Section 7.3: Electric Fields

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1. (a) Given: $\vec{F}_E = 2.5$ N [left]; $q = -5.0$ C

Required: $\vec{\varepsilon}$

Analysis: $\vec{F}_E = q\vec{\varepsilon}$

Solution: $\vec{F}_E = q\vec{\varepsilon}$

$$\begin{aligned}\vec{\varepsilon} &= \frac{\vec{F}_E}{q} \\ &= \frac{2.5 \text{ N [left]}}{-5.0 \text{ C}} \\ &= -0.50 \text{ N/C [left]} \\ \vec{\varepsilon} &= 0.50 \text{ N/C [right]}\end{aligned}$$

Statement: The electric field in which the charge is located is 0.50 N/C [toward the right].

(b) Given: $\vec{F}_E = 2.5$ N [left]; $q = -0.75$ C

Required: $\vec{\varepsilon}$

Analysis: $\vec{F}_E = q\vec{\varepsilon}$

Solution: $\vec{F}_E = q\vec{\varepsilon}$

$$\begin{aligned}\vec{\varepsilon} &= \frac{\vec{F}_E}{q} \\ &= \frac{2.5 \text{ N [left]}}{-0.75 \text{ C}} \\ &= -3.3 \text{ N/C [left]} \\ \vec{\varepsilon} &= 3.3 \text{ N/C [right]}\end{aligned}$$

Statement: The electric field in which the charge is located is 3.3 N/C [toward the right].

2. Given: $r = 2.50$ m; $q = 6.25 \times 10^{-6}$ C; $k = 8.99 \times 10^9$ N·m^2/C^2

Required: $\vec{\varepsilon}$

Analysis: $\varepsilon = \dfrac{kq}{r^2}$

Solution: $\varepsilon = \dfrac{kq}{r^2}$

$$= \frac{\left(8.99 \times 10^9 \ \dfrac{\text{N} \cdot \cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(6.25 \times 10^{-6} \ \cancel{\text{C}})}{(2.50 \ \cancel{\text{m}})^2}$$

$$\varepsilon = 8.99 \times 10^3 \text{ N/C}$$

Since the charge is positive, the direction of the electric field is toward the point, right.

Statement: The electric field at the point is 8.99×10^3 N/C [toward the right].

3. Given: $r_1 = 0.668$ m; $r_2 = 0.332$ m; $q_1 = 5.56 \times 10^{-9}$ C; $q_2 = -1.23 \times 10^{-9}$ C; $k = 8.99 \times 10^9\ \text{N·m}^2/\text{C}^2$

Required: $\vec{\varepsilon}_{\text{net}}$

Analysis: The direction of the electric field is to the right, toward point Z. Determine the magnitude of the electric field at point Z; $\varepsilon = \dfrac{kq}{r^2}$; first, calculate r:

$$
\begin{aligned}
r &= r_1 + r_2 \\
&= 0.668\ \text{m} + 0.332\ \text{m} \\
r &= 1.000\ \text{m}
\end{aligned}
$$

Solution:

$$
\begin{aligned}
\varepsilon_1 &= \frac{kq_1}{r^2} \\
&= \frac{\left(8.99\times10^9\ \dfrac{\text{N}\cdot \cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(5.56\times10^{-9}\ \cancel{\text{C}})}{(1.000\ \cancel{\text{m}})^2}
\end{aligned}
$$

$\varepsilon_1 = 49.984$ N/C (two extra digits carried)

$$
\begin{aligned}
\varepsilon_2 &= \frac{kq_2}{r_2^2} \\
&= \frac{\left(8.99\times10^9\ \dfrac{\text{N}\cdot \cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(-1.23\times10^{-9}\ \cancel{\text{C}})}{(0.332\ \cancel{\text{m}})^2}
\end{aligned}
$$

$\varepsilon_2 = -1.0032\times10^2$ N/C (two extra digits carried)

$$
\begin{aligned}
\vec{\varepsilon}_{\text{net}} &= \vec{\varepsilon}_1 + \vec{\varepsilon}_2 \\
&= \left(49.984\ \text{N/C [right]}\right) + \left(-1.0032\times10^2\ \text{N/C [right]}\right) \\
&= -50.336\ \text{N/C [right]} \\
\vec{\varepsilon}_{\text{net}} &= 50.3\ \text{N/C [left]}
\end{aligned}
$$

Statement: The electric field at the point Z is –50.3 N/C, or 50.3 N/C [toward the left].

Research This: Fish and Electric Fields, page 344

A. Answers may vary. Sample answers: I chose electric eels. Electric eels produce electric fields for self-defence; they also use electric fields to stun prey.

B. Answers may vary. Sample answers: Fish that stun prey with electric fields are typically freshwater species because salt water conducts electricity. Therefore, a fish that produces a strong enough field in salt water to stun prey can also injure itself in the salt water.

C. Answers may vary. Sample answers: Low light levels and poor visibility in certain rivers would make it difficult for fish to detect prey visually. Since the transmission of electric fields is not affected by the amount of soil and silt in the water, the ability to detect electric fields is a beneficial adaptation for fish living in these rivers.

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1. For a proton and an electron placed in a uniform electric field, the magnitudes of the forces will be equal.

2. Given: r = 1.5 m; q = 3.5 C; $k = 8.99 \times 10^9$ N·m²/C²

Required: ε

Analysis: $\varepsilon = \dfrac{kq}{r^2}$

Solution: $\varepsilon = \dfrac{kq}{r^2}$

$$= \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(3.5\ \cancel{\text{C}})}{(1.5\ \cancel{\text{m}})^2}$$

$$\varepsilon = 1.4\times10^{10}\ \text{N/C}$$

Statement: The magnitude of the electric field at the point is 1.4×10^{10} N/C.

3. Given: r_1 = 10 cm = 0.10 m; r_2 = 25 cm = 0.25 m; $q_1 = 4.5 \times 10^{-6}$ C; $\vec{\varepsilon}_{\text{net}}$ = 0 N/C; $k = 8.99 \times 10^9$ N·m²/C²

Required: q_2

Analysis: $\varepsilon_1 = \dfrac{kq_1}{r_1^2}$; $\varepsilon_2 = \dfrac{kq_2}{r_2^2}$; $q_2 = \dfrac{\varepsilon_2 r_2^2}{k}$

Solution: Determine the magnitude of the electric field from q_1 at the origin.

$$\varepsilon_1 = \frac{kq_1}{r_1^2}$$

$$= \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(4.5\times10^{-6}\ \cancel{\text{C}})}{(0.10\ \cancel{\text{m}})^2}$$

$$= 4.046\times10^6\ \text{N/C (two extra digits carried)}$$

The second charge's electric field must have the same magnitude at the origin:

$$q_2 = \frac{\varepsilon_2 r_2^2}{k}$$

$$= \frac{\left(4.046\times10^6\ \frac{\cancel{\text{N}}}{\cancel{\text{C}}}\right)(0.25\ \cancel{\text{m}})^2}{\left(8.99\times10^9\ \frac{\cancel{\text{N}}\cdot\cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)}$$

$$q_2 = 2.8\times10^{-5}\ \text{C}$$

Statement: The charge on q_2 is 2.8×10^{-5} C.

4. The origin is centred in the ring, so for every position on the ring, there is an equal and opposite charge on the other side of the ring. Therefore, the net electric field at the origin is 0 N/C.

5. When drawing electric field lines, the number of lines originating from a charge is determined by the relative strength of the charge from which the lines originate to the other charges in the sketch.

6. Given: $r_1 = \dfrac{L}{4}$; $r_2 = \dfrac{3L}{4}$; $\vec{\varepsilon}_{\text{net}} = 0$ N/C

Required: q_1:q_2

Analysis: Since the electric field is zero at A, the components from each charge must be equal.

Use $\varepsilon = \dfrac{kq}{r^2}$ to determine the ratio.

Solution:

$$\varepsilon_1 = \varepsilon_2$$

$$\frac{\cancel{k}q_1}{r_1^2} = \frac{\cancel{k}q_2}{r_2^2}$$

$$\frac{q_1}{\left(\dfrac{L}{4}\right)^2} = \frac{q_2}{\left(\dfrac{3L}{4}\right)^2}$$

$$\frac{q_1}{\dfrac{L^2}{16}} = \frac{q_2}{\dfrac{9L^2}{16}}$$

$$\frac{q_1}{1} = \frac{q_2}{9}$$

$$\frac{q_1}{q_2} = \frac{1}{9}$$

Statement: The ratio between the charges, q_1:q_2, is 1:9.

7. Given: $q = 7.5$ C; $r = 2.3$ m; $k = 8.99 \times 10^9$ N·m²/C²

Required: $\vec{\varepsilon}_{\text{net}}$

Analysis: The point charges on the *x*-axis result in a zero electric field because they have equal charges and are on opposite sides of the origin. Likewise, the two point charges not on an axis will only contribute a vertical component. The direction of the electric field will be down.

Determine the magnitude of the electric field from a point charge at the origin, $\varepsilon = \dfrac{kq}{r^2}$. Then determine the total electric field at the origin.

Solution: The magnitude of the electric field from a point charge at the origin:

$$\begin{aligned}\varepsilon &= \frac{kq}{r^2}\\ &= \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(7.5\ \cancel{\text{C}})}{(2.3\ \cancel{\text{m}})^2}\end{aligned}$$

$\varepsilon = 1.275\times10^{10}$ N/C (two extra digits carried)

The total electric field at the origin:

$$\begin{aligned}\varepsilon_{\text{net}} &= \varepsilon + \varepsilon\sin 45^\circ + \varepsilon\sin 45^\circ\\ &= \varepsilon + \frac{2\varepsilon}{\sqrt{2}}\\ &= \varepsilon + \sqrt{2}\varepsilon\\ &= 1.275\times10^{10}\ \text{N/C} + \sqrt{2}(1.275\times10^{10}\ \text{N/C})\end{aligned}$$

$\varepsilon_{\text{net}} = 3.1\times10^{10}$ N/C [down]

Statement: The electric field at the origin is 3.1×10^{10} N/C [down].

8.