My lecture slides may be found on my website at
http://www.physics.ohio-state.edu/~humanic/

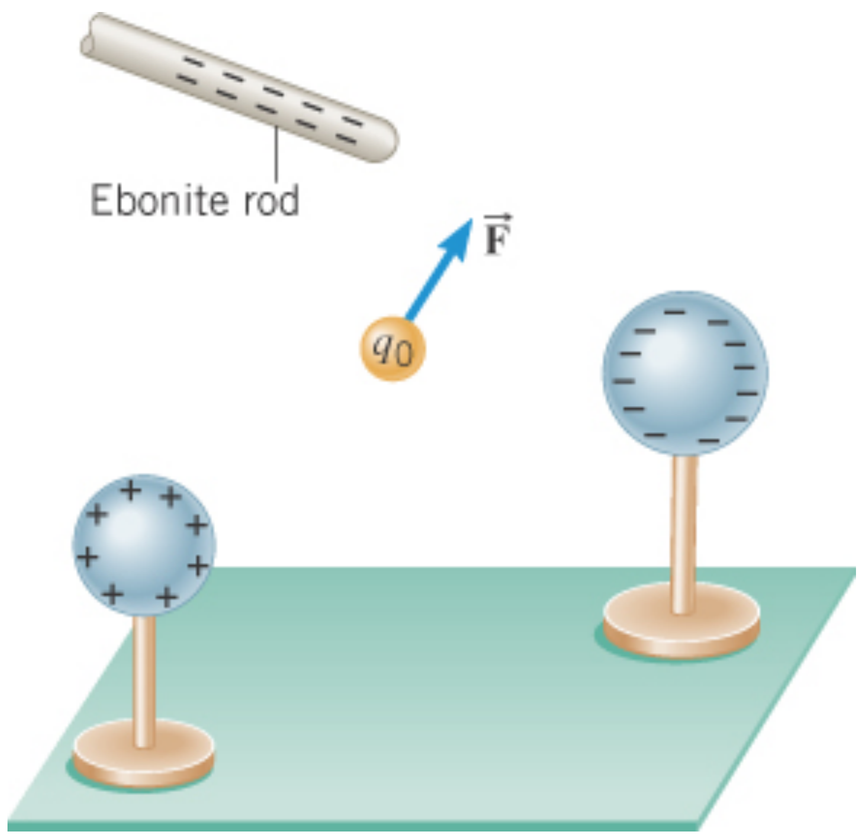
Chapter 18

Electric Forces and Electric Fields

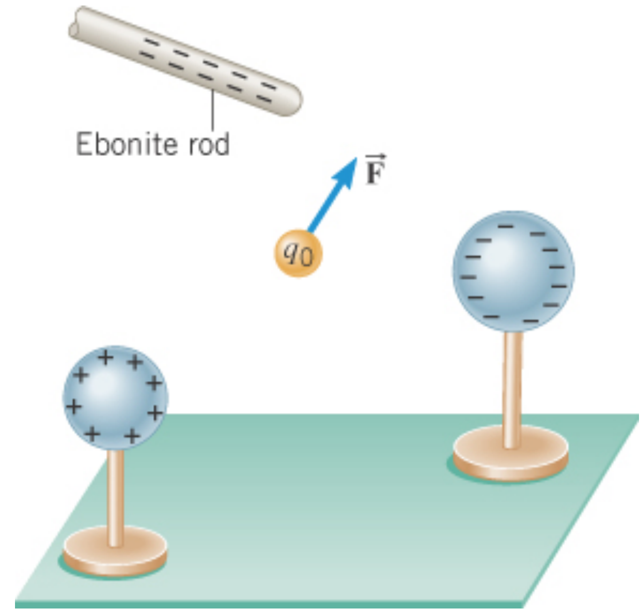
18.6 The Electric Field

The positive charge experiences a force which is the vector sum of the forces exerted by the charges on the rod and the two spheres.

This ***test charge*** should have a small magnitude so it doesn't affect the other charge.



Example 6 A Test Charge



The positive test charge has a magnitude of 3.0×10^{-8}C and experiences a force of 6.0×10^{-8}N.

(a) Find the *force per coulomb* that the test charge experiences.

(b) Predict the force that a charge of $+12 \times 10^{-8}$C would experience if it replaced the test charge.

(a) $$\frac{F}{q_o} = \frac{6.0\times10^{-8}\,\text{N}}{3.0\times10^{-8}\,\text{C}} = 2.0\,\text{N/C}$$

(b) $$F = (2.0\,\text{N/C})(12.0\times10^{-8}\,\text{C}) = 24\times10^{-8}\,\text{N}$$

DEFINITION OF ELECTRIC FIELD

The electric field that exists at a point is the electrostatic force experienced by a small test charge placed at that point divided by the charge itself:

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_o}$$

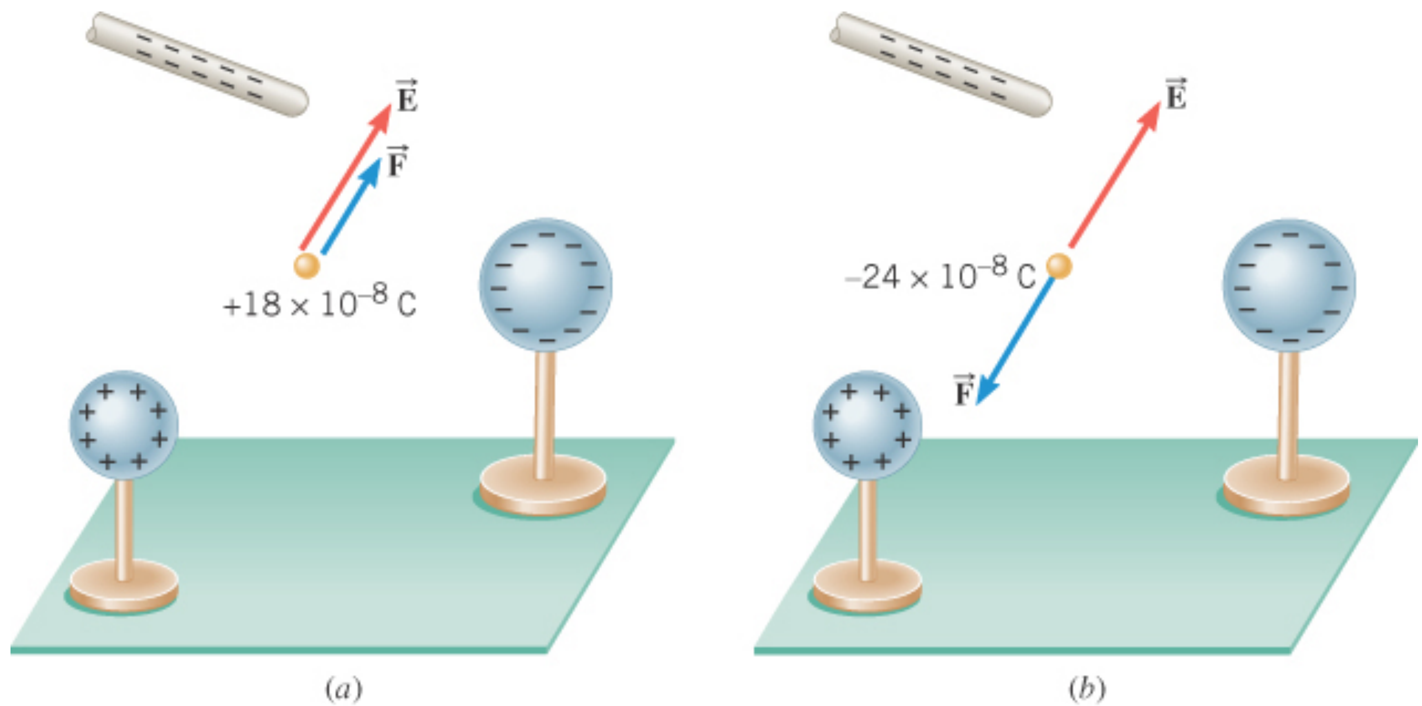
SI Units of Electric Field: newton per coulomb (N/C)

Normally a **positive test charge** is used in defining the electric field so that the force on a positive charge in a given electric field points in the direction of the electric field.

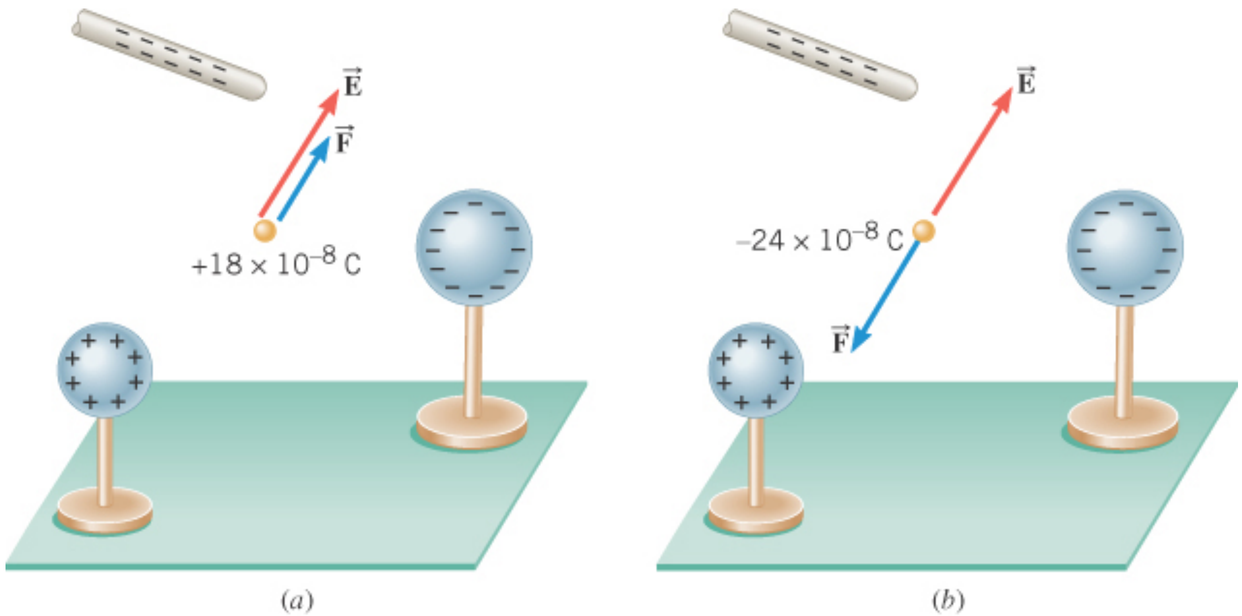
18.6 The Electric Field

Example 7 An Electric Field Leads to a Force

The charges on the two metal spheres and the ebonite rod create an electric field at the spot indicated. The field has a magnitude of 2.0 N/C. Determine the force on the charges in (a) and (b)

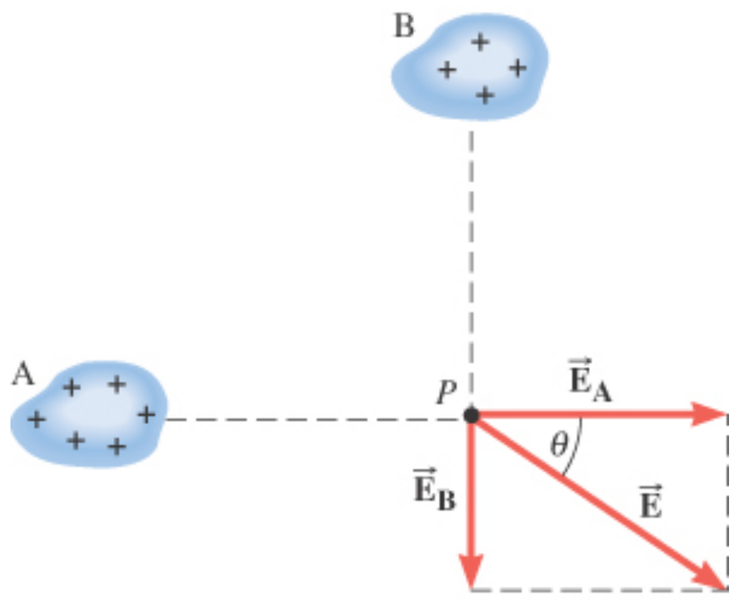


18.6 The Electric Field



(a) $F = |q_o|E = (2.0\,\mathrm{N/C})(18.0\times10^{-8}\,\mathrm{C}) = 36\times10^{-8}\,\mathrm{N}$

(b) $F = |q_o|E = (2.0\,\mathrm{N/C})(24.0\times10^{-8}\,\mathrm{C}) = 48\times10^{-8}\,\mathrm{N}$



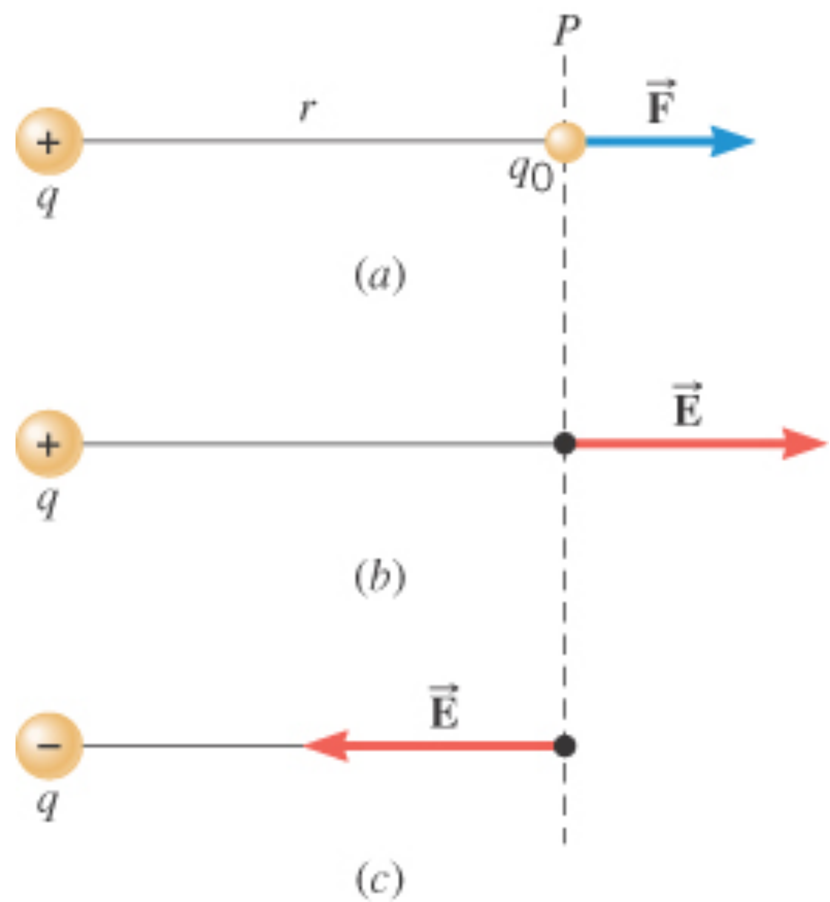
Electric fields from different sources add as vectors.

18.6 *The Electric Field*

Example 10 The Electric Field of a Point Charge

The isolated point charge of q=+15 μC is in a vacuum. The test charge is 0.20 m to the right and has a charge q_o=+0.80 μC.

Determine the electric field at point P.



$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_o}$$

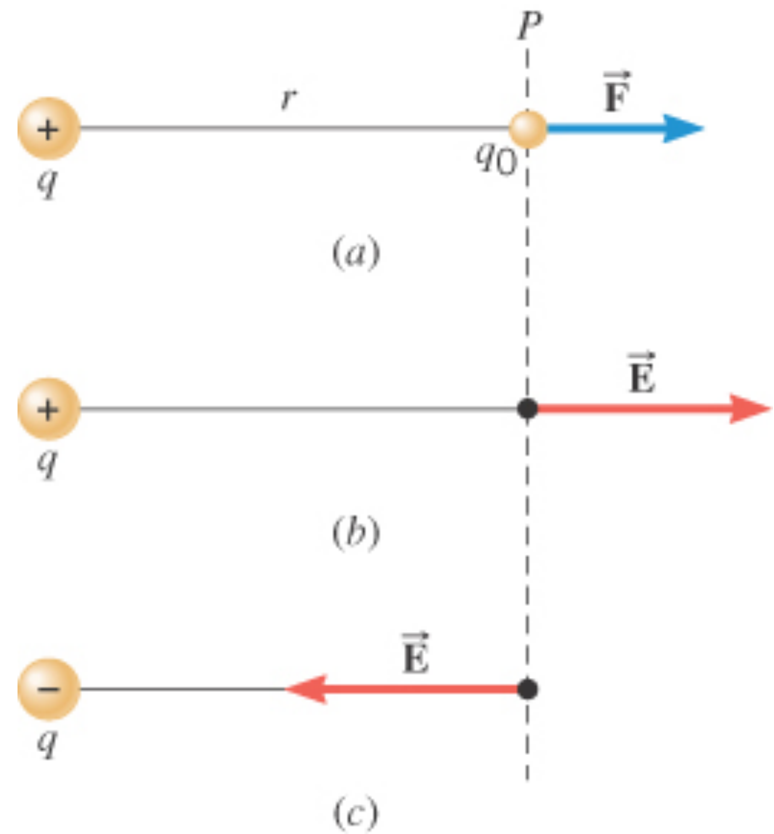
$$F = k\frac{|q_1||q_2|}{r^2}$$

18.6 The Electric Field

$$F = k\frac{|q||q_o|}{r^2}$$

$$= \frac{\left(8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}\right)\left(0.80\times10^{-6}\,\mathrm{C}\right)\left(15\times10^{-6}\,\mathrm{C}\right)}{\left(0.20\mathrm{m}\right)^2} = 2.7\mathrm{N}$$

$$E = \frac{F}{|q_o|} = \frac{2.7\ \mathrm{N}}{0.80\times10^{-6}\,\mathrm{C}} = 3.4\times10^{6}\ \mathrm{N/C}$$



18.6 The Electric Field

$$E = \frac{F}{|q_o|} = k\frac{|q||q_o|}{r^2}\frac{1}{|q_o|}$$

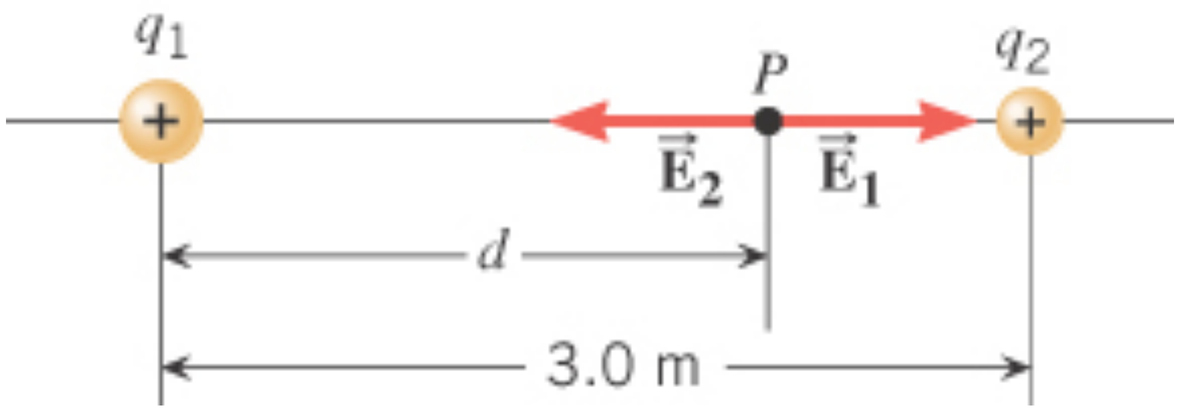
The electric field does not depend on the test charge.

Point charge q:

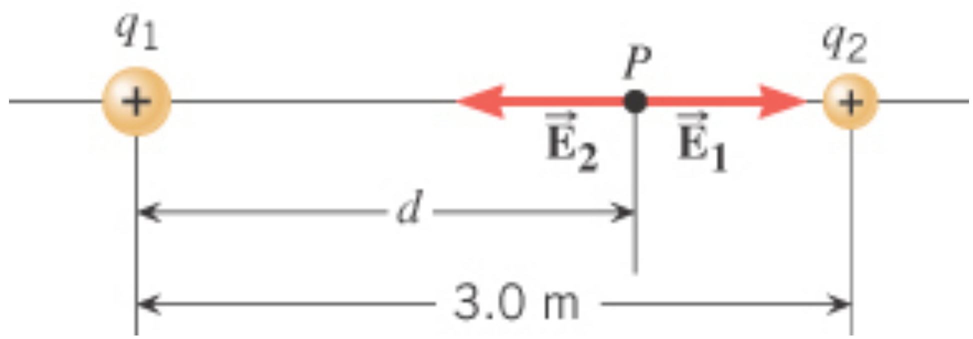
$$E = k\frac{|q|}{r^2}$$

Example 11 The Electric Fields from Separate Charges May Cancel

Two positive point charges, q_1=+16 μC and q_2=+4.0 μC are separated in a vacuum by a distance of 3.0 m. Find the spot on the line between the charges where the **net electric field is zero**.



$$E = k\frac{|q|}{r^2}$$



$$E_1 = E_2$$

$$E = k\frac{|q|}{r^2}$$

$$k\frac{\left(16\times10^{-6}\,\mathrm{C}\right)}{d^2} = k\frac{\left(4.0\times10^{-6}\,\mathrm{C}\right)}{\left(3.0\mathrm{m}-d\right)^2}$$

$$4(3.0\mathrm{m} - d)^2 = d^2$$

two solutions: $2(3.0\mathrm{m} - d) = d$ and $2(3.0\mathrm{m} - d) = -d$

$d = +2.0$ m and $+6.0$ m

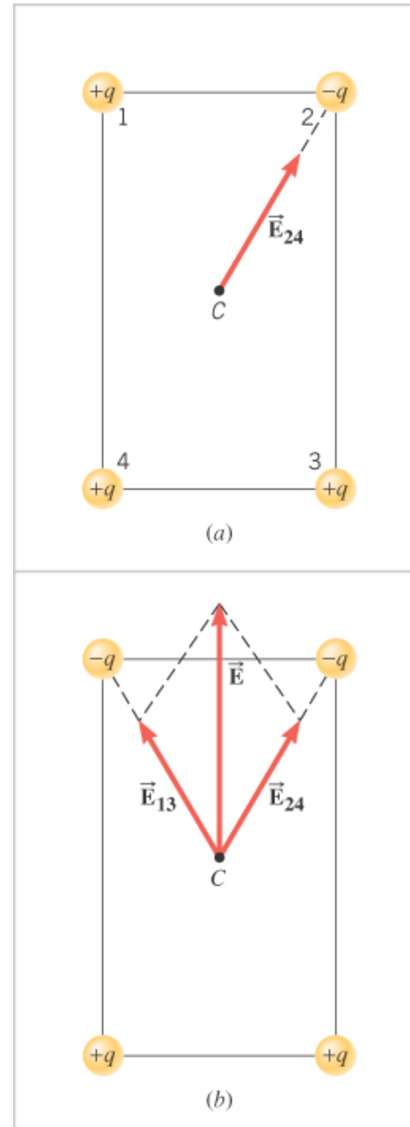
$$d = +2.0\ \mathrm{m}$$

not between the charges

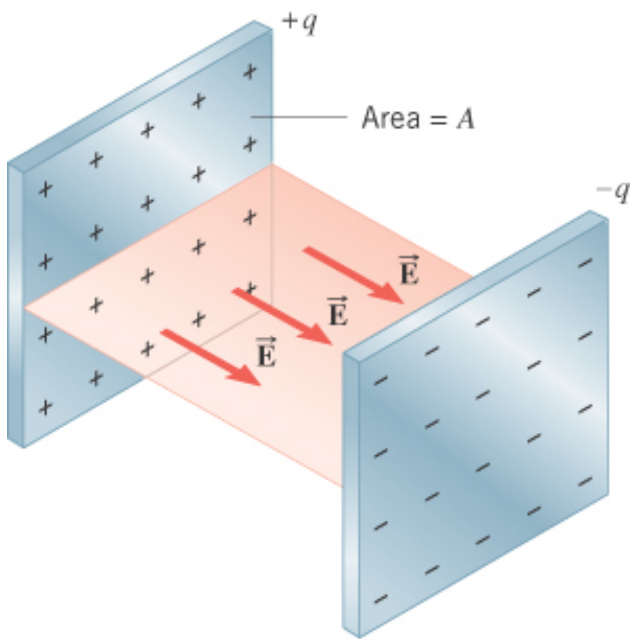
Conceptual Example 12 Symmetry and the Electric Field

Point charges are fixed to the corners of a rectangle in two different ways. The charges have the same magnitudes but different signs.

Consider the net electric field at the center of the rectangle in each case. Which field is stronger?



THE PARALLEL PLATE CAPACITOR



The electric field is uniform between the plates as long as you stay away from the edges.

charge density = *q/A*

Parallel plate capacitor

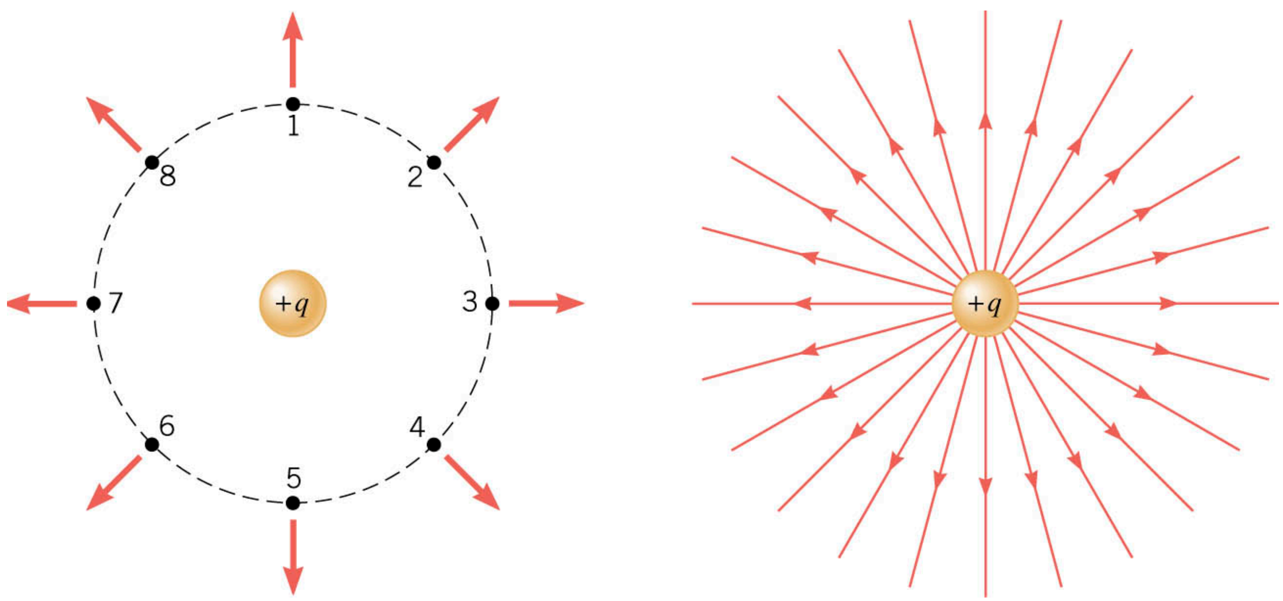
$$E = \frac{q}{\varepsilon_o A} = \frac{\sigma}{\varepsilon_o}$$

$$\varepsilon_o = 8.85 \times 10^{-12}\ \mathrm{C^2/\left(N \cdot m^2\right)}$$

permittivity of free space

18.7 Electric Field Lines

Electric field lines or ***lines of force*** provide a map of the electric field in the space surrounding electric charges.

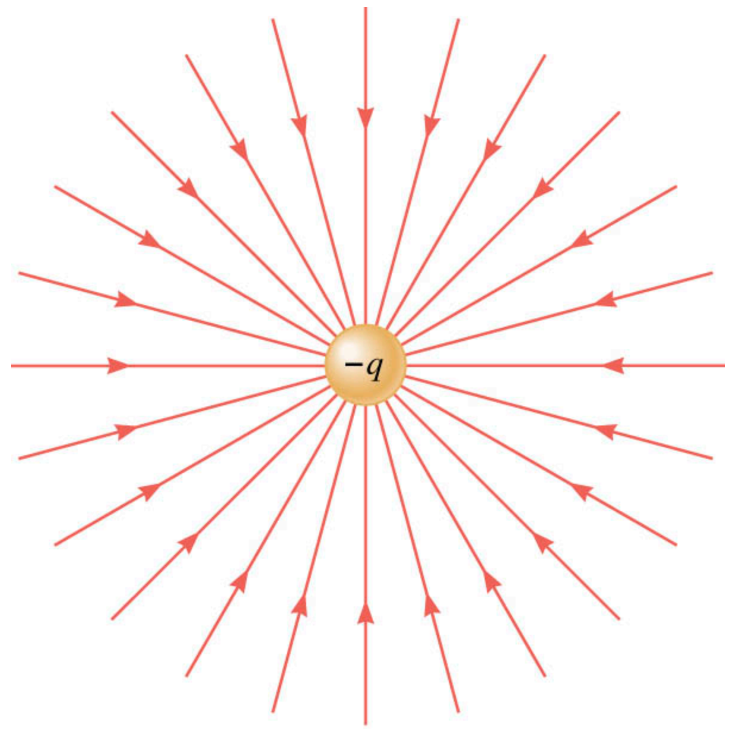


(a) (b)

Force on a positive test charge placed at various positions around a positive charge.

electric field lines (or lines of force) emanating from a positive charge.

18.7 Electric Field Lines

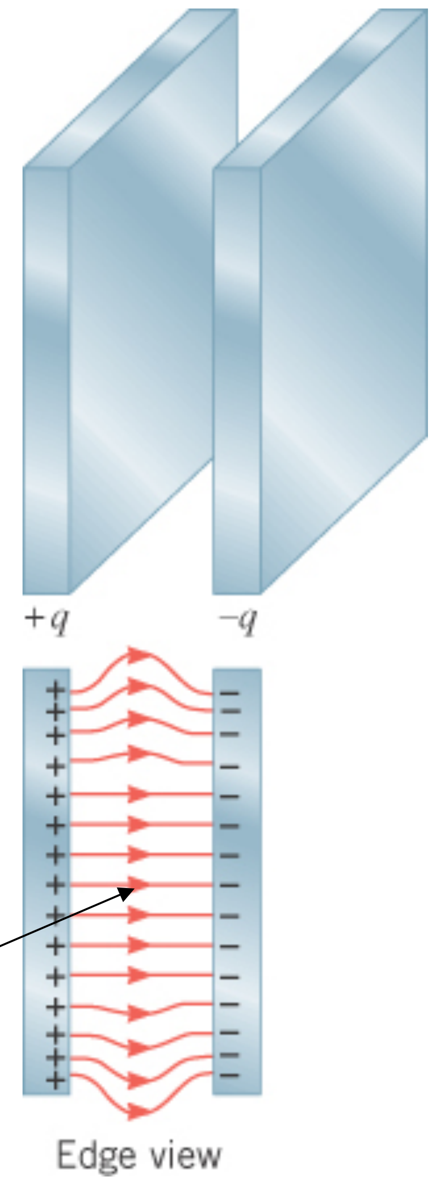


Electric field lines are always directed away from positive charges and toward negative charges.

18.7 Electric Field Lines

Electric field lines always begin on a positive charge and end on a negative charge and do not stop in midspace.

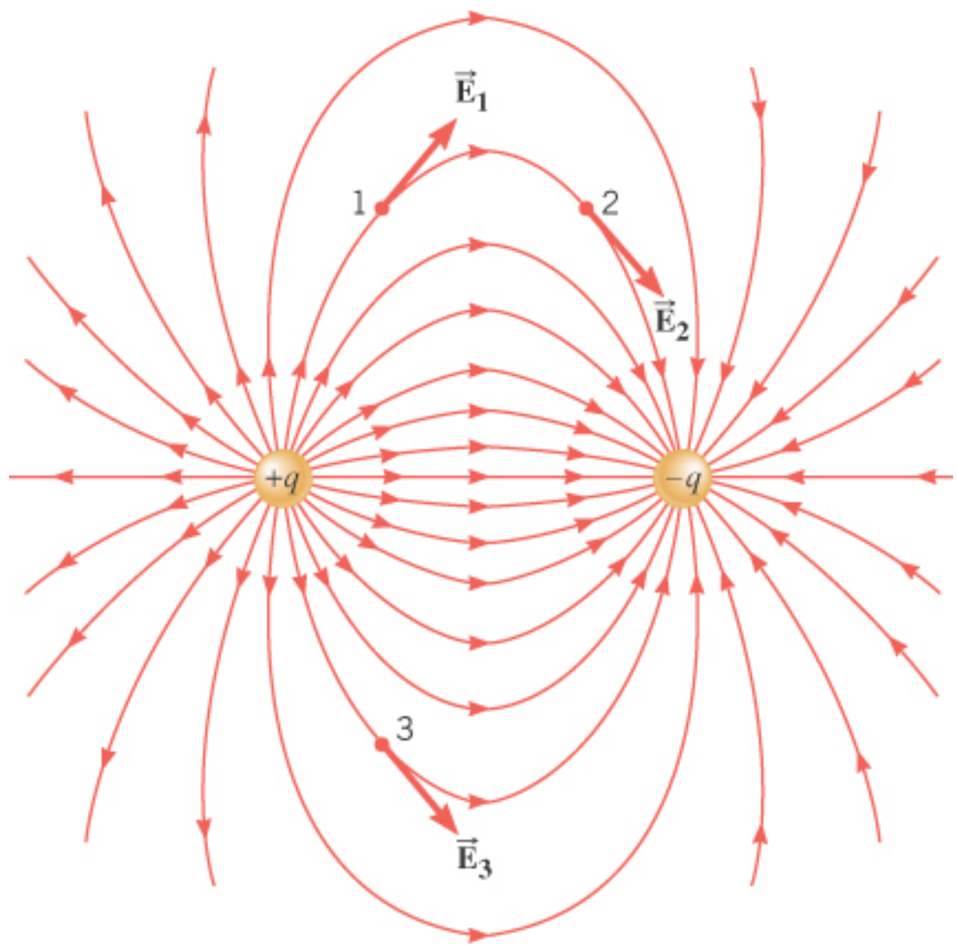
The number of lines per cross sectional area is proportional to the strength of the electric field in that region.



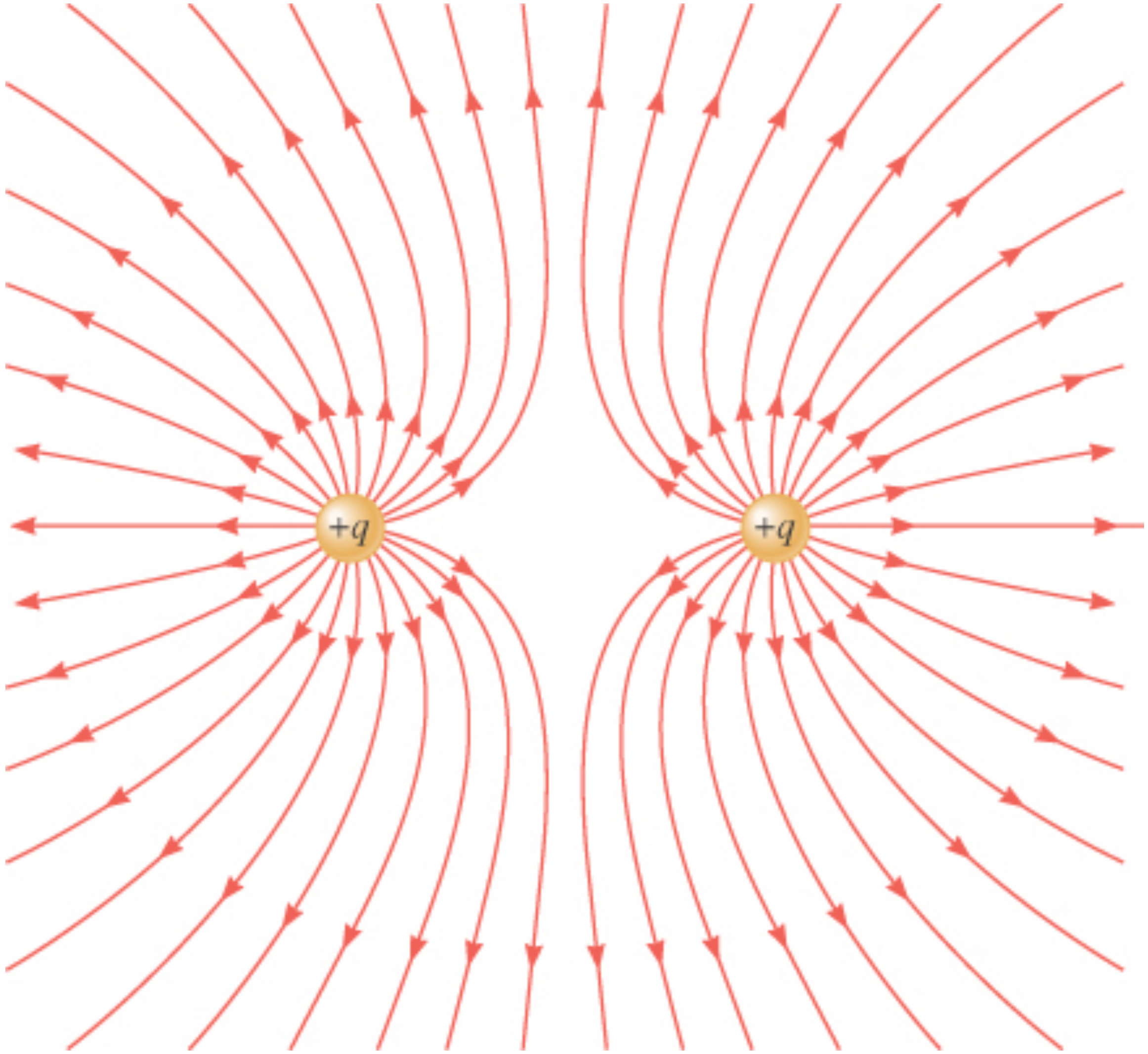
The electric field is uniform here

18.7 Electric Field Lines

The number of lines leaving a positive charge or entering a negative charge is proportional to the magnitude of the charge.

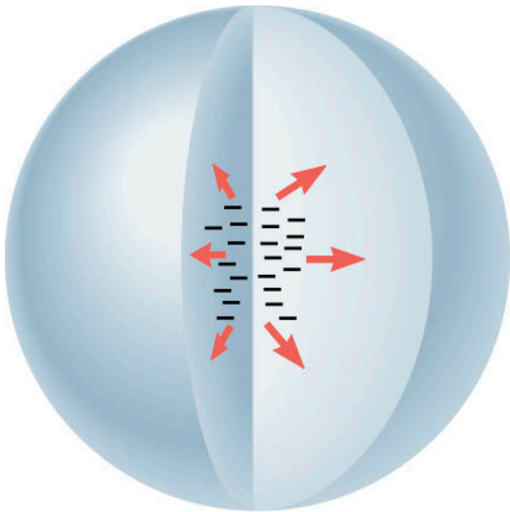


18.7 Electric Field Lines



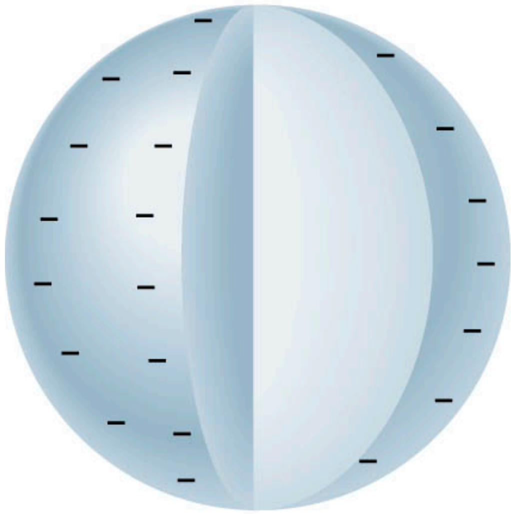
18.8 The Electric Field Inside a Conductor: Shielding

At equilibrium under electrostatic conditions, any excess charge resides on the surface of a conductor.



(a)

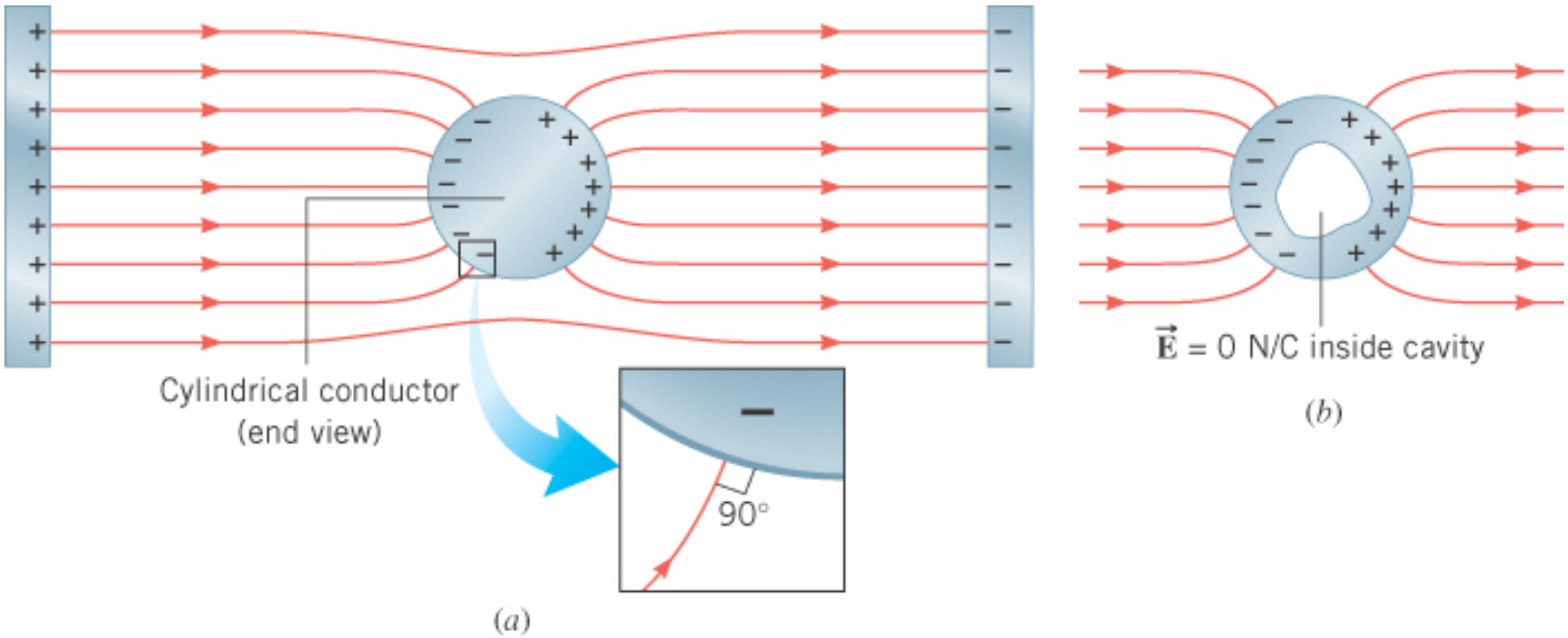
At equilibrium under electrostatic conditions, the electric field is zero at any point within a conducting material.



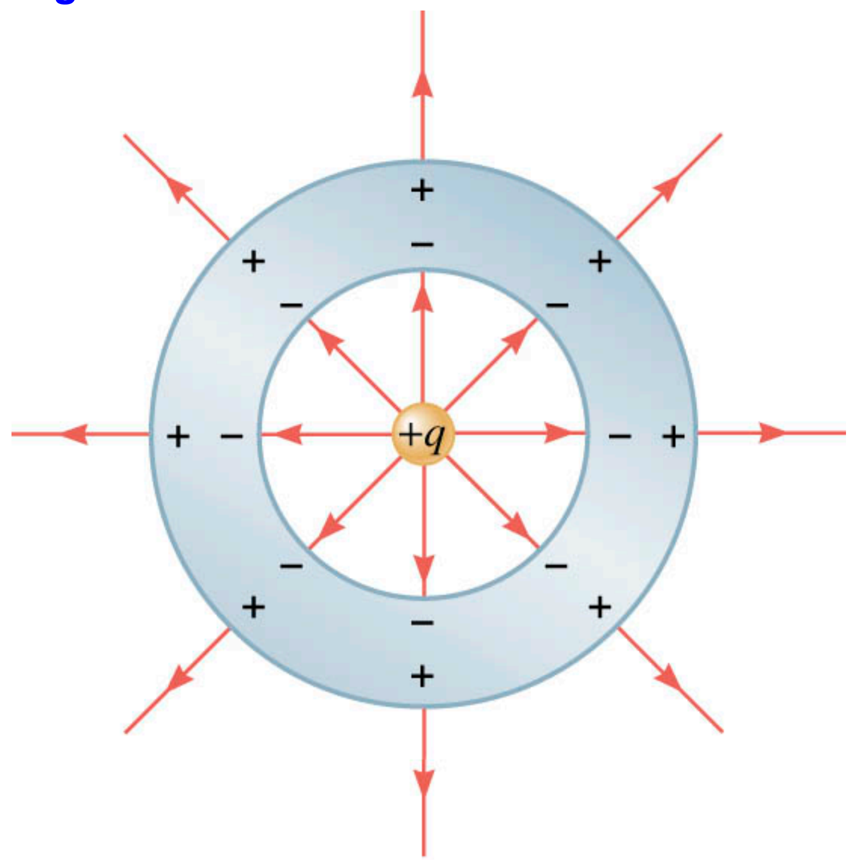
(b)

The conductor shields any charge within it from electric fields created outside the condictor.

18.8 The Electric Field Inside a Conductor: Shielding



The electric field just outside the surface of a conductor is perpendicular to the surface at equilibrium under electrostatic conditions.



***Conceptual Example 14* A Conductor in an Electric Field**

A charge is suspended at the center of a hollow, electrically neutral, spherical conductor. Show that this charge induces

(a) a charge of –q on the interior surface and

(b) a charge of +q on the exterior surface of the conductor.