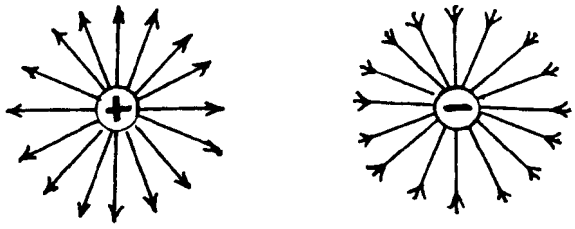
16-2 Electric Field

Vocabulary **Electric Field:** An area of influence around a charged object. The magnitude of the field is proportional to the amount of electrical force exerted on a positive test charge placed at a given point in the field.

$$\textbf{electric field} = \frac{\textbf{electric force}}{\textbf{test charge}} \quad \text{or} \quad E = \frac{F}{q_o}$$

The SI unit of electric field is the **newton per coulomb (N/C).**

The electric field around a charged object is a vector and can be represented with electric field lines that point in the direction of the force exerted on a unit of positive charge. In other words, electric field lines point away from a positive charge and toward a negative charge, as shown in the diagram.



For a point charge (or other spherical charge distribution), the magnitude of the electric field can be written as

$$E = \frac{F}{q_o} = \frac{kq_oq}{q_od^2} = \frac{kq}{d^2}$$

where q is the charge on the surface of the object, and d is the distance between the center of the charged object and a small positive test charge, q_o, placed in the field.

Solved Examples

Example 3: Deepika pulls her wool sweater over her head, which charges her body as the sweater rubs against her cotton shirt. a) What is the electric field at a location where a 1.60×10^{-19} C-piece of lint experiences a force of 3.2×10^{-9} N as it floats near Deepika? b) What will happen if Deepika now touches a conductor such as a door knob?

a. *Given:* $q_o = 1.60 \times 10^{-19}$ C
$F = 3.2 \times 10^{-9}$ N

Unknown: $E = ?$
Original equation: $F = q_o E$

Solved: $$E = \frac{F}{q_o} = \frac{3.2 \times 10^{-9}\ \text{N}}{1.60 \times 10^{-19}\ \text{C}} = \mathbf{2.0 \times 10^{10}\ N/C}$$

b. She will reduce her charge in a process called **grounding,** in which excess electrons flow from her body into the ground and spread evenly over the surface of Earth.

Example 4: A fly accumulates 3.0×10^{-10} C of positive charge as it flies through the air. What is the magnitude and direction of the electric field at a location 2.0 cm away from the fly?

Solution: First, convert cm to m. 2.0 cm = 0.020 m

Given: $k = 9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2$
$q = 3.0 \times 10^{-10}$ C
$d = 0.020$ m

Unknown: $E = ?$
Original equation: $E = \dfrac{kq}{d^2}$

Solve: $$E = \frac{kq}{d^2} = \frac{(9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2)(3.0 \times 10^{-10}\ \text{C})}{(0.020\ \text{m})^2} = \mathbf{6800\ N/C\ away\ from\ the\ fly}$$

Practice Exercises

Exercise 6: Mr. Patel is photocopying lab sheets for his first period class. A particle of toner carrying a charge of 4.0×10^{-9} C in the copying machine experiences an electric field of 1.2×10^{6} N/C as it's pulled toward the paper. What is the electric force acting on the toner particle?

$F = q_o E = (4.0 \times 10^{-9}\ \text{C})(1.2 \times 10^{6}\ \text{N/C}) = \mathbf{4.8 \times 10^{-3}\ N}$

Answer: **4.8×10^{-3} N**

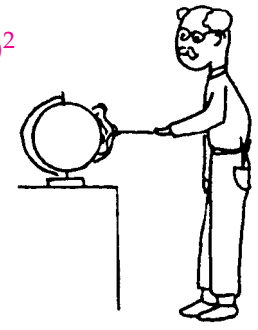
Exercise 7: As Courtney switches on the TV set to watch her favorite cartoon, the electron beam in the TV tube is steered across the screen by the field between two charged plates. If the electron experiences a force of 3.0×10^{-6} N, how large is the field between the deflection plates?

$E = F/q_o = (3.0 \times 10^{-6}\ \text{N})/(1.60 \times 10^{-19}\ \text{C}) = \mathbf{1.9 \times 10^{13}\ N/C}$

Answer: **1.9×10^{13} N/C**

Exercise 8: Gordon, the night custodian, dusts off a classroom globe with a feather duster, causing the globe to acquire a charge of -8.0×10^{-9} C. What is the magnitude and direction of the electric field at a point 0.40 m from the center of the charged globe?

$E = kq/d^2 = (9.0 \times 10^{9}\ \text{N} \cdot \text{m}^2/\text{C}^2)(8.0 \times 10^{-9}\ \text{C})/(0.40\ \text{m})^2$
$= \mathbf{450\ N/C\ toward\ globe}$



Answer: **450 N/C toward globe**

Exercise 9: April is decorating a tree in her backyard with plastic eggs in preparation for Easter. She hangs two eggs side by side so that their centers are 0.40 m apart. April rubs the eggs to shine them up, and in doing so places a charge on each egg. The egg on the left acquires a charge of 6.0×10^{-6} C while the egg on the right is charged with 4.0×10^{-6} C. What is the electric field at a point 0.15 m to the right of the egg on the left?

$$E_1 = kq_1/d^2 = (9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2)(6.0 \times 10^{-6}\ \text{C})/(0.15\ \text{m})^2$$
$$= 24 \times 10^5\ \text{N/C to the right}$$
$$E_2 = kq_2/d^2 = (9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2)(4.0 \times 10^{-6}\ \text{C})/(0.25\ \text{m})^2$$
$$= 5.8 \times 10^5\ \text{N/C to the left}$$
$$E_T = E_1 + E_2 = 24 \times 10^5\ \text{N/C} - 5.8 \times 10^5\ \text{N/C}$$
$$= \mathbf{18 \times 10^5\ N/C\ to\ the\ right}$$

Answer: **18×10^5 N/C to the right**