

Last Name

KEY

First Name

21

Enter T (True) or F (False) for 5 questions below.

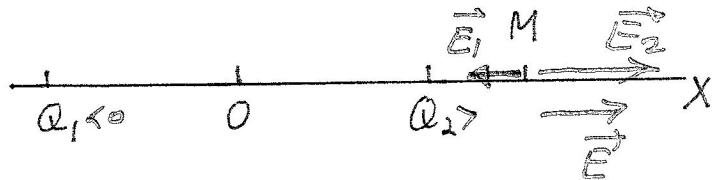
1. T Electric field at the center of a square loop of charge is zero.
 2. F Electric potential at the center of a square loop of charge is zero.
 3. T Electric potential due to a ring of charge (total charge Q) at a distance $r \gg R$ (radius: R) is kQ/r .
 4. F Electric field inside an insulator is always zero.
 5. F The electric field due to a long straight wire cannot be calculated using Gauss' law.

You must show the details of your calculations in three problems below.

1. Calculate the magnitude and direction of the electric field at point M on the x-axis with $x = 0.3$ m due to 2 charges $Q_1 = -10^{-9}$ C at $x_1 = -0.2$ m and $Q_2 = +10^{-9}$ C at $x_2 = +0.2$.

$$|\vec{E}_1| = k \frac{q_1}{r_1^2}$$

$$|\vec{E}_1| = \frac{9 \times 10^9 \times 10^{-9}}{(0.5)^2} = 36 \text{ N/C}$$



$$|\vec{E}_2| = k \frac{q_2}{r_2^2} = 9 \times 10^9 \frac{10^{-9}}{(0.1)^2} = 900 \text{ N/C}$$

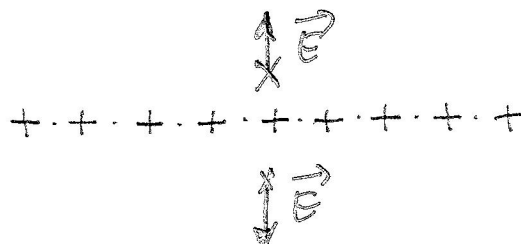
$$|\vec{E}| = |\vec{E}_2| - |\vec{E}_1| = 900 - 36 = 864 \text{ N/C}$$

$\vec{E}$ directs along positive x axis.

2. A proton is positioned close to a horizontal sheet of positive uniform charge with surface charge density σ .

a. Show the direction of electric field near this sheet of charge on both sides of the sheet.

(2)



b. The strength of the electric field near the sheet is $E = \sigma/2\epsilon_0$. What should be σ such that a proton levitates near this sheet of charge?

Proton charge is 1.6×10^{-19} C, and proton mass is 1.67×10^{-27} kg



$$mg = qE$$

$$mg = q \frac{\sigma}{2\epsilon_0}$$

(3)

$$\sigma = \frac{2mg\epsilon_0}{q} = \frac{2 \times 1.67 \times 10^{-27} \times 9.8 \times 8.85 \times 10^{-12}}{1.6 \times 10^{-19}}$$

$$\sigma = 181 \times 10^{-20} = 1.81 \times 10^{-18} \text{ coul/m}^2$$

3. Two equal charges ($q = 1 \mu\text{C}$) are positioned at 2 corners of an equilateral triangle with side $a = 1.0 \text{ m}$. What is the electric potential at the third corner of this triangle? $1/4\pi\epsilon_0 = 9 \times 10^9 \text{ SI}$.

$$V = V_1 + V_2$$

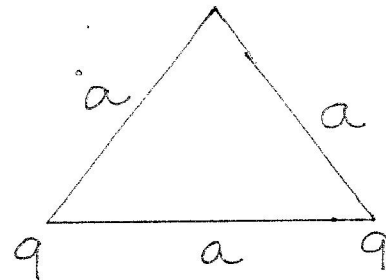
$$V = k \frac{q_1}{r_1} + k_2 \frac{q_2}{r_2}$$

$$V = k \frac{q}{a} + k \frac{q}{a} = 2k \frac{q}{a}$$

(3)

$$V = 2 \times 9 \times 10^9 \frac{1 \times 10^{-6}}{1.0} = 18 \times 10^3$$

$$V = 1.8 \times 10^4 \text{ volts}$$



4. Consider a conducting spherical shell with inner radius $a = 1.0$ m and outer radius $b = 2.0$ m. We place a charge $Q = 1 \mu\text{C}$ on the shell.

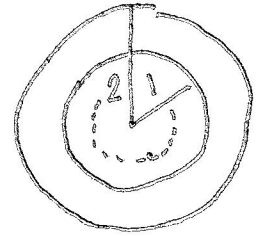
a. Calculate the electric field at a distance $x = 0.5$ m from the center of the shell?

①

$$\oint \vec{E} \cdot d\vec{a} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

$$EA = \frac{0}{\epsilon_0}$$

$$E = 0$$



b. Calculate the electric field at a distance $x = 1.5$ m from the center of the shell?

E inside the conductor is zero

①

$$E = 0 \text{ @ } r = 1.5 \text{ m}$$

c. Calculate the electric field at a distance $x = 2.5$ m from the center of the shell?

②

$$\oint \vec{E} \cdot d\vec{a} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

$$E \times 4\pi r^2 = \frac{Q}{\epsilon_0}$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2} \quad r > 2$$

$$E = 9 \times 10^9 \frac{1 \times 10^{-6}}{(2.5)^2}$$

$$E = 1.44 \times 10^3 \text{ N/C}$$

