$ C between two points in an electric field, given that the potential difference between the points is $V = 100$ V.

(c) Two charges $q_1 = 1 \times 10^{-6}$ C and $q_2 = -2 \times 10^{-6}$ C are placed 0.1 m apart. Calculate the potential energy of the system.

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Question 8

(a) Derive the relationship between electric potential V and electric field E.

(b) Explain how the electric field can be calculated from the electric potential using the concept of the gradient.

(c) Calculate the electric field at a point where the electric potential is given by $V(x) = 5x^2 + 2x - 3$ V, where x is in meters.

(d) If the electric field in a region is given by $E = -5x$ N/C, find the potential difference between two points separated by 2 m along the x-axis.

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Extension Questions

Question 9

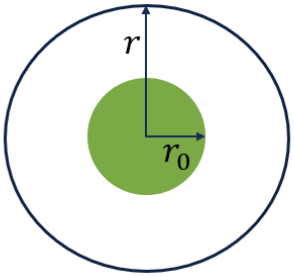
A metal sphere of radius, $r_0 = 0.44$ m, carries a charge Q = 0.50 μC. Equipotential surfaces are to be drawn for 100 V intervals outside the sphere.

Determine the radius r, of

(a) the first,

(b) the tenth, and

(c) the 100th equipotential from the surface.



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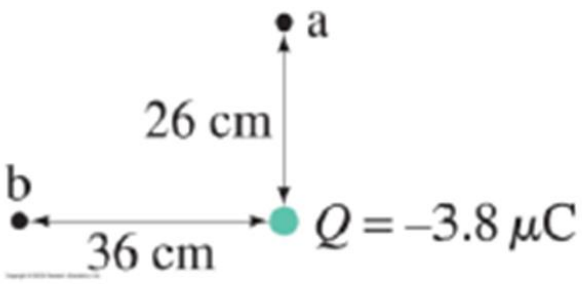
Question 10

Point a is 26 cm north of a -3.8 μC point charge, and point b is 36 cm west of the charge. Determine

(a) $V_b - V_a$ and

(b) $\vec{E}_b - \vec{E}_a$ (magnitude and direction).



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Question 11

Three point charges are arranged at the corners of a square of side, l. What is the potential at the fourth corner (point A), taking $V = 0$ at a great distance?