Solution Set: College Physics II – Electrostatic Forces & Fields, Electric Potential

1. Coulomb's Law

Given:

$q_1 = +2.0\ \mu\text{C} = 2.0 \times 10^{-6}\ \text{C}$

$q_2 = -3.0\ \mu\text{C} = -3.0 \times 10^{-6}\ \text{C}$

$r = 0.50\ \text{m}$

$k = 8.99 \times 10^9\ \text{N m}^2/\text{C}^2$

a) Magnitude of force:

$$F = \frac{k|q_1 q_2|}{r^2} = \frac{8.99 \times 10^9 \times (2.0 \times 10^{-6})(3.0 \times 10^{-6})}{(0.50)^2}$$

$$= \frac{8.99 \times 10^9 \times 6.0 \times 10^{-12}}{0.25} = \frac{53.94 \times 10^{-3}}{0.25} = 0.216\ \text{N}$$

b) **Direction:**

Since the charges are opposite, the force is **attractive**. Each charge pulls the other toward itself.

2. Electric Field of a Point Charge

Given:

$q = +5.0\ \mu\text{C} = 5.0 \times 10^{-6}\ \text{C}$

$r = 0.30\ \text{m}$

$$E = \frac{k|q|}{r^2} = \frac{8.99 \times 10^9 \times 5.0 \times 10^{-6}}{(0.30)^2} = \frac{44.95 \times 10^3}{0.09} = 499{,}444\ \text{N/C}$$

Direction:

Radially outward from the charge (since it is positive).

3. Electric Field from Multiple Charges

Given:

$q_1 = +1.0\ \mu\text{C}$

$q_2 = -2.0\ \mu\text{C}$

Distance between them: 0.40 m

Midpoint is 0.20 m from each.

a) Electric field at midpoint:

- Field due to q_1 (to the right):

$$E_1 = \frac{k|q_1|}{(0.20)^2} = \frac{8.99 \times 10^9 \times 1.0 \times 10^{-6}}{0.04} = 224{,}750\ \text{N/C}$$

(Direction: away from q_1, so to the right)

- Field due to q_2 (to the left, since it's negative):

$$E_2 = \frac{k|q_2|}{(0.20)^2} = \frac{8.99 \times 10^9 \times 2.0 \times 10^{-6}}{0.04} = 449{,}500\ \text{N/C}$$

(Direction: toward q_2, so to the left)

- Net field at midpoint (left is negative, right is positive):

$$E_{net} = E_1 - E_2 = 224{,}750 - 449{,}500 = -224{,}750\ \text{N/C}$$

So, **224,750 N/C to the left**.

b) Force on $+1.0$ nC $= 1.0 \times 10^{-9}$ C test charge:

$$F = qE = 1.0 \times 10^{-9} \times (-224{,}750) = -2.25 \times 10^{-4}\ \text{N}$$

Direction: **to the left**.

4. Electric Potential (Point Charges)

Given:

$q = -4.0\ \mu\text{C} = -4.0 \times 10^{-6}\ \text{C}$

$r = 0.25$ m

$$V = \frac{kq}{r} = \frac{8.99 \times 10^9 \times -4.0 \times 10^{-6}}{0.25} = \frac{-35.96 \times 10^3}{0.25} = -143{,}840\ \text{V}$$

5. Potential Difference and Work

Given:

$V_A = +100$ V

$V_B = -50$ V

Electron charge: $q = -1.60 \times 10^{-19}$ C

a)

$$\Delta V = V_B - V_A = -50 - 100 = -150 \text{ V}$$

b)

Work done by the field:

$$W = q\Delta V = (-1.60 \times 10^{-19}) \times (-150) = 2.4 \times 10^{-17} \text{ J}$$

(The work is **positive**, so the field does positive work as the electron moves from higher to lower potential.)