15.3 Electric Fields

The electric field $\vec{E}$ produced by a charge Q at the location of a small "test" charge q_0 is defined as the electric force $\vec{F}$ exerted by Q on q_0 divided by the test charge q_0:

$$\vec{E} = \frac{\vec{F}}{q_0}$$

Where E = the electric field (N/C), F = the electric force (N), q_0 = the test charge (C).

$\vec{F} = q\vec{E} \quad and \quad E = k_e \frac{|q|}{r^2}$ where q is replaced by q.

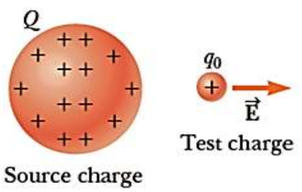
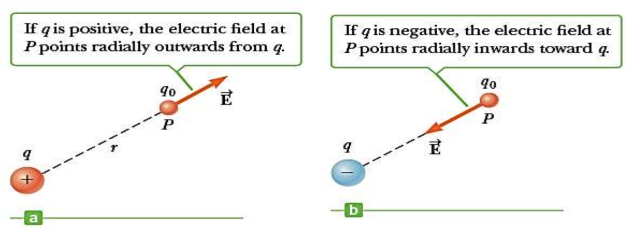


Figure 15.9 A small object with a positive charge q_0 placed near an object with a larger positive charge Q is subject to an electric field $\vec{E}$ directed as shown.

Figure 15.11 A test charge q_0 at P is a distance r from a point charge q.



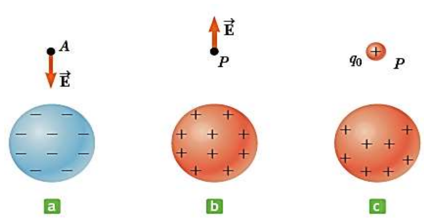


Figure 15.10 (a) The electric field at **A** due to the negatively-charged sphere is downward, toward the negative charge. (b) The electric field at **P** due to the positively-charged conducting sphere is upward, away from the positive charge. (c) A test charge q_0 placed at **P** will cause a rearrangement of charge on the sphere unless q_0 is negligibly small compared with the charge on the sphere.

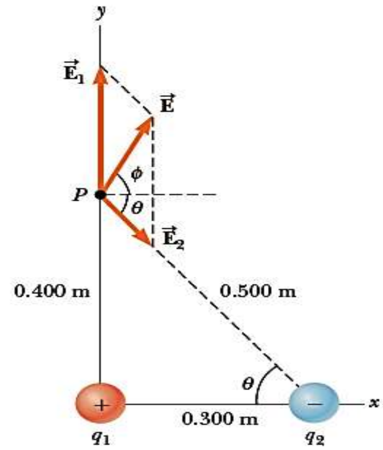
Quick Quiz 15.3 A test charge of $+3\mu C$ is at a point P where the electric field due to other charges is directed to the right and has a magnitude of 4×10^6N/C. If the test charge is replaced with a charge of $-3\mu C$, the electric field at P (a) has the same magnitude as before but changes direction (b) increases in magnitude and changes direction (c) remains the same or (d) decreases in magnitude and changes direction.

Solution: The correct answer is (c). The electric field at point P is due to charges other than the test charge. Thus, it is unchanged when the test charge is altered. However, the direction of the force this field exerts on the test change is reversed when the sign of the test charge is changed.

Example 15.5 Charge $q_1 = 7.00\mu C$ is at the origin and charge $q_2 = -5.00\mu C$ is on the x - axis, 0.300 m from the origin. (a) Find the magnitude and direction of the electric field at point P, which has coordinates (0, 0.400) m. (b) Find the force on a charge of $2.00 \times 10^{-8} C$ placed at P.

Solution:

(a) $E\ = ?\ ,\ \emptyset = ?$



$$E_1 = k_e \frac{|q_1|}{{r_1}^2}$$

$$E_1 = (8.99 \times 10^9)\frac{(7.00 \times 10^{-6})}{(0.400)^2} = 3.93 \times 10^5 \text{N/C}$$

$$E_{1x} = E_1 \cos(90°) = 0$$

$$E_{1y} = E_1 \sin(90°) = 3.93 \times 10^5 \text{N/C}$$

$$E_2 = k_e \frac{|q_2|}{{r_2}^2} = (8.99 \times 10^9)\frac{(5.00 \times 10^{-6})}{(0.500)^2} = 1.80 \times 10^5 \text{N/C}$$

$$\cos\theta = \frac{0.300}{0.500} = 0.600\ \ ,\ \ \sin\theta = \frac{0.400}{0.500} = 0.800$$

$$E_{2x} = E_2 \cos\theta = (1.80 \times 10^5\ )(0.600) = 1.08 \times 10^5 \text{N/C}$$

$$E_{2y} = E_2 \sin\theta = (1.80 \times 10^5\ )(-0.800) = -1.44 \times 10^5 \text{N/C}$$

$$E_x = E_{1x} + E_{2x} = 0 + (1.08 \times 10^5) = 1.08 \times 10^5 \text{N/C}$$

$$E_y = E_{1y} + E_{2y} = (3.93 \times 10^5) - (1.44 \times 10^5) = 2.49 \times 10^5 \text{N/C}$$

$$E = \sqrt{{E_x}^2 + {E_y}^2} = \sqrt{(1.08 \times 10^5\ )^2 + (2.49 \times 10^5\ )^2} = 2.71 \times 10^5 \text{N/C}$$

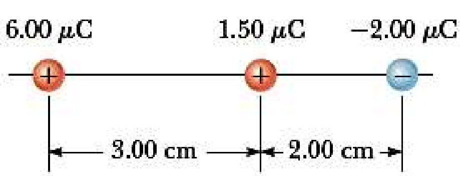
$$\emptyset = \tan^{-1}\left(\frac{E_y}{E_x}\right) = \tan^{-1}\left(\frac{2.49 \times 10^5}{1.08 \times 10^5}\right) = 66.6°$$

(b) $F\ = ?\ ,\ q\ = 2.00 \times 10^{-8} C$

$$F = qE = (2.00 \times 10^{-8})(2.71 \times 10^5\ ) = 5.42 \times 10^{-3} \text{N}$$

Problems

Problem 18. Determine the electric field strength at a point 1.00 cm to the left of the middle charge shown in Figure. (b) If a charge of $-2.00\ \mu$C is placed at this point, what are the magnitude and direction of the force on it?



Problem 25. A proton accelerates from rest in a uniform electric field of 640 N/C. At some later time, its speed is 1.20×10^6 m/s. (a) Find the magnitude of the acceleration of the proton. (b)How long does it take the proton to reach this speed? (c) How far has it moved in that interval? (d) What is its kinetic energy at the later time?