

If we are given the electric field \vec{E} at a given point in space, then we can calculate the force \vec{F} on any charge q placed at that point by writing (see Eq. 16-3):

$$\vec{F} = q\vec{E}. \quad (16-5)$$

This is valid even if q is not small as long as q does not cause the charges creating \vec{E} to move. If q is positive, \vec{F} and \vec{E} point in the same direction. If q is negative, \vec{F} and \vec{E} point in opposite directions. See Fig. 16-24.

EXAMPLE 16-6 Photocopy machine. A photocopy machine works by arranging positive charges (in the pattern to be copied) on the surface of a drum, then gently sprinkling negatively charged dry toner (ink) particles onto the drum. The toner particles temporarily stick to the pattern on the drum (Fig. 16-25) and are later transferred to paper and “melted” to produce the copy. Suppose each toner particle has a mass of 9.0×10^{-16} kg and carries an average of 20 extra electrons to provide an electric charge. Assuming that the electric force on a toner particle must exceed twice its weight in order to ensure sufficient attraction, compute the required electric field strength near the surface of the drum.

APPROACH The electric force on a toner particle of charge $q = 20e$ is $F = qE$, where E is the needed electric field. This force needs to be at least as great as twice the weight (mg) of the particle.

SOLUTION The minimum value of electric field satisfies the relation

$$qE = 2mg$$

where $q = 20e$. Hence

$$E = \frac{2mg}{q} = \frac{2(9.0 \times 10^{-16} \text{ kg})(9.8 \text{ m/s}^2)}{20(1.6 \times 10^{-19} \text{ C})} = 5.5 \times 10^3 \text{ N/C}.$$

EXAMPLE 16-7 Electric field of a single point charge. Calculate the magnitude and direction of the electric field at a point P which is 30 cm to the right of a point charge $Q = -3.0 \times 10^{-6}$ C.

APPROACH The magnitude of the electric field due to a single point charge is given by Eq. 16-4. The direction is found using the sign of the charge Q .

SOLUTION The magnitude of the electric field is:

$$E = k \frac{Q}{r^2} = \frac{(9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(3.0 \times 10^{-6} \text{ C})}{(0.30 \text{ m})^2} = 3.0 \times 10^5 \text{ N/C}.$$

The direction of the electric field is *toward* the charge Q , to the left as shown in Fig. 16-26a, since we defined the direction as that of the force on a positive test charge which here would be attractive. If Q had been positive, the electric field would have pointed away, as in Fig. 16-26b.

NOTE There is no electric charge at point P. But there is an electric field there. The only real charge is Q .

This Example illustrates a general result: The electric field \vec{E} due to a positive charge points away from the charge, whereas \vec{E} due to a negative charge points toward that charge.

EXERCISE F What is the magnitude and the direction of the electric field due to a $+2.5 \mu\text{C}$ charge at a point 50 cm below it?

If the electric field at a given point in space is due to more than one charge, the individual fields (call them \vec{E}_1 , \vec{E}_2 , etc.) due to each charge are added vectorially to get the total field at that point:

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \dots$$

The validity of this **superposition principle** for electric fields is fully confirmed by experiment.

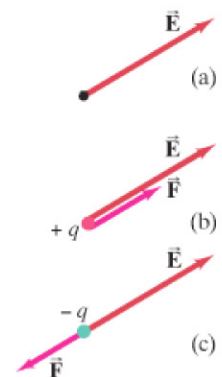


FIGURE 16-24 (a) Electric field at a given point in space. (b) Force on a positive charge at that point. (c) Force on a negative charge at that point.

PHYSICS APPLIED
Photocopier

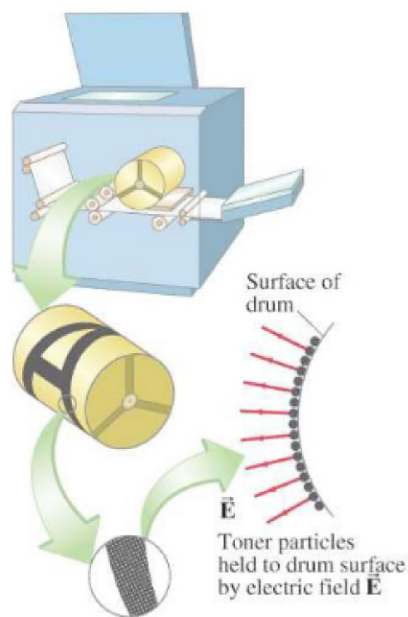
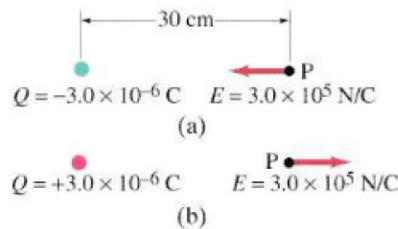


FIGURE 16-25 Example 16-6.

FIGURE 16-26 Example 16-7. Electric field at point P (a) due to a negative charge Q , and (b) due to a positive charge Q , each 30 cm from P.



Superposition principle for electric fields