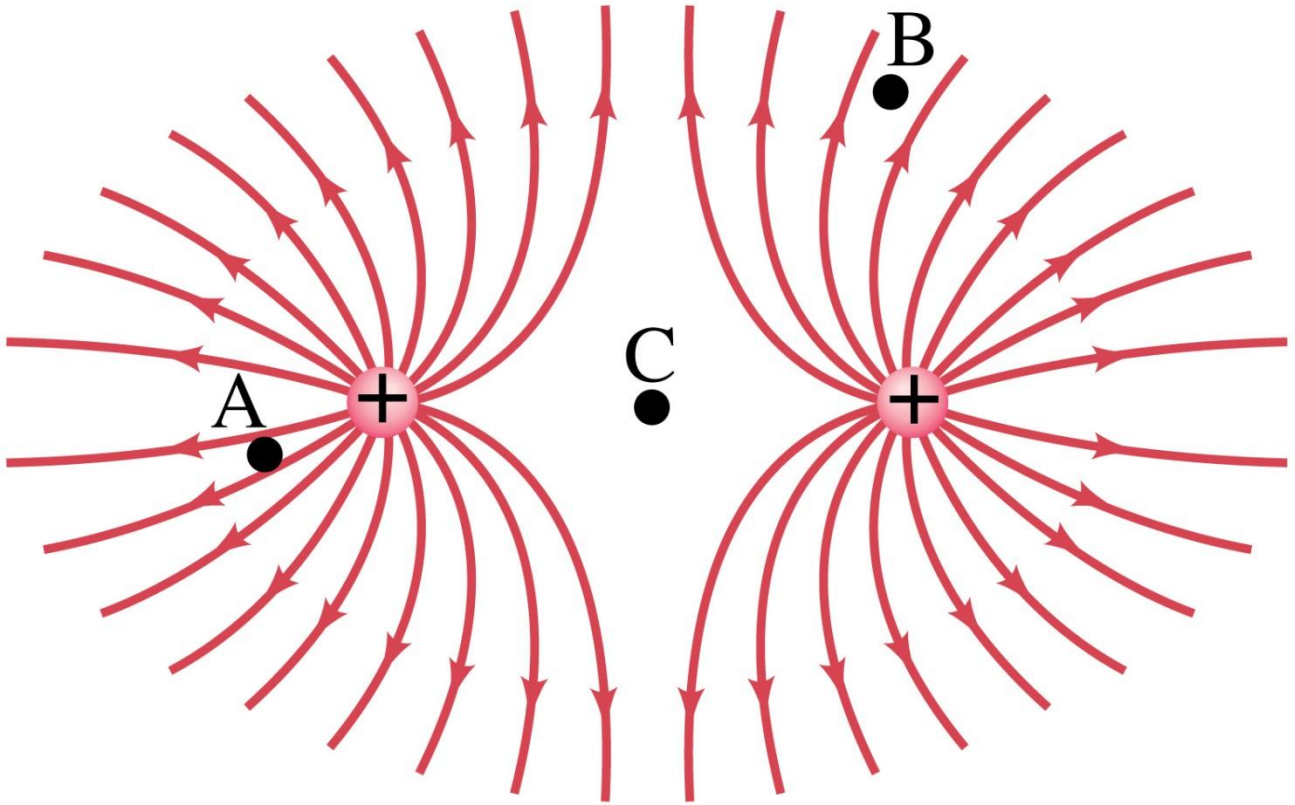
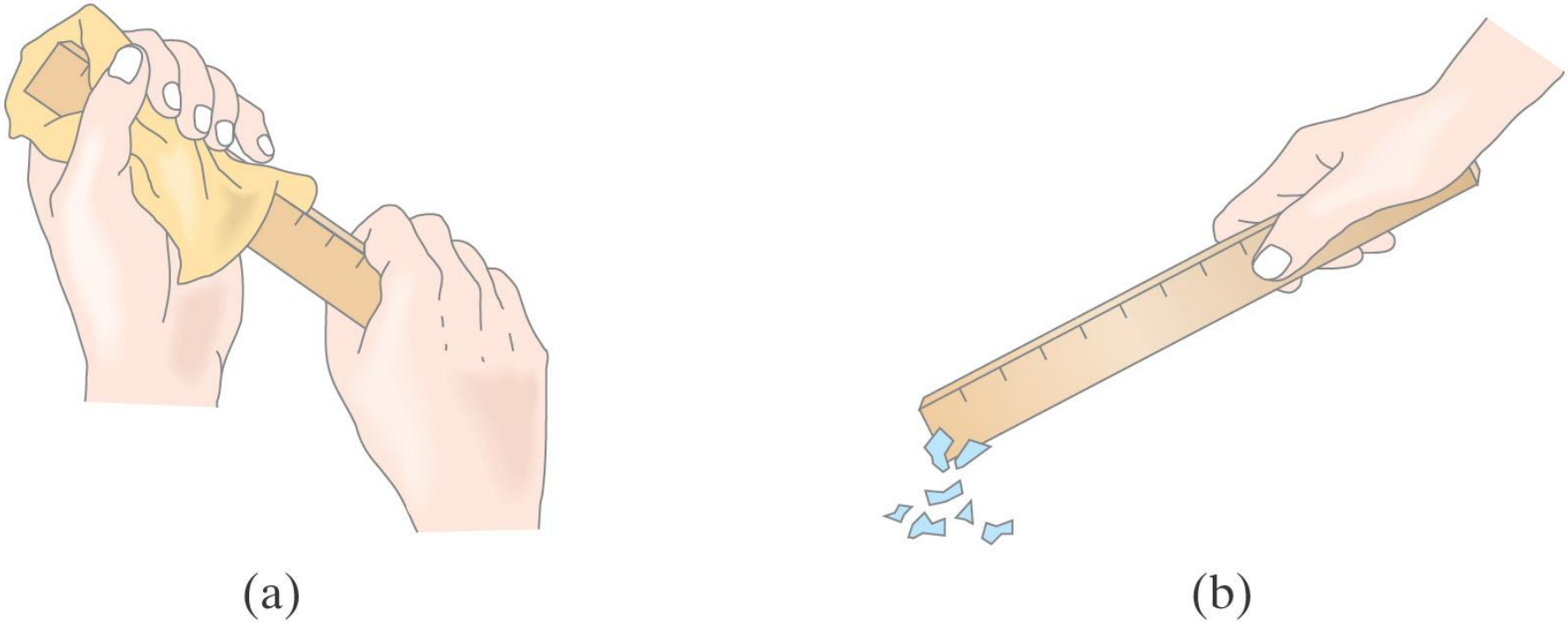
Chapter 16

Electric Charge and Electric Field



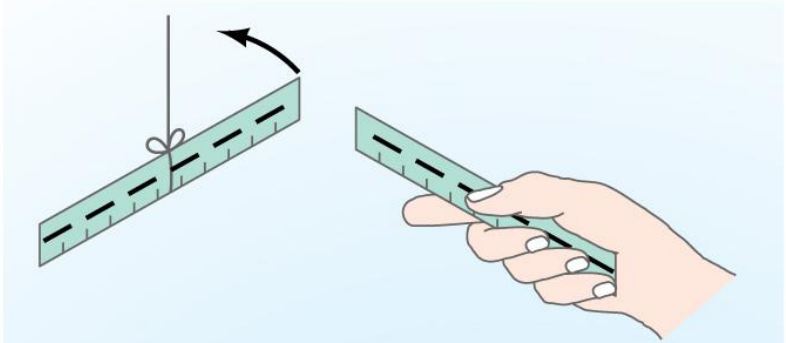
16.1 Static Electricity; Electric Charge and Its Conservation

Objects can be charged by rubbing

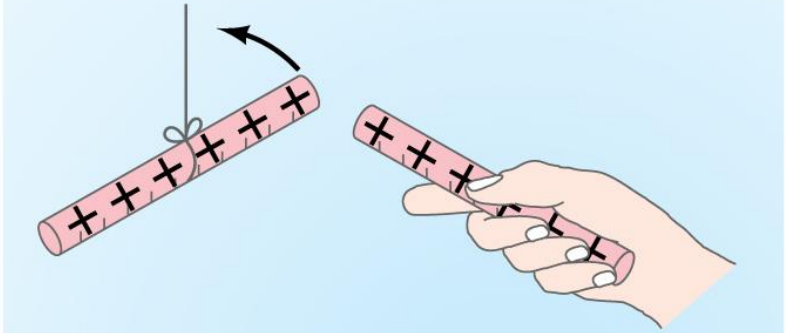


(a) (b)

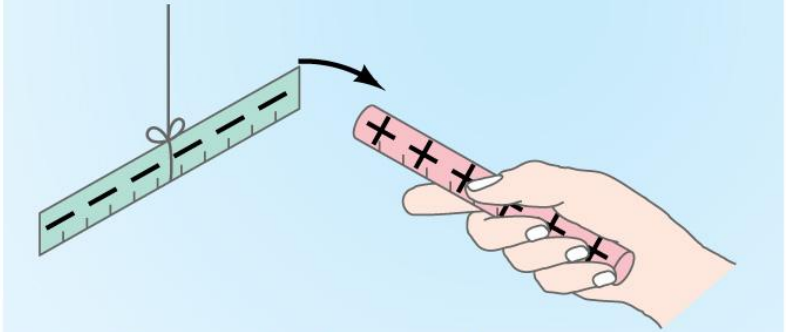
16.1 Static Electricity; Electric Charge and Its Conservation



(a) Two charged plastic rulers repel



(b) Two charged glass rods repel



(c) Charged glass rod attracts charged plastic ruler

Charge comes in two types, positive and negative; like charges repel and opposite charges attract

16.1 Static Electricity; Electric Charge and Its Conservation

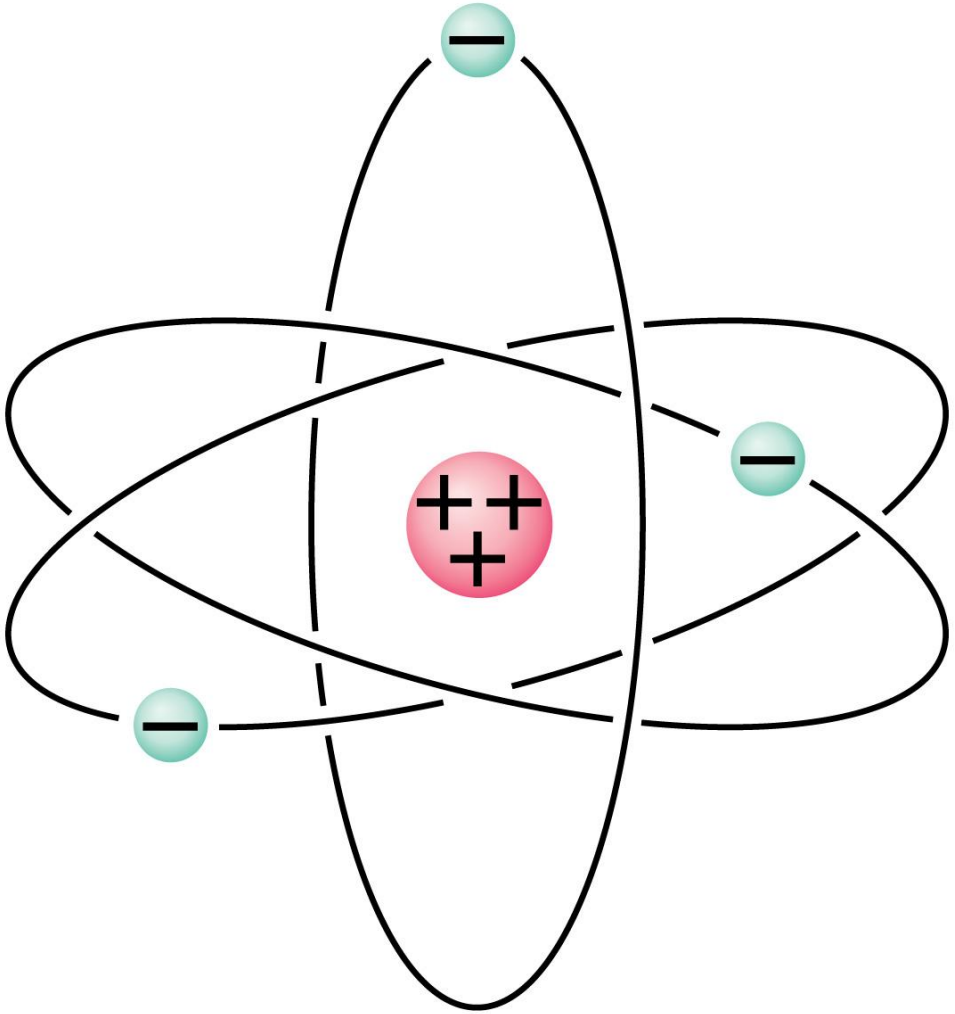
Electric charge is conserved – the arithmetic sum of the total charge cannot change in any interaction.

16.2 Electric Charge in the Atom

Atom:

Nucleus (small, massive, positive charge)

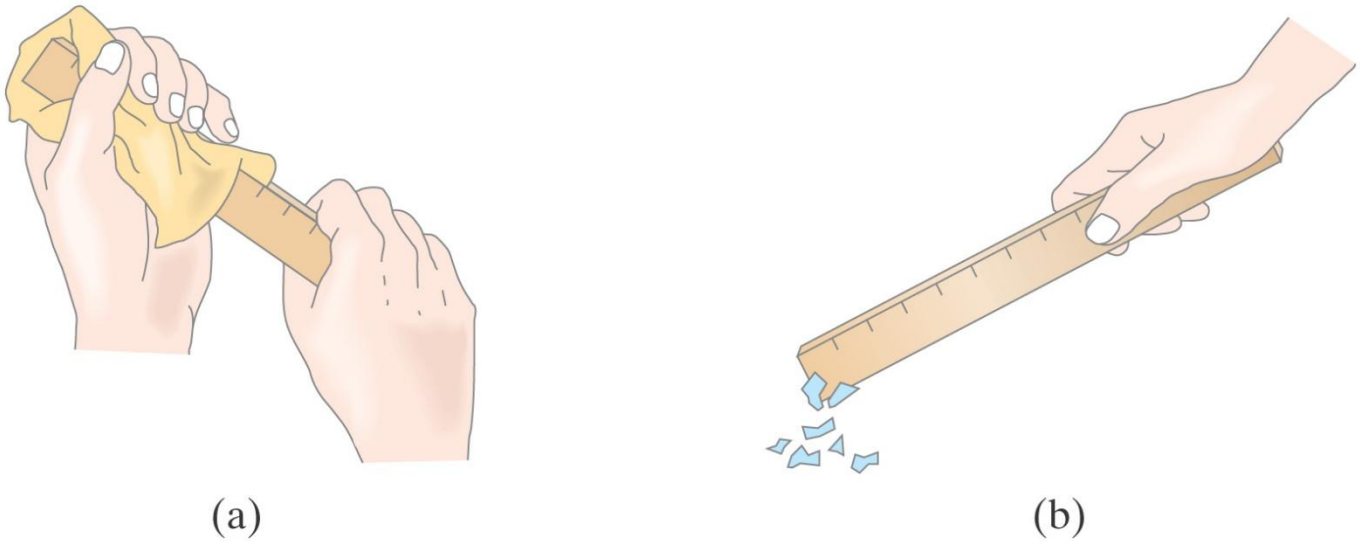
Electron cloud (large, very low density, negative charge)



16.2 Electric Charge in the Atom

Atom is electrically neutral.

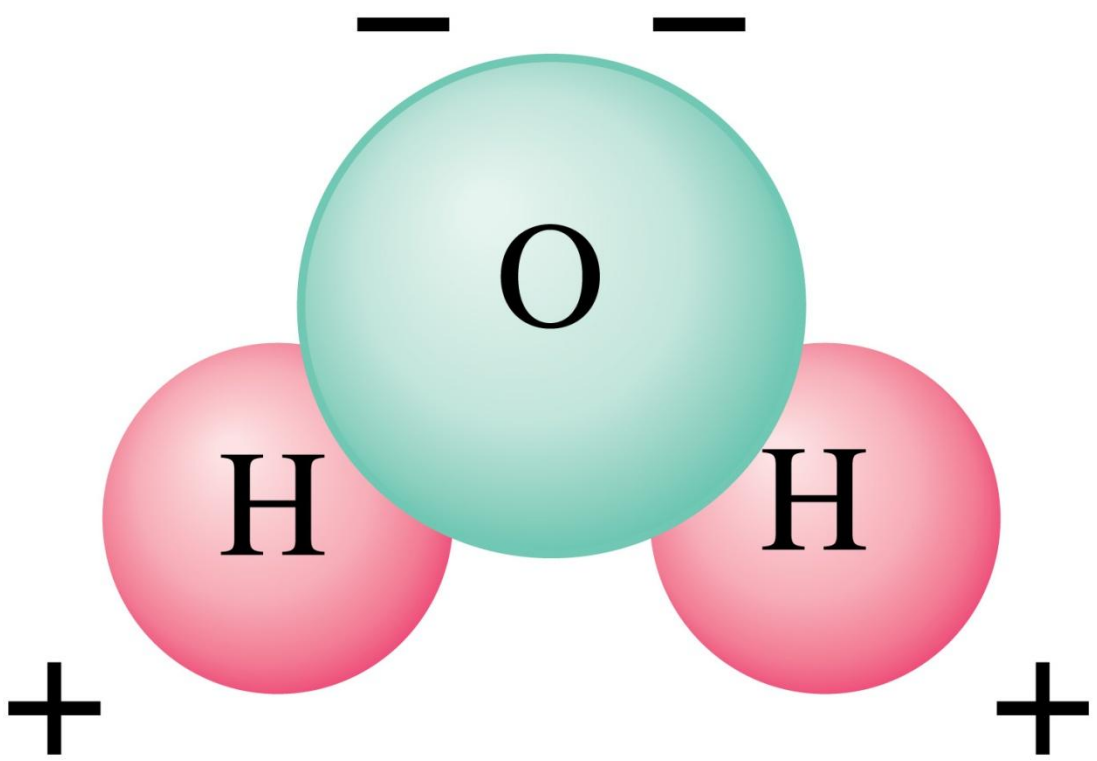
Rubbing charges objects by moving electrons from one to the other.



(a) (b)

16.2 Electric Charge in the Atom

Polar molecule: neutral overall, but charge not evenly distributed



16.3 Insulators and Conductors

Conductor:

Charge flows freely

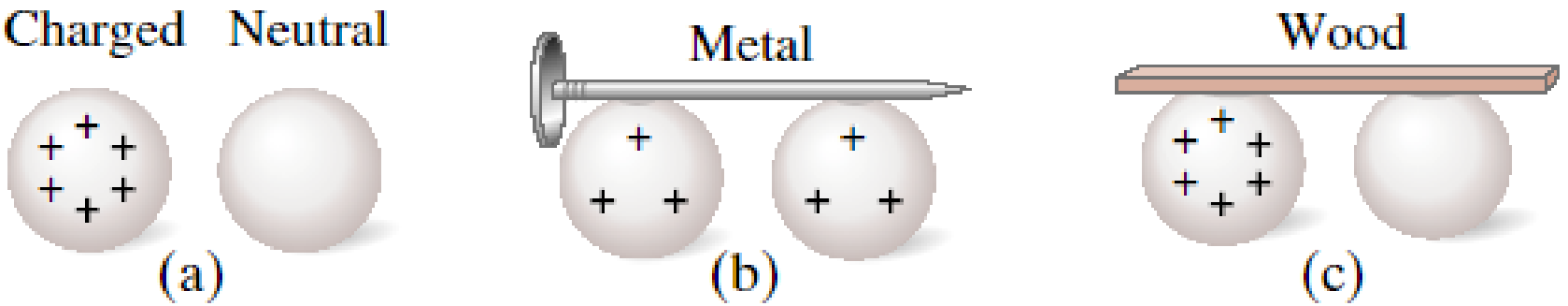
Metals

Insulator:

Almost no charge flows

Most other materials

Some materials are semiconductors.

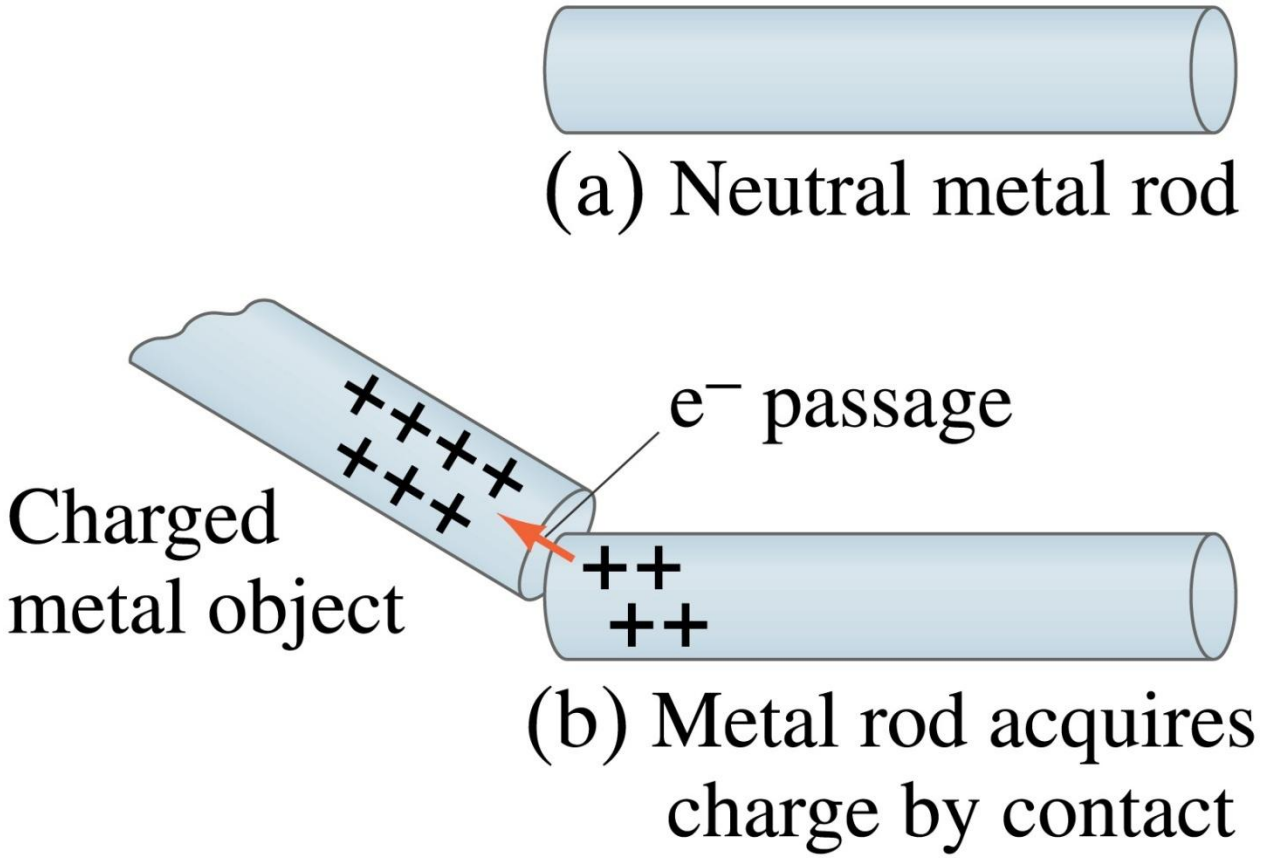


16.3 Insulators and Conductors

Time for a Gizmo!

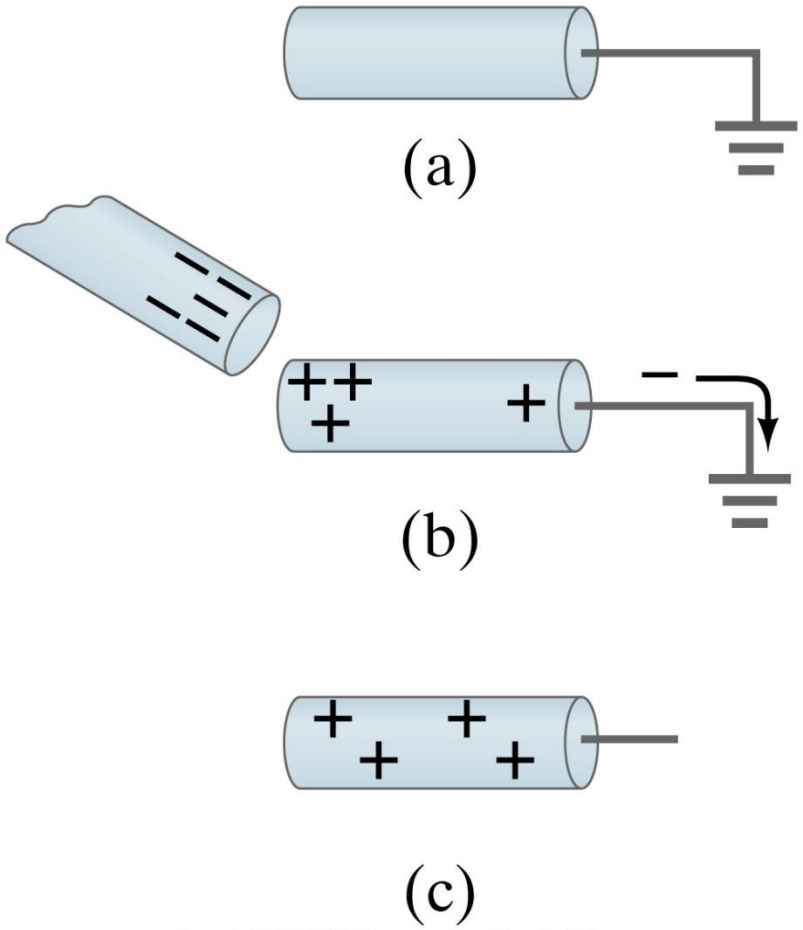
16.4 Induced Charge; the Electroscope

Metal objects can be charged by conduction:



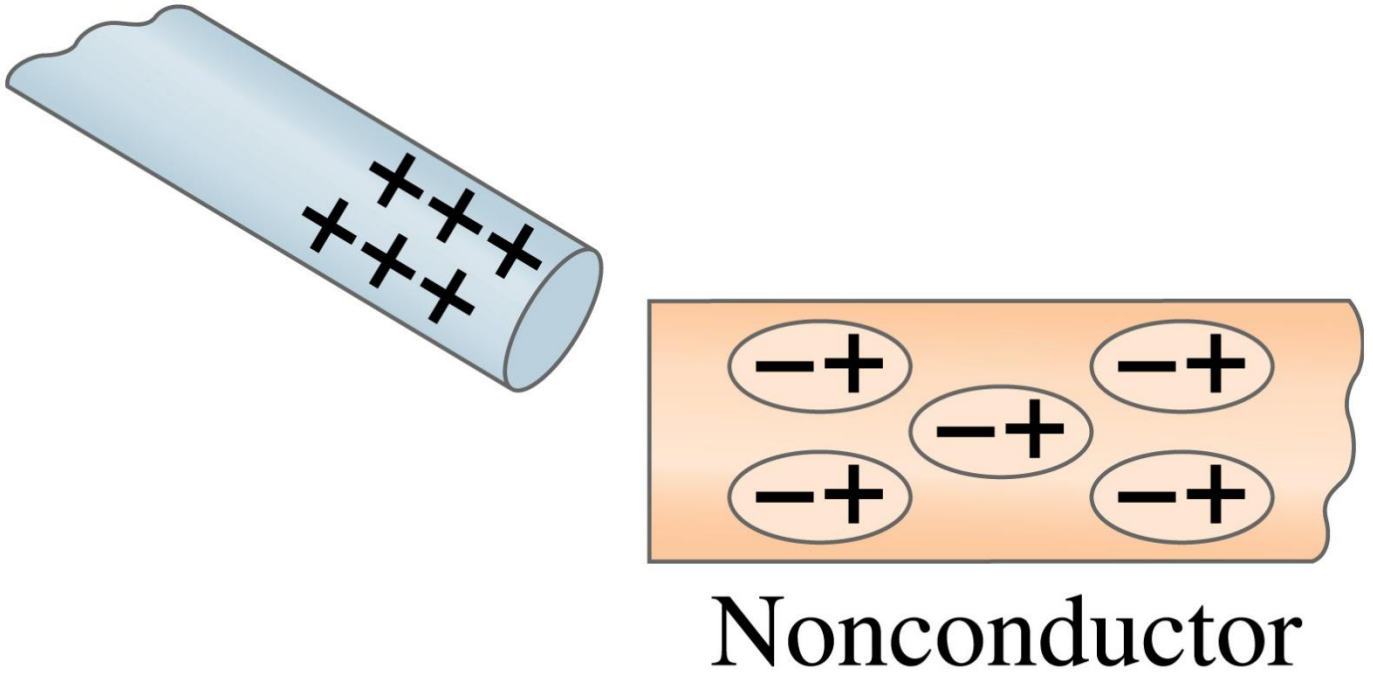
16.4 Induced Charge; the Electroscope

They can also be charged by induction:



16.4 Induced Charge; the Electroscope

Nonconductors won't become charged by conduction or induction, but will experience charge separation:

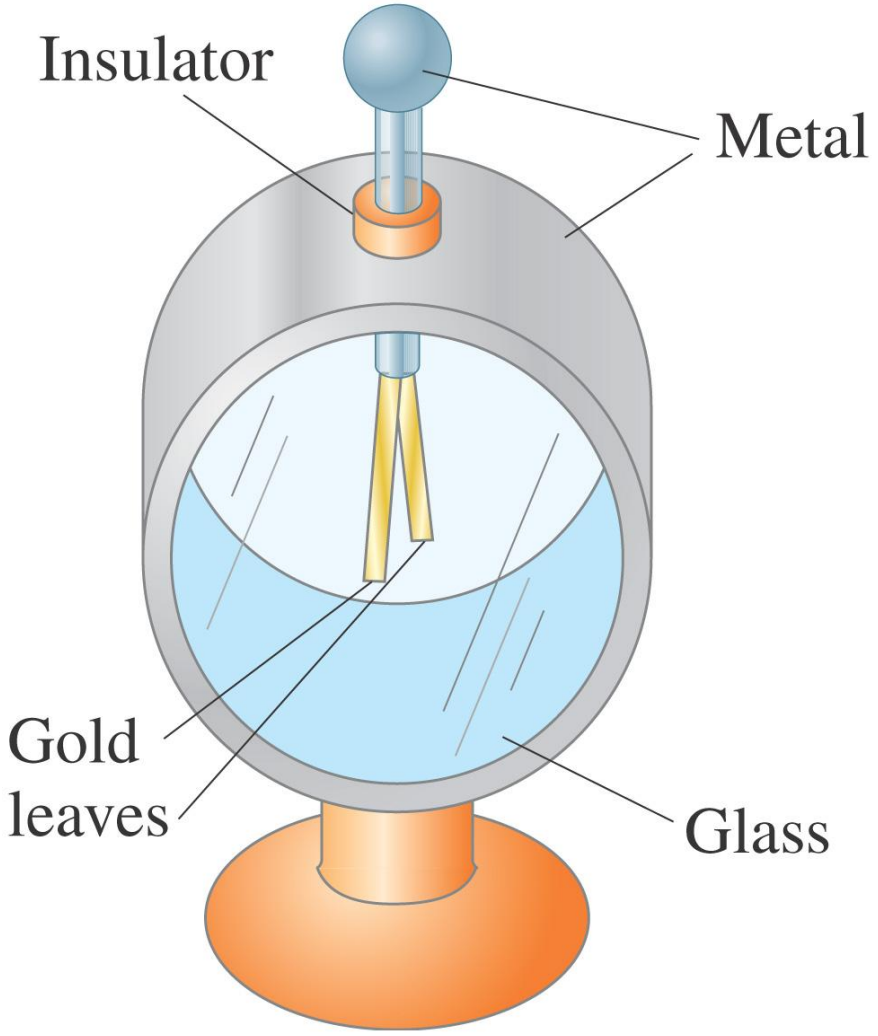


16.4 Induced Charge; the Electroscope

Time for a Gizmo!

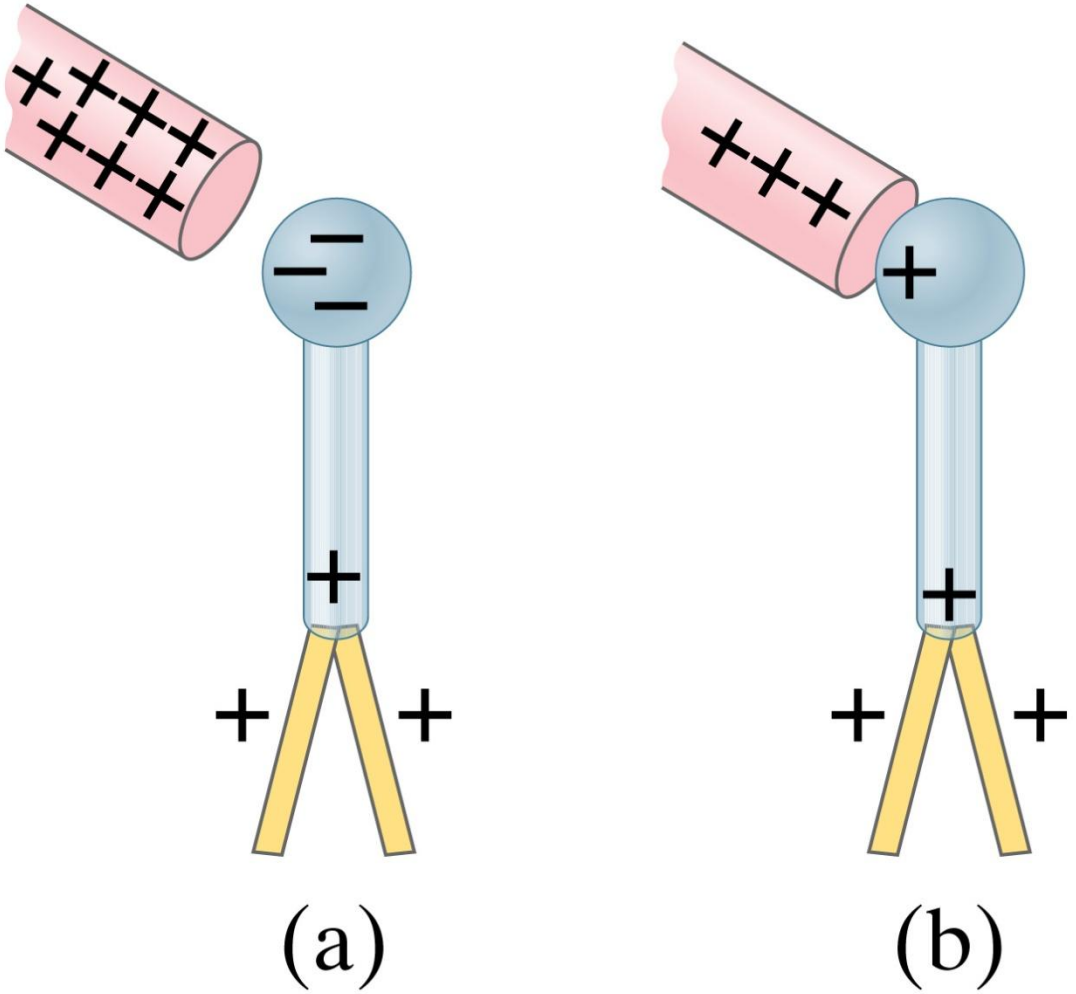
16.4 Induced Charge; the Electroscope

The electroscope can be used for detecting charge:



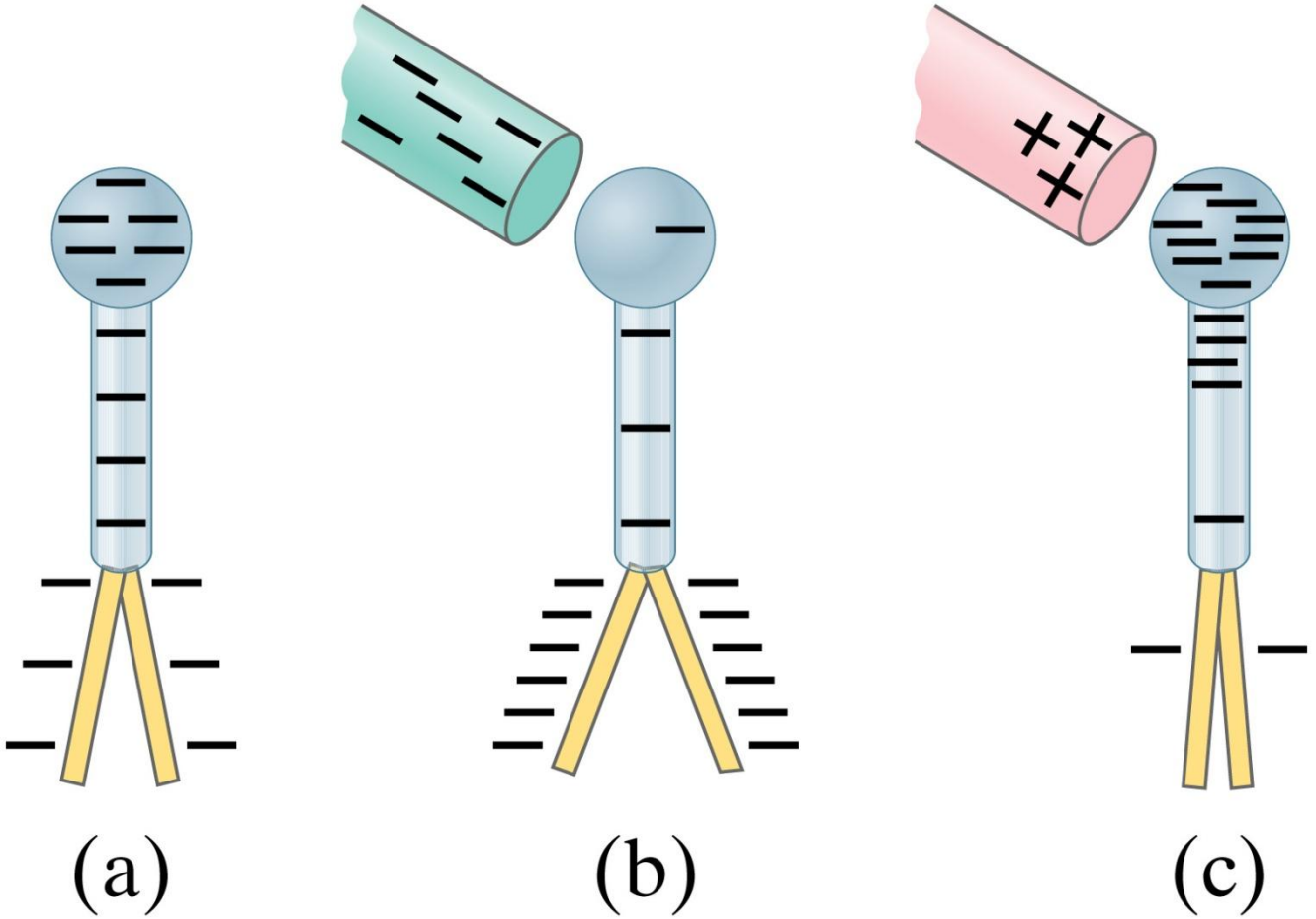
16.4 Induced Charge; the Electroscope

The electroscope can be charged either by conduction or by induction.



16.4 Induced Charge; the Electroscope

The charged electroscope can then be used to determine the sign of an unknown charge.

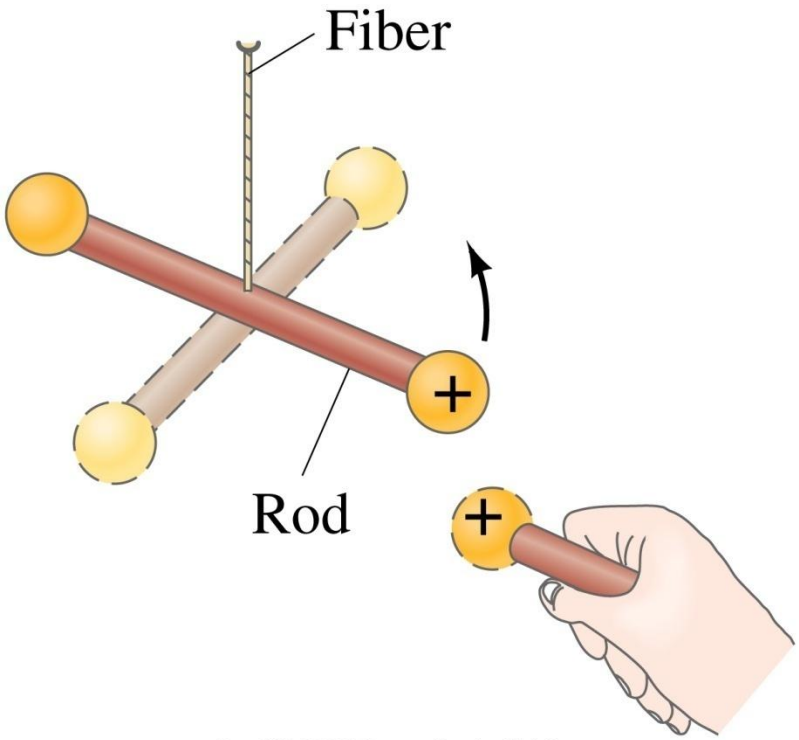


16.4 Induced Charge; the Electroscope

Time for a Gizmo!

16.5 Coulomb's Law

Experiment shows that the electric force between two charges is proportional to the product of the charges and inversely proportional to the distance between them.



16.5 Coulomb's Law

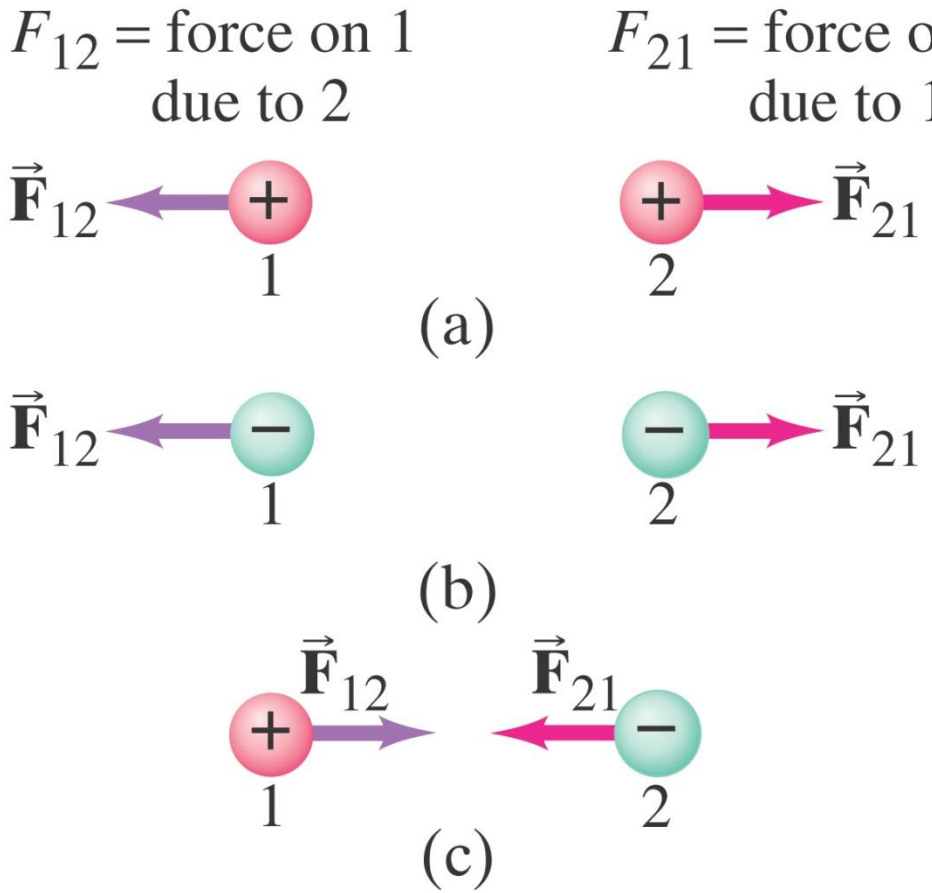
Coulomb's law:

$$F = k\frac{Q_1 Q_2}{r^2} \qquad \textbf{(16-1)}$$

This equation gives the magnitude of the force.

16.5 Coulomb's Law

The force is along the line connecting the charges, and is attractive if the charges are opposite, and repulsive if they are the same.



16.5 Coulomb's Law

Time for a Gizmo!

16.5 Coulomb's Law

Unit of charge: coulomb, C

The proportionality constant in Coulomb's law is then:

$$k = 8.988 \times 10^9\,\mathrm{N \cdot m^2/C^2}$$

Charges produced by rubbing are typically around a microcoulomb:

$$1\,\mu\mathrm{C} = 10^{-6}\,\mathrm{C}$$

16.5 Coulomb's Law

Charge on the electron:

$$e = 1.602 \times 10^{-19}\,\mathrm{C}$$

Electric charge is quantized in units of the electron charge.

16.5 Coulomb's Law

The proportionality constant k can also be written in terms of ϵ_0, the permittivity of free space:

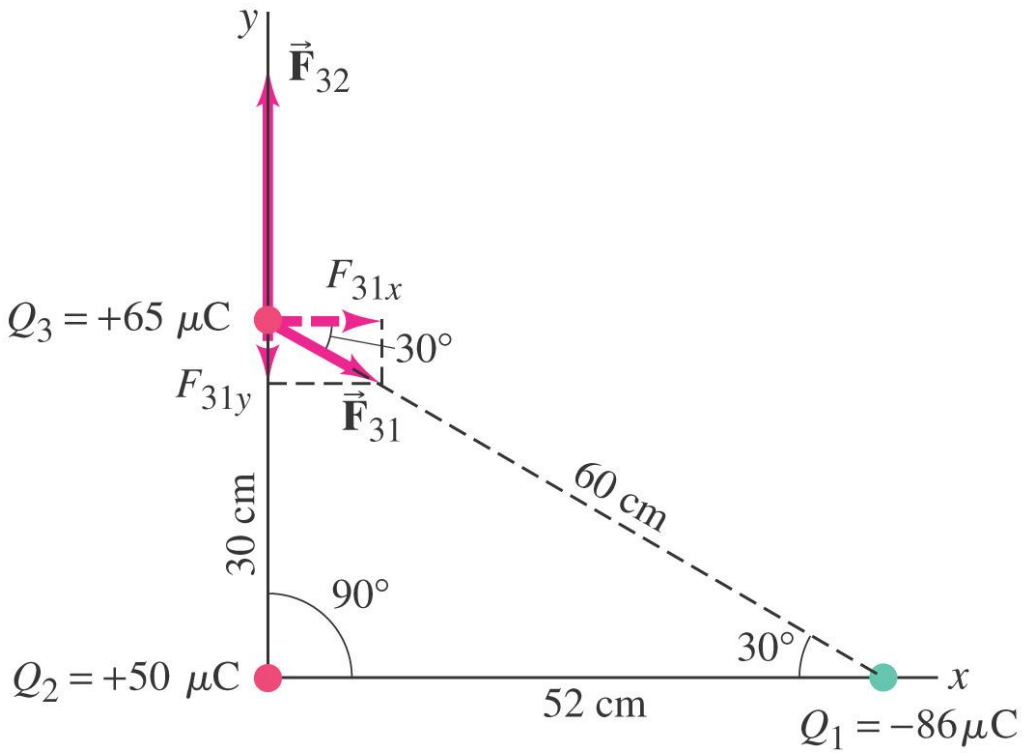
$$F = \frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{r^2}$$

$$\epsilon_0 = \frac{1}{4\pi k} = 8.85 \times 10^{-12}\,\mathrm{C}^2/\mathrm{N}\cdot\mathrm{m}^2 \qquad \textbf{(16-2)}$$

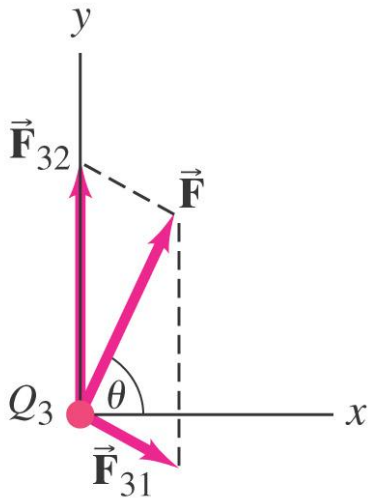
16.5 Coulomb's Law

Coulomb's law strictly applies only to point charges.

Superposition: for multiple point charges, the forces on each charge from every other charge can be calculated and then added as vectors.



(a)



(b)

16.6 Solving Problems Involving Coulomb's Law and Vectors

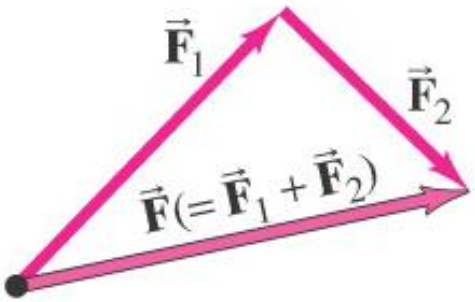
The net force on a charge is the vector sum of all the forces acting on it.

$$\vec{\mathbf{F}}_{\text{net}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \cdots$$

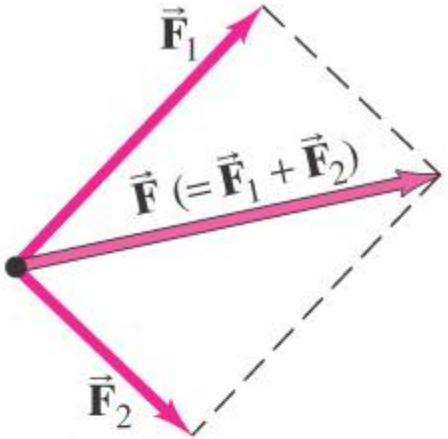
16.6 Solving Problems Involving Coulomb's Law and Vectors

Vector addition review:

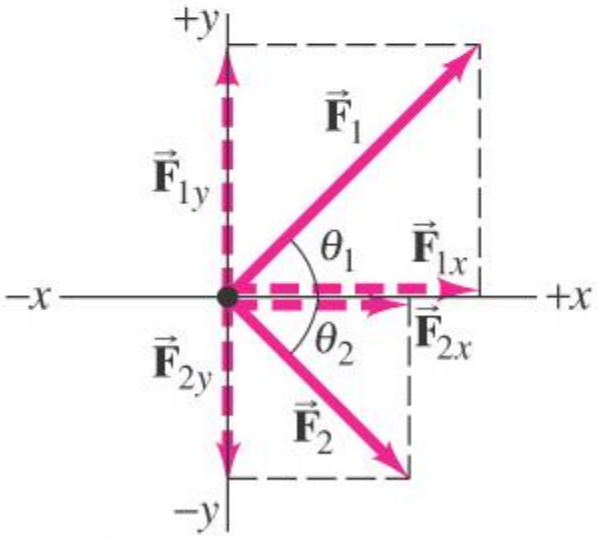
(a) Two forces acting on an object.



(b) The total, or net, force is $\vec{F} = \vec{F}_1 + \vec{F}_2$ by the tail-to-tip method of adding vectors.



(c) $\vec{F} = \vec{F}_1 + \vec{F}_2$ by the parallelogram method.

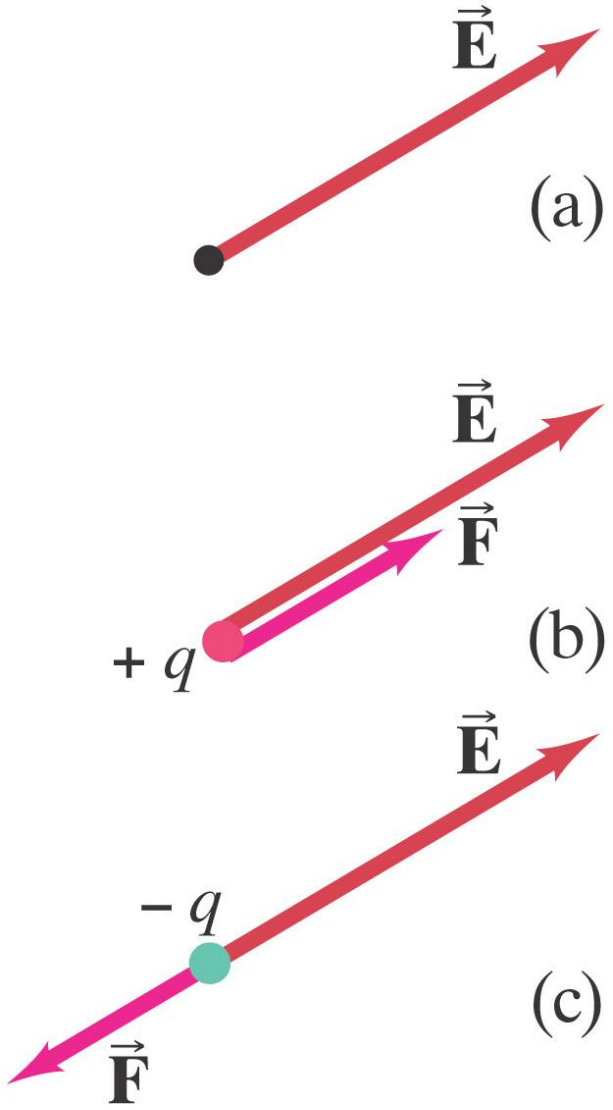


(d) $\vec{F}_1$ and $\vec{F}_2$ resolved into their x and y components.

16.7 The Electric Field

The electric field is the force on a small charge, divided by the charge:

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q} \qquad \textbf{(16-3)}$$



16.7 The Electric Field

For a point charge:

$$E = k\frac{Q}{r^2} \qquad \textbf{(16-4a)}$$

$$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2} \qquad \textbf{(16-4b)}$$

16.7 The Electric Field

Force on a point charge in an electric field:

$$\vec{\mathbf{F}} = q\vec{\mathbf{E}} \qquad \textbf{(16-5)}$$

Superposition principle for electric fields:

$$\vec{\mathbf{E}} = \vec{\mathbf{E}}_1 + \vec{\mathbf{E}}_2 + \cdots$$

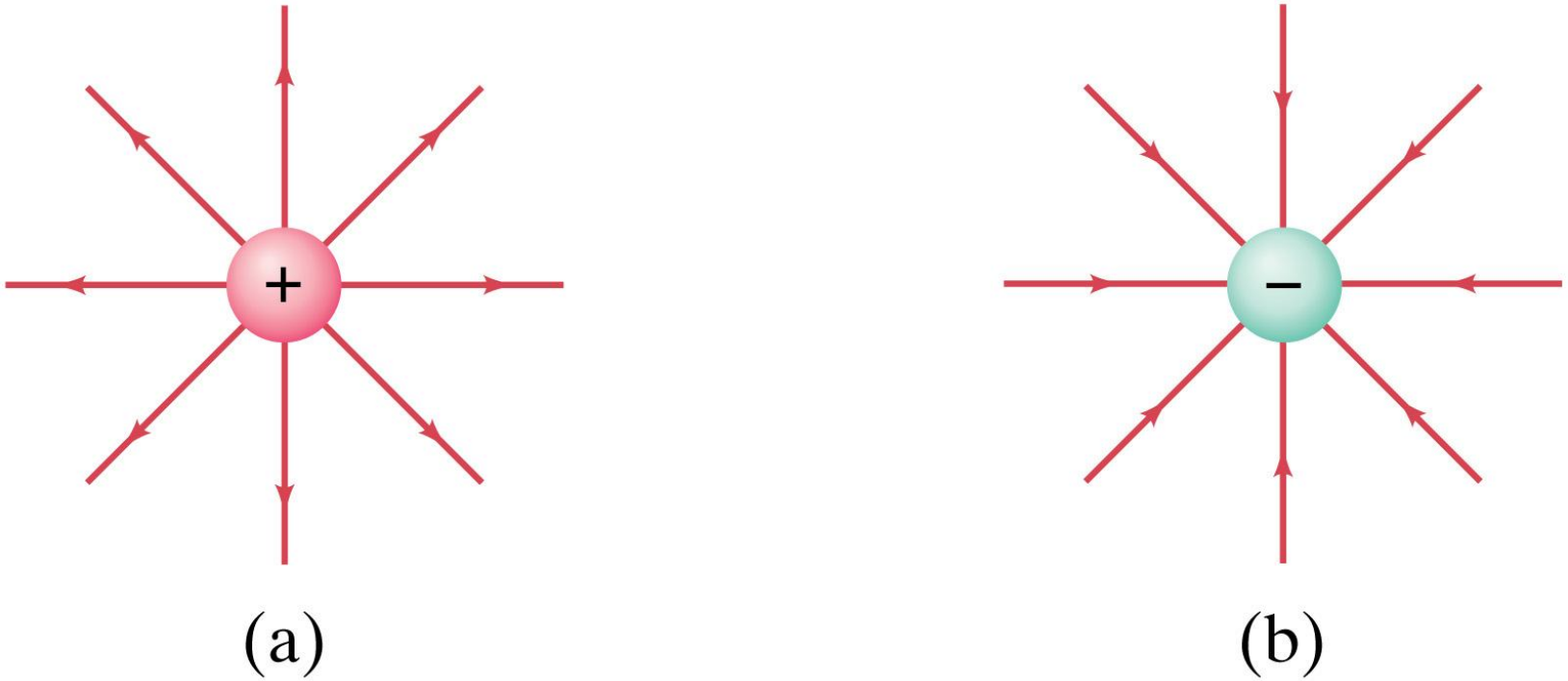
16.7 The Electric Field

Problem solving in electrostatics: electric forces and electric fields

1. **Draw a diagram; show all charges, with signs, and electric fields and forces with directions**
2. **Calculate forces using Coulomb's law**
3. **Add forces vectorially to get result**

16.8 Field Lines

The electric field can be represented by field lines. These lines start on a positive charge and end on a negative charge.



16.8 Field Lines

Time for a Gizmo!

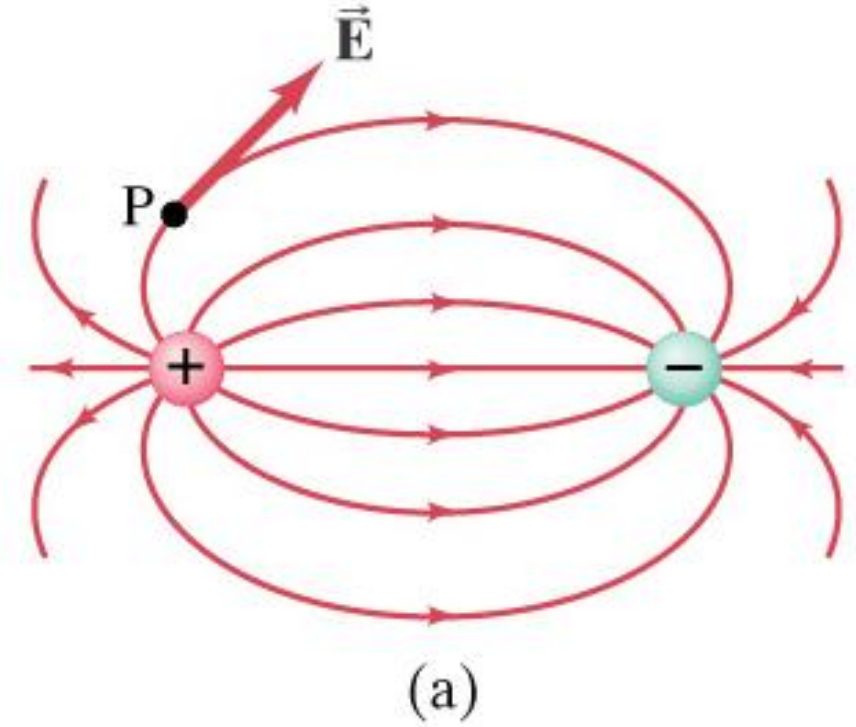
16.8 Field Lines

The number of field lines starting (ending) on a positive (negative) charge is proportional to the magnitude of the charge.

The electric field is stronger where the field lines are closer together.

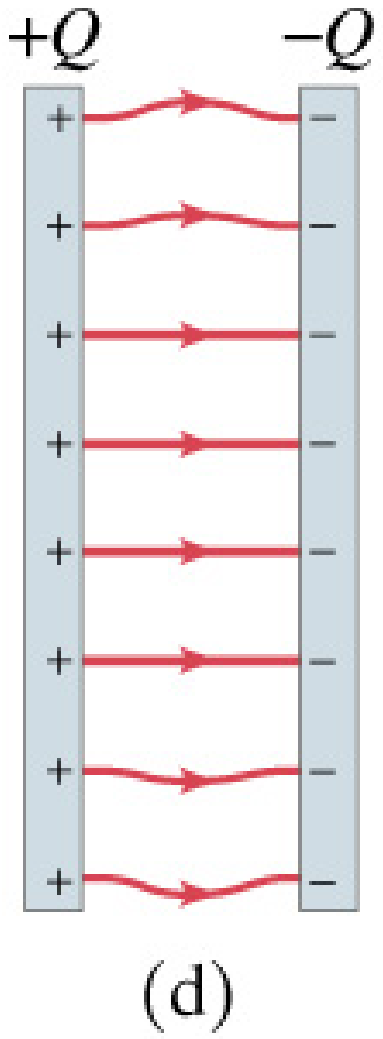
16.8 Field Lines

Electric dipole: two equal charges, opposite in sign:



(a)

16.8 Field Lines



The electric field between two closely spaced, oppositely charged parallel plates is constant.

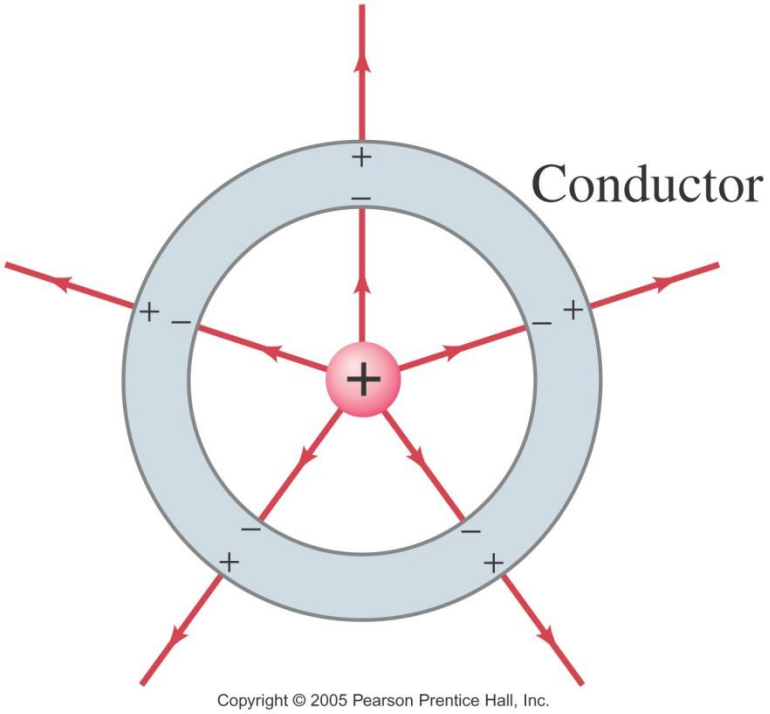
16.8 Field Lines

Summary of field lines:

1. **Field lines indicate the direction of the field; the field is tangent to the line.**
2. **The magnitude of the field is proportional to the density of the lines.**
3. **Field lines start on positive charges and end on negative charges; the number is proportional to the magnitude of the charge.**

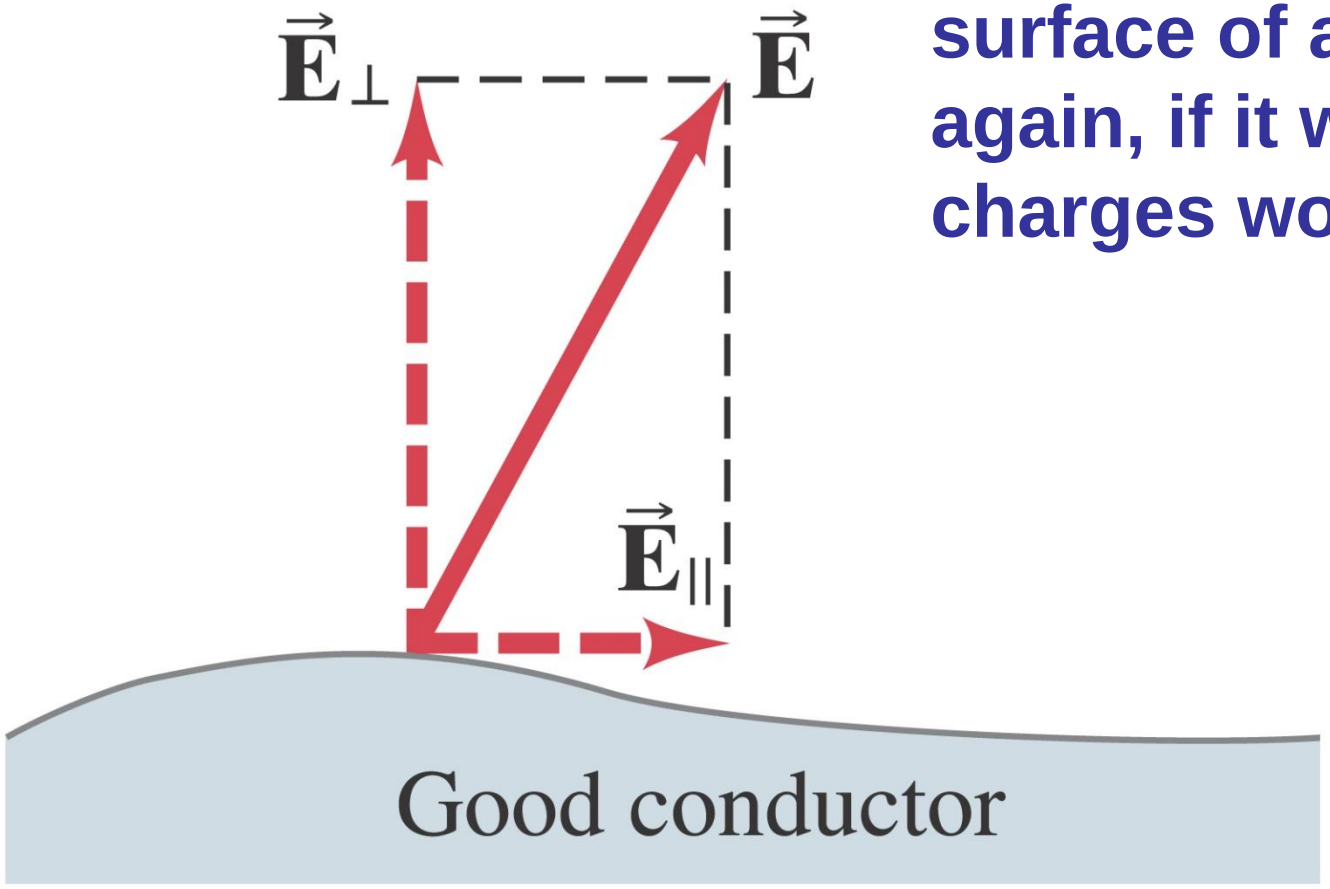
16.9 Electric Fields and Conductors

The static electric field inside a conductor is zero – if it were not, the charges would move.



The net charge on a conductor is on its surface.

16.9 Electric Fields and Conductors



The electric field is perpendicular to the surface of a conductor – again, if it were not, charges would move.