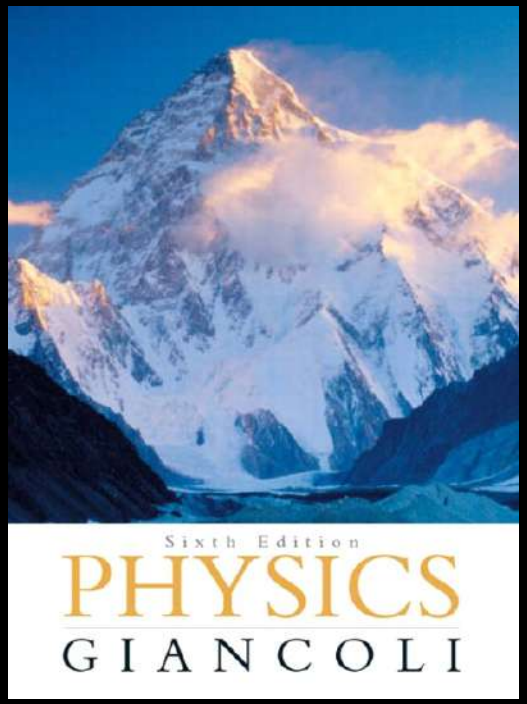


Lecture PowerPoints

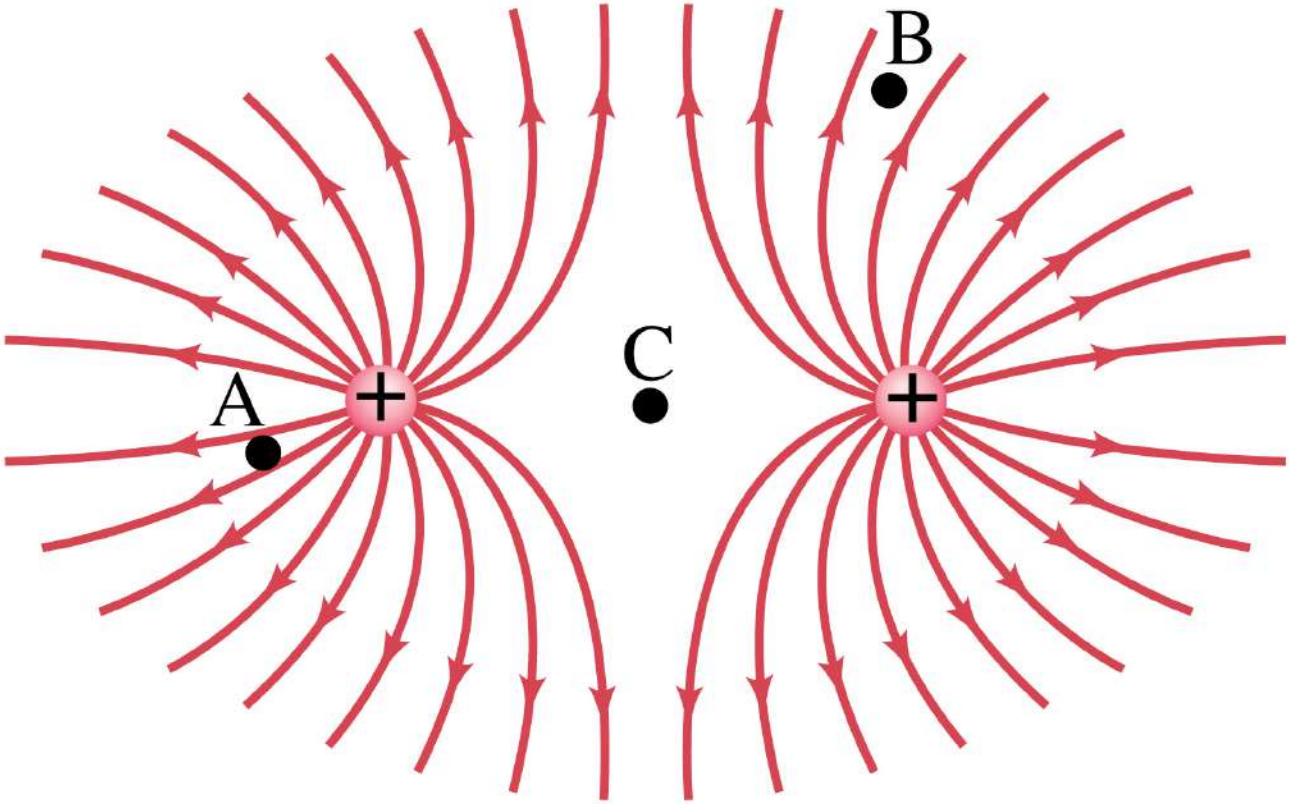
Chapter 16

Physics: Principles with Applications, 6th edition

Giancoli

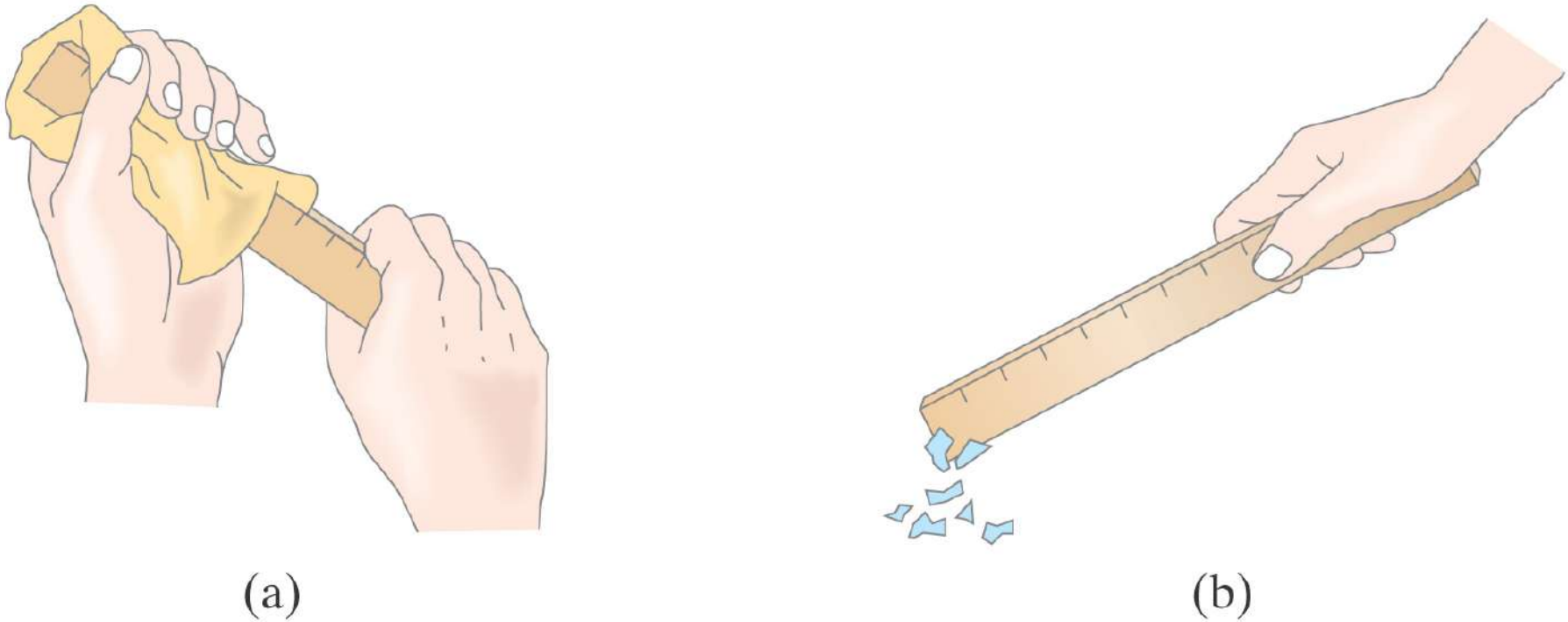
Chapter 16

Electric Charge and Electric Field

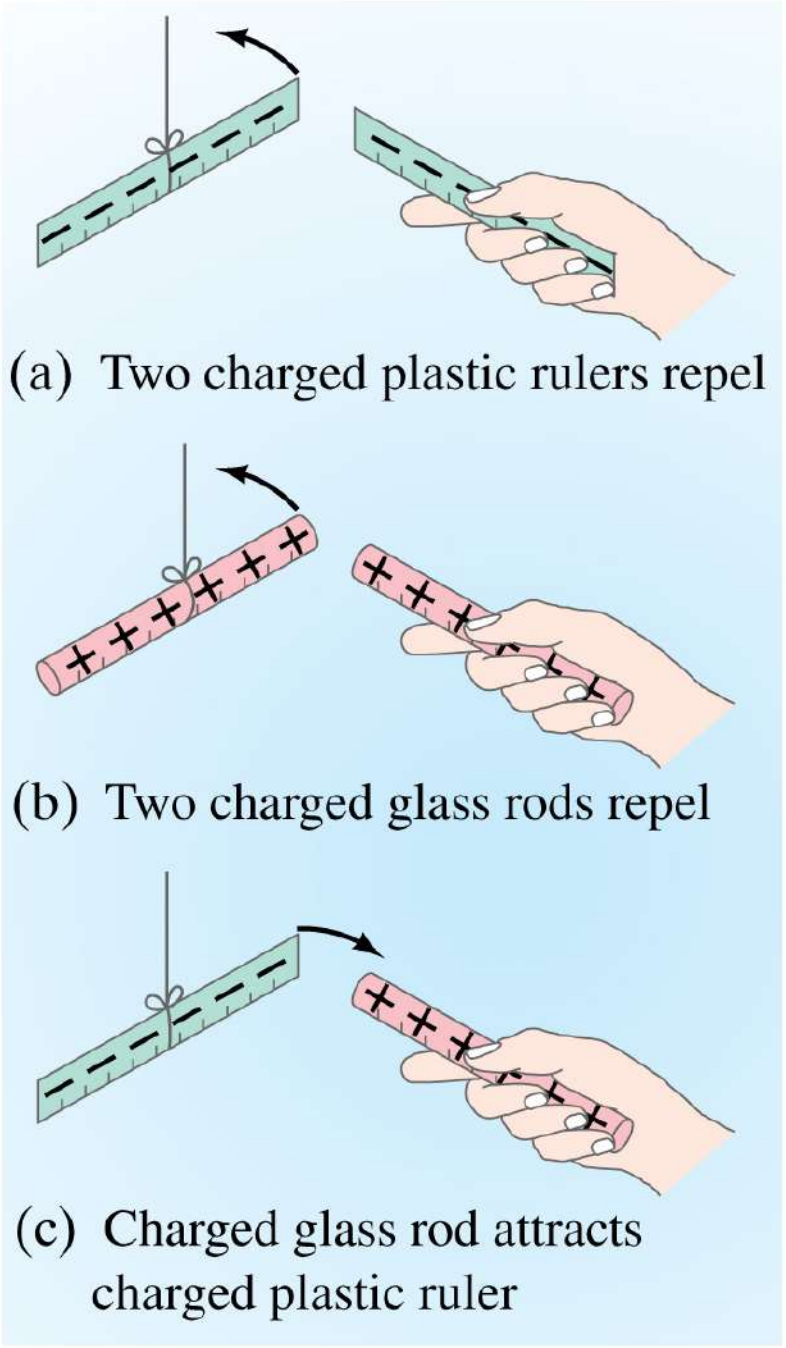


16.1 Static Electricity; Electric Charge and Its Conservation

Objects can be charged by rubbing



(a) (b)



16.1 Static Electricity; Electric Charge and Its Conservation

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

16.1 Static Electricity; Electric Charge and Its Conservation

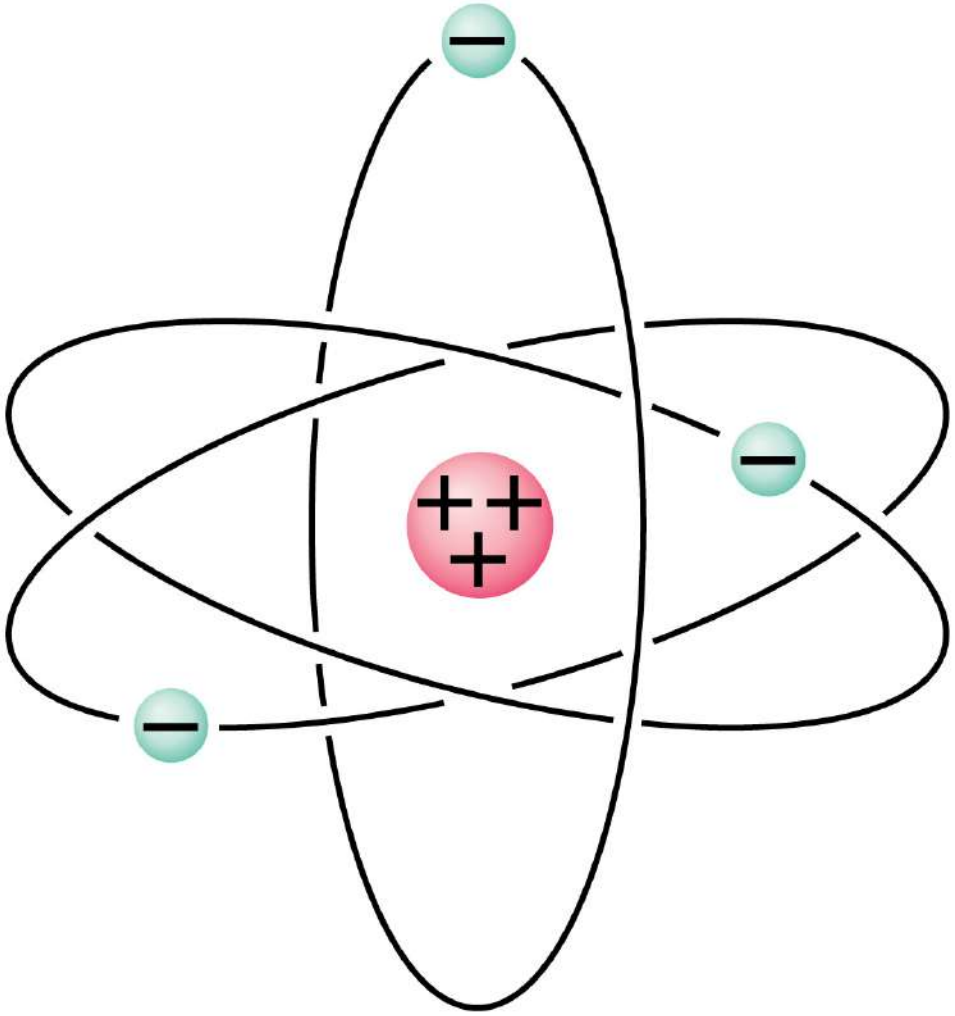
Electric charge is conserved – the arithmetic sum of the total charge cannot change in any interaction.

16.2 Electric Charge in the Atom

Atom:

Nucleus (small, massive, positive charge)

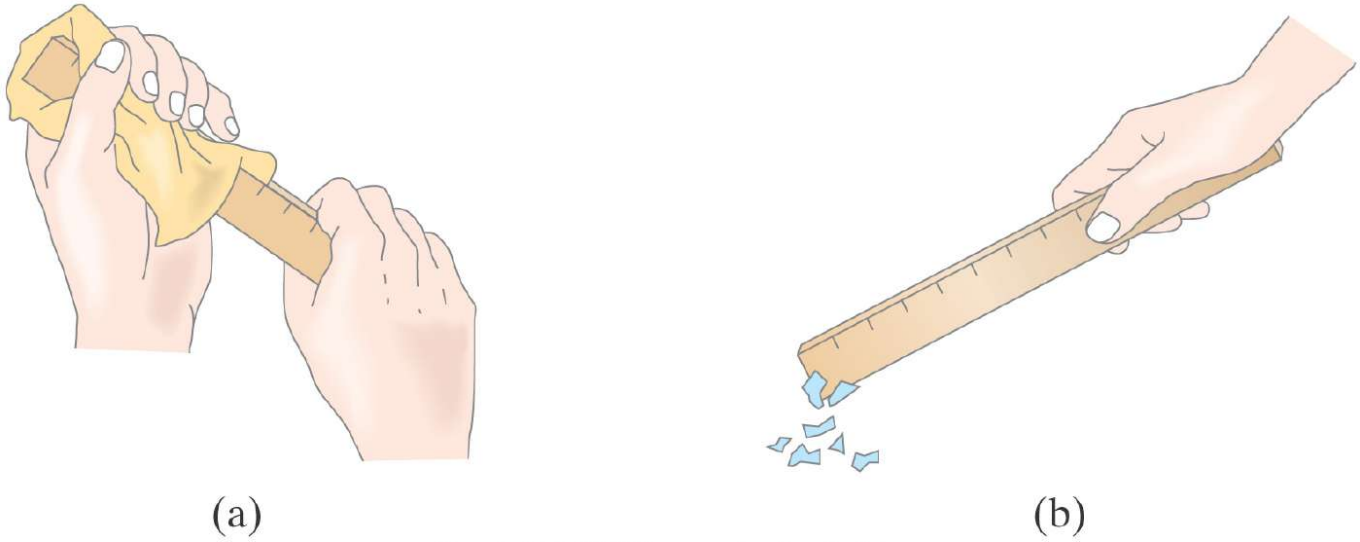
Electron cloud (large, very low density, negative charge)



16.2 Electric Charge in the Atom

Atom is electrically neutral.

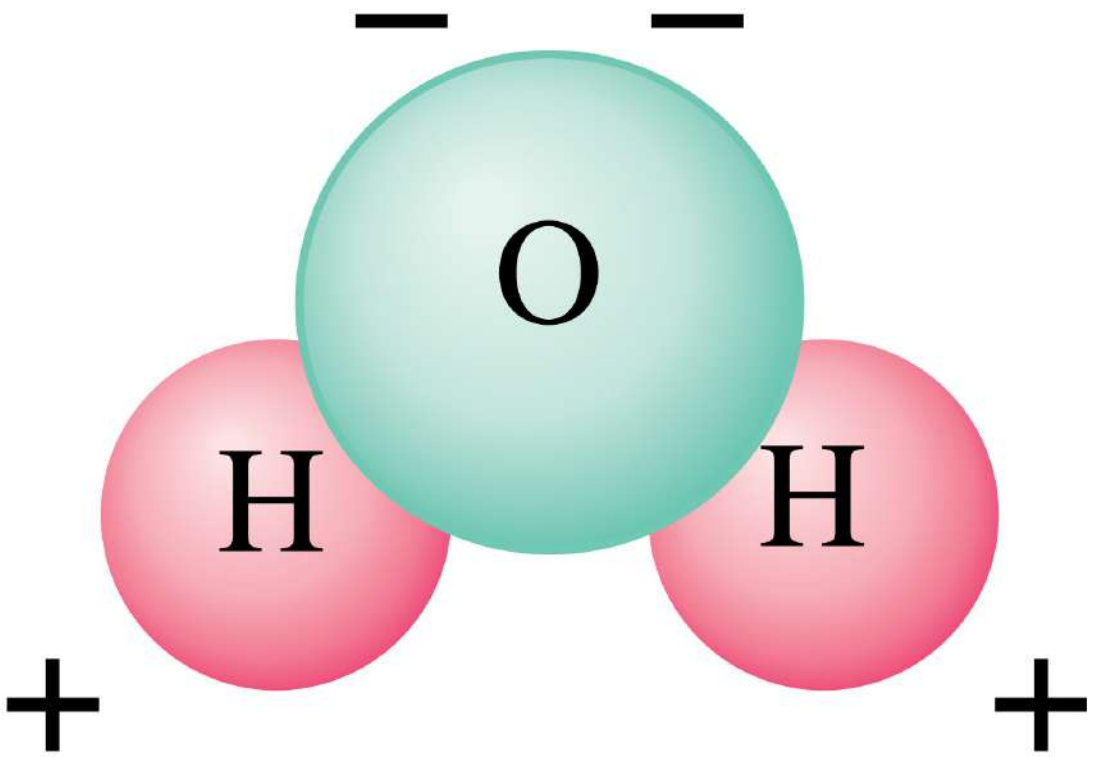
Rubbing charges objects by moving electrons from one to the other.



(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

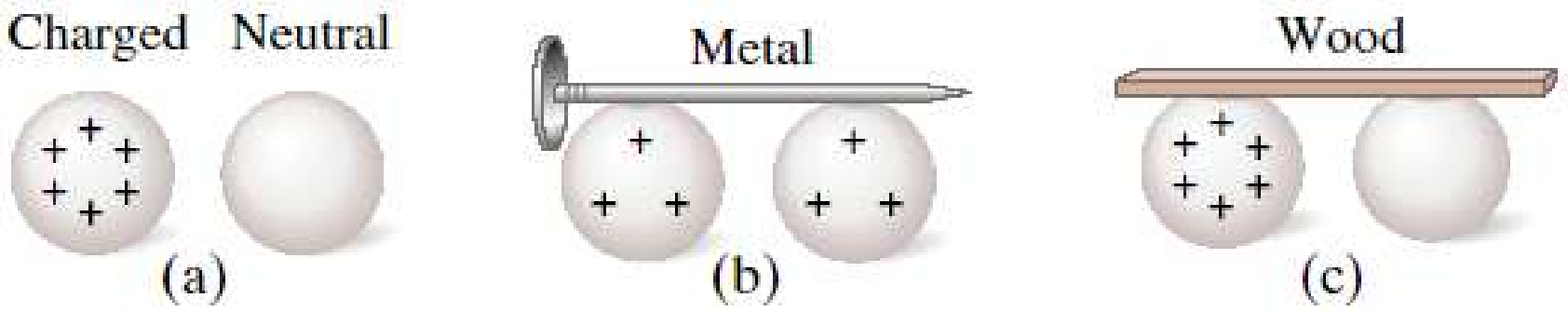
Metals

Insulator:

Almost no charge flows

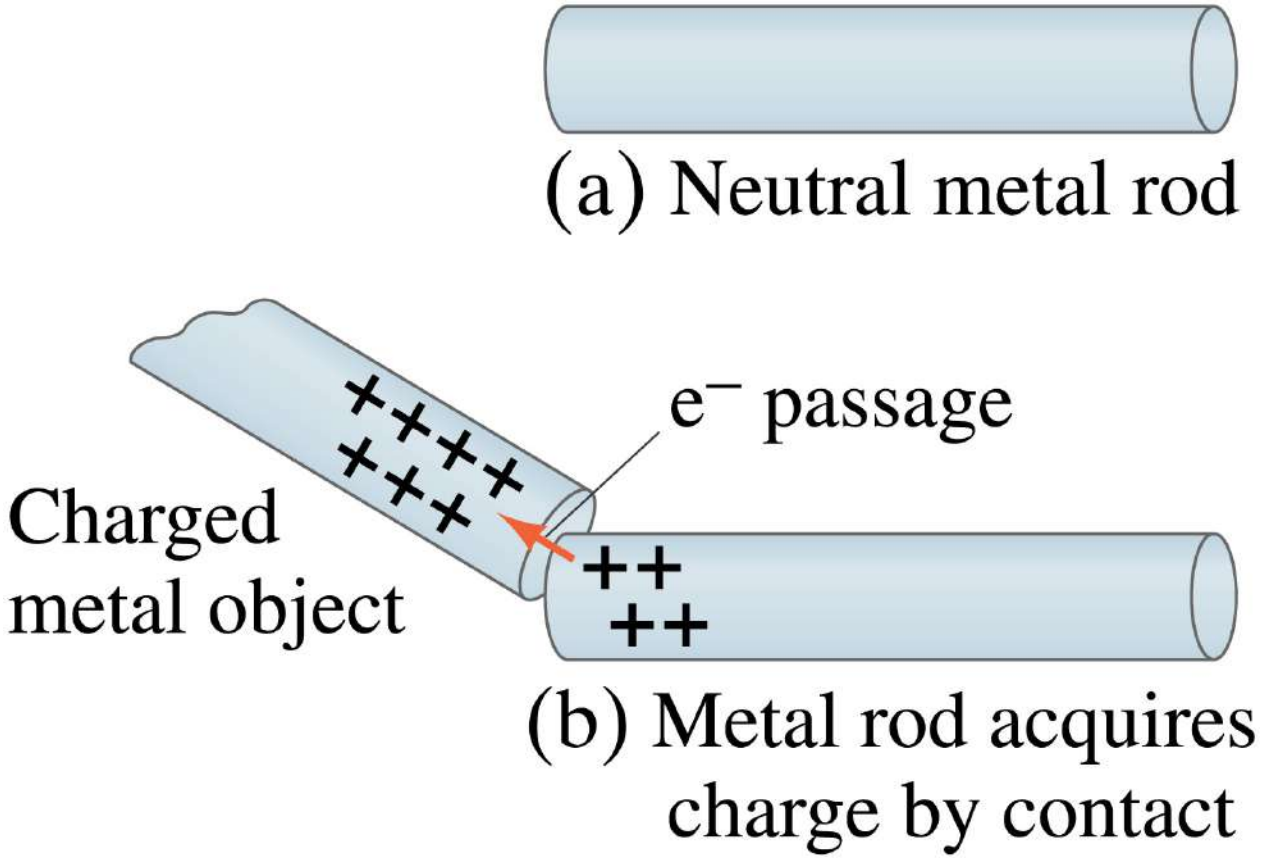
Most other materials

Some materials are semiconductors.



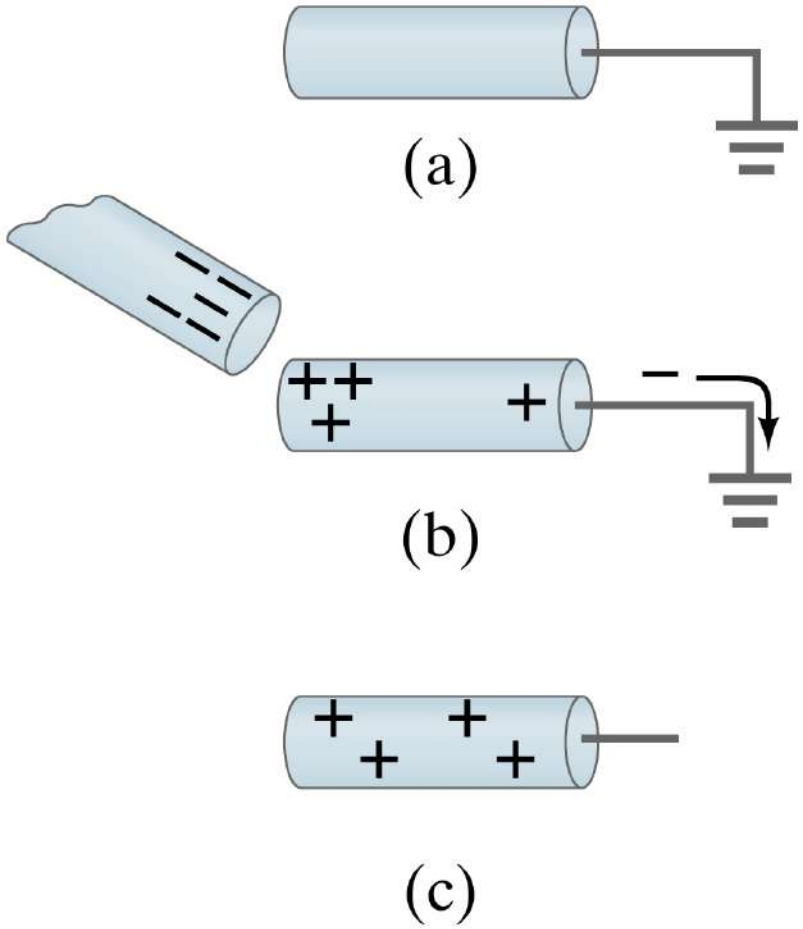
16.4 Induced Charge; the Electroscope

Metal objects can be charged by conduction:



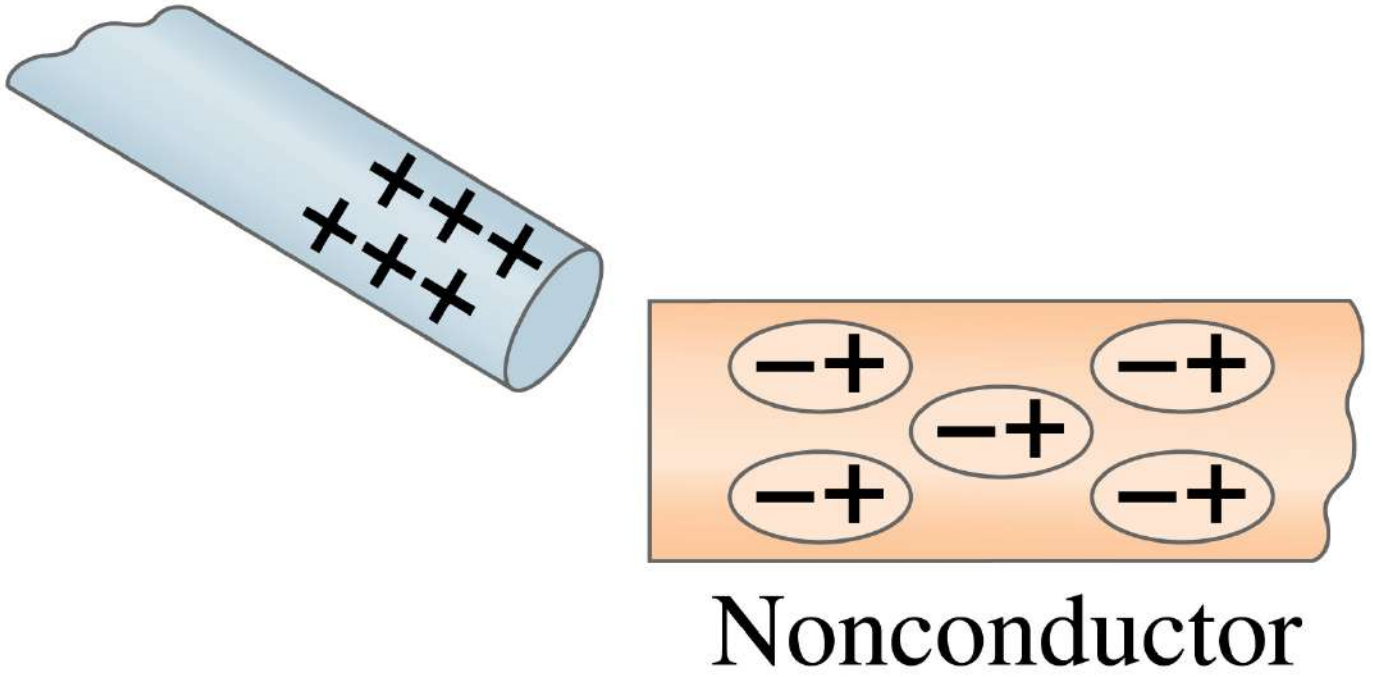
16.4 Induced Charge; the Electroscope

They can also be charged by induction:



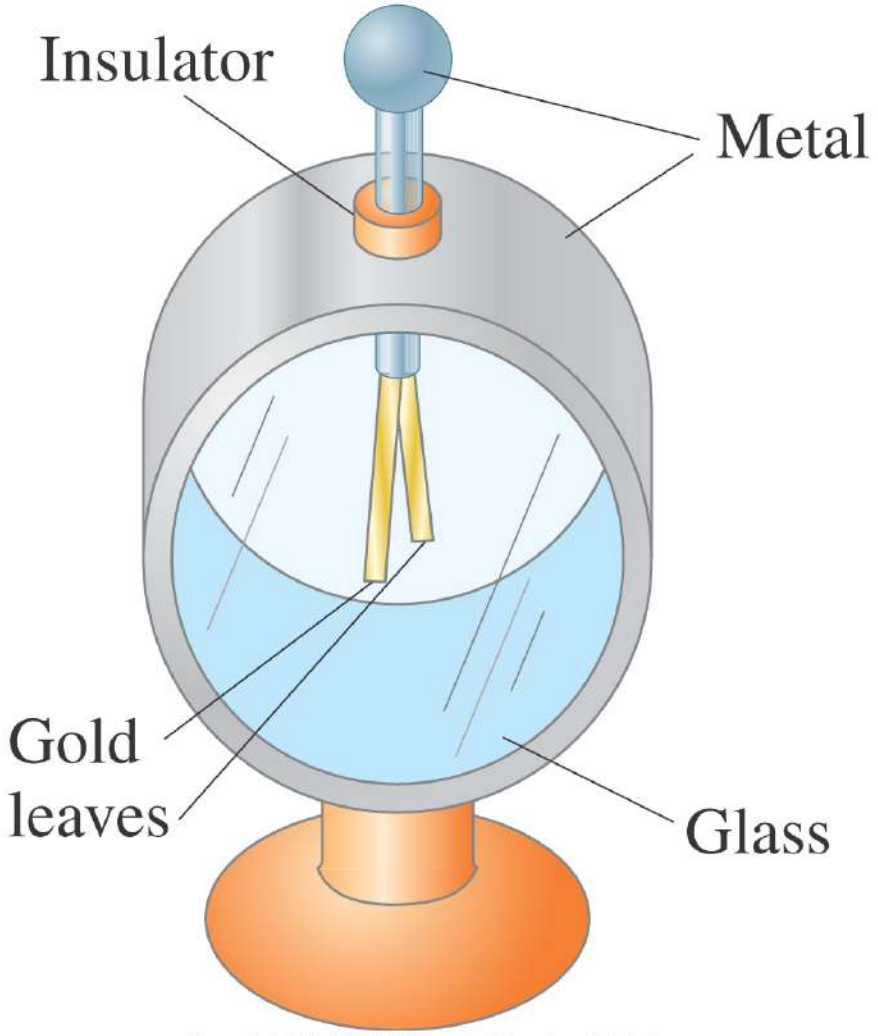
16.4 Induced Charge; the Electroscope

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



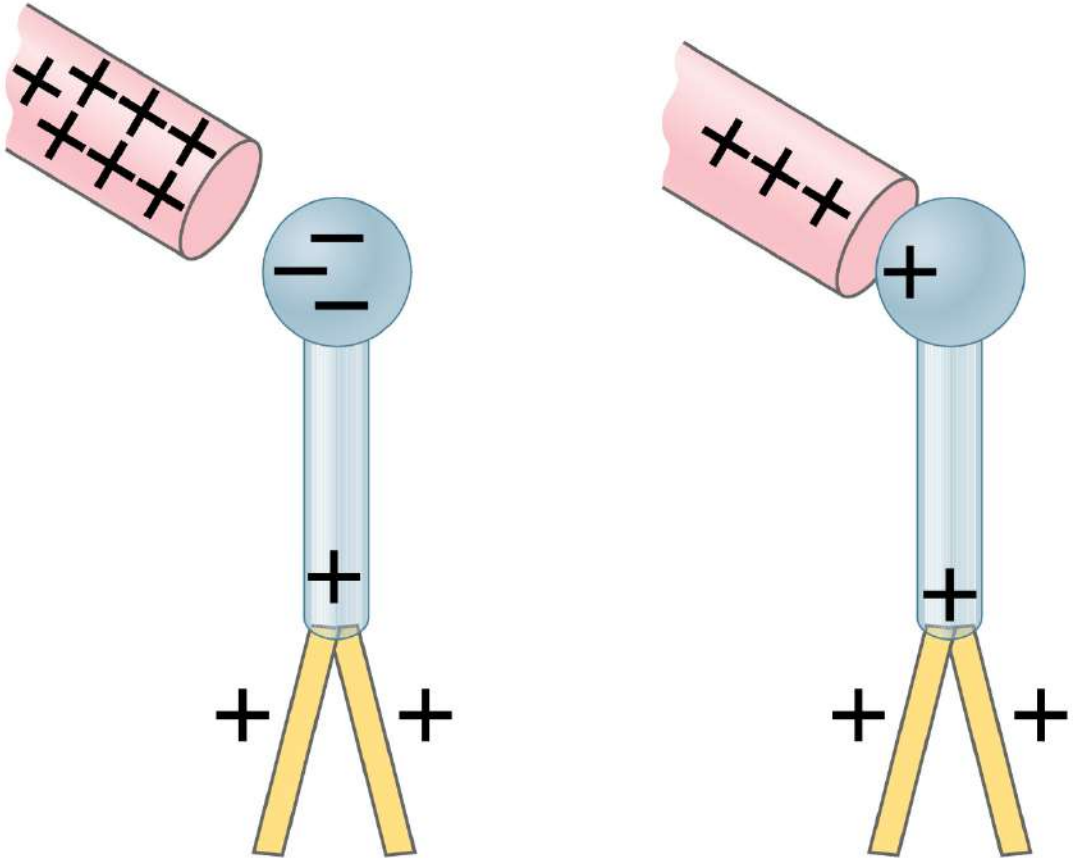
16.4 Induced Charge; the Electroscope

The electroscope can be used for detecting charge:



16.4 Induced Charge; the Electroscope

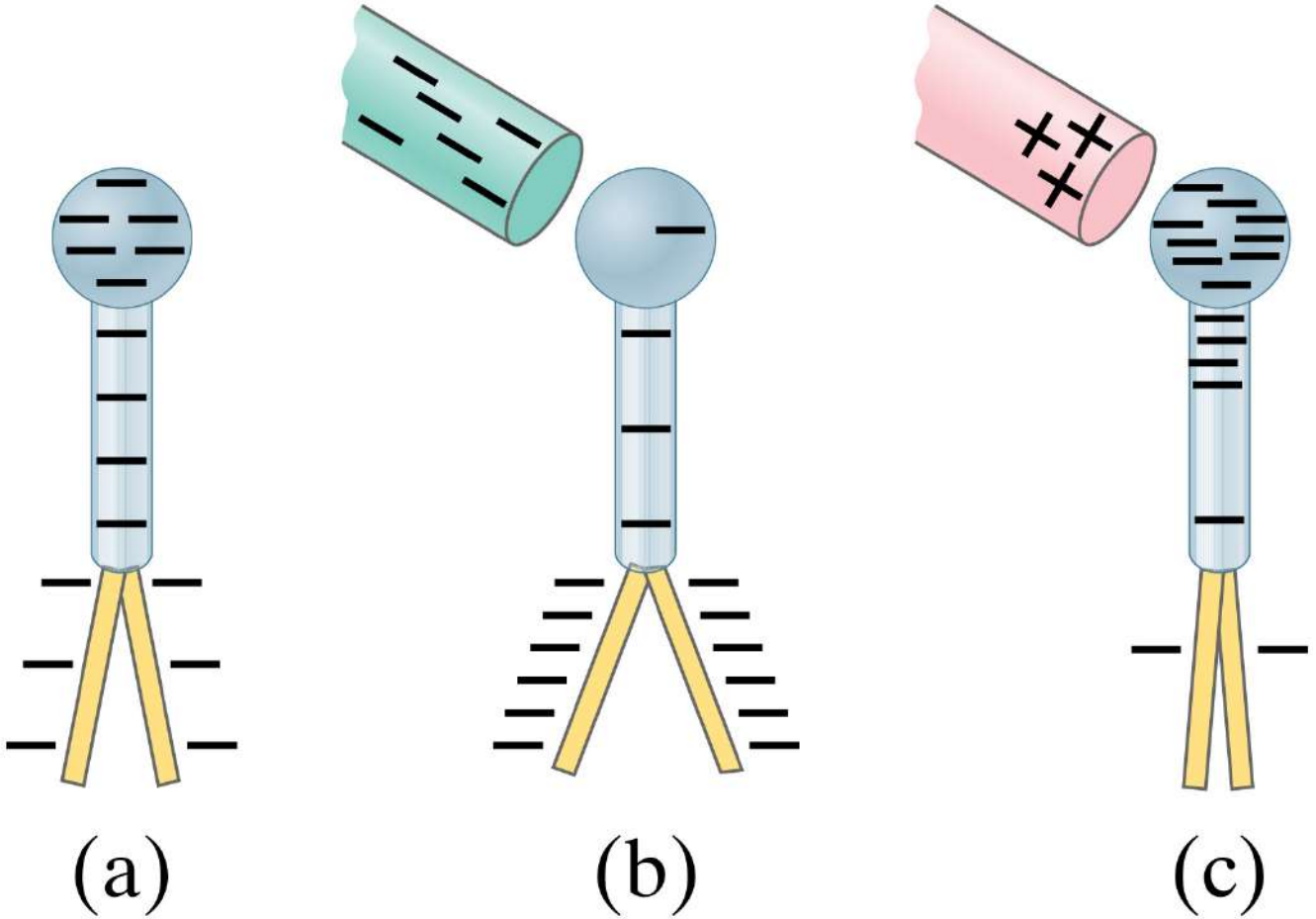
The electroscope can be charged either by conduction or by induction



(a) (b)

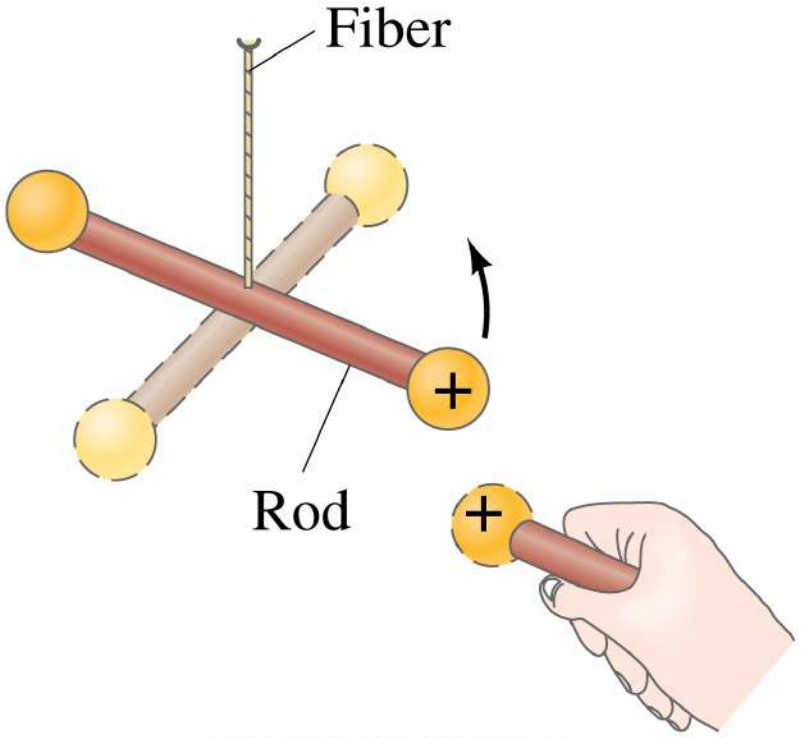
16.4 Induced Charge; the Electroscope

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



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:

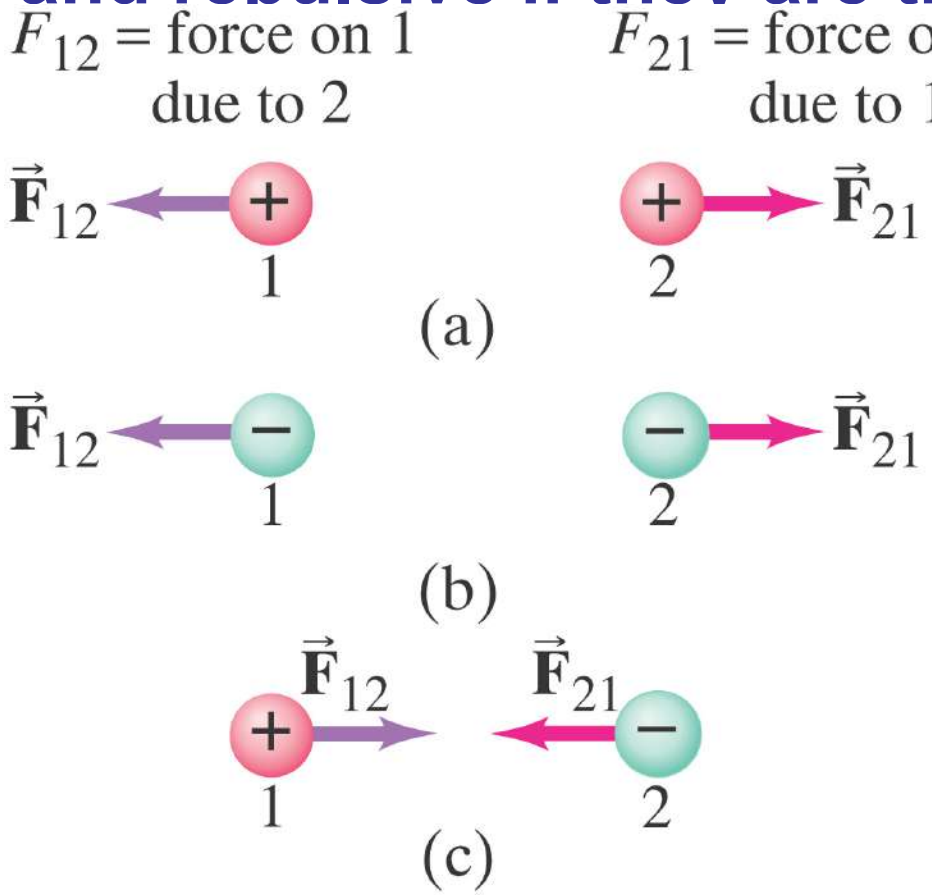
$$F = k\frac{Q_1 Q_2}{r^2} \qquad \textbf{(16-1)}$$

(compare this equation with the one on the formula sheet)

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

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:

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

(This is also the charge on a proton)

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:

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

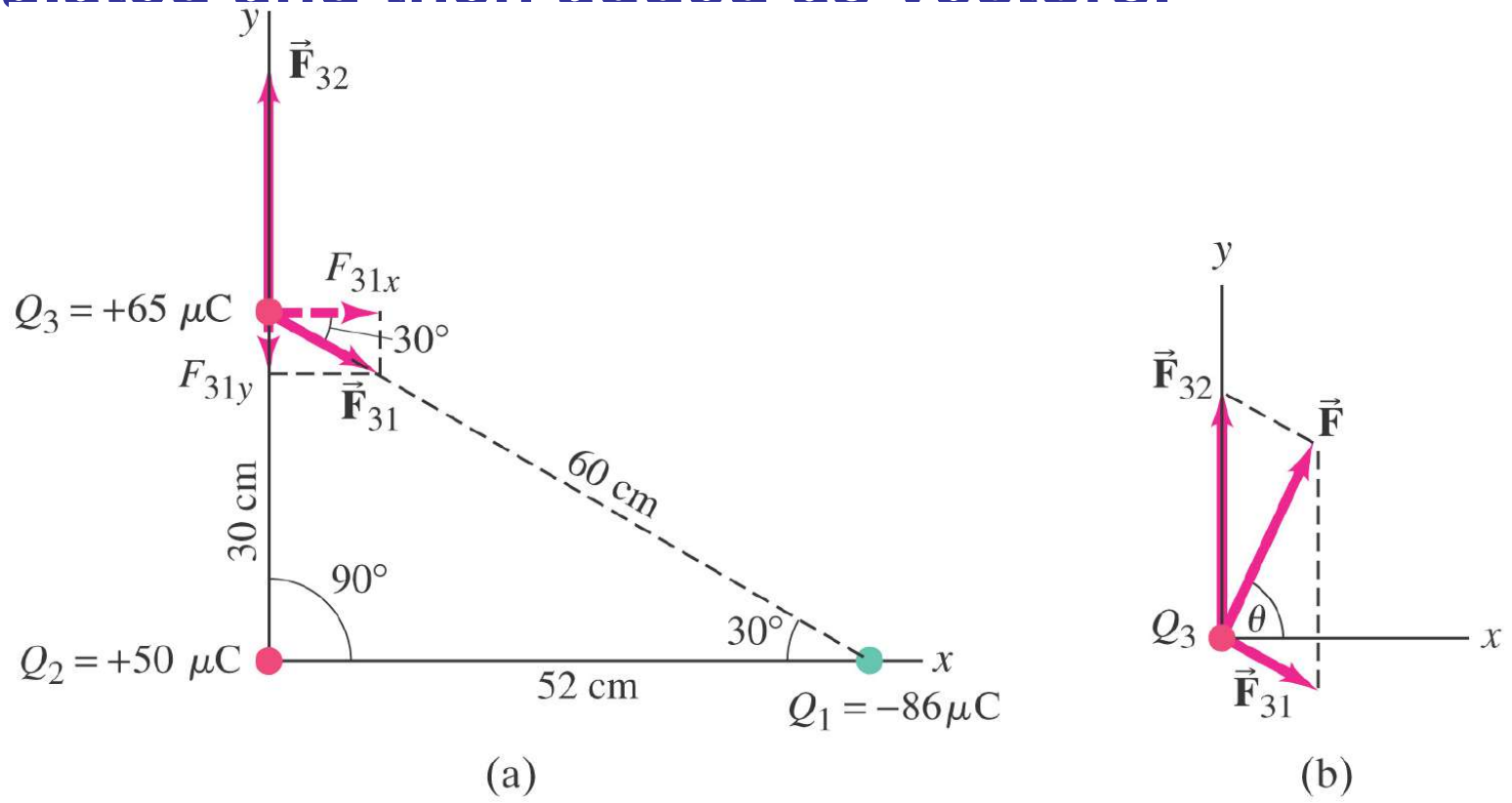
(on formula sheet)

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

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.

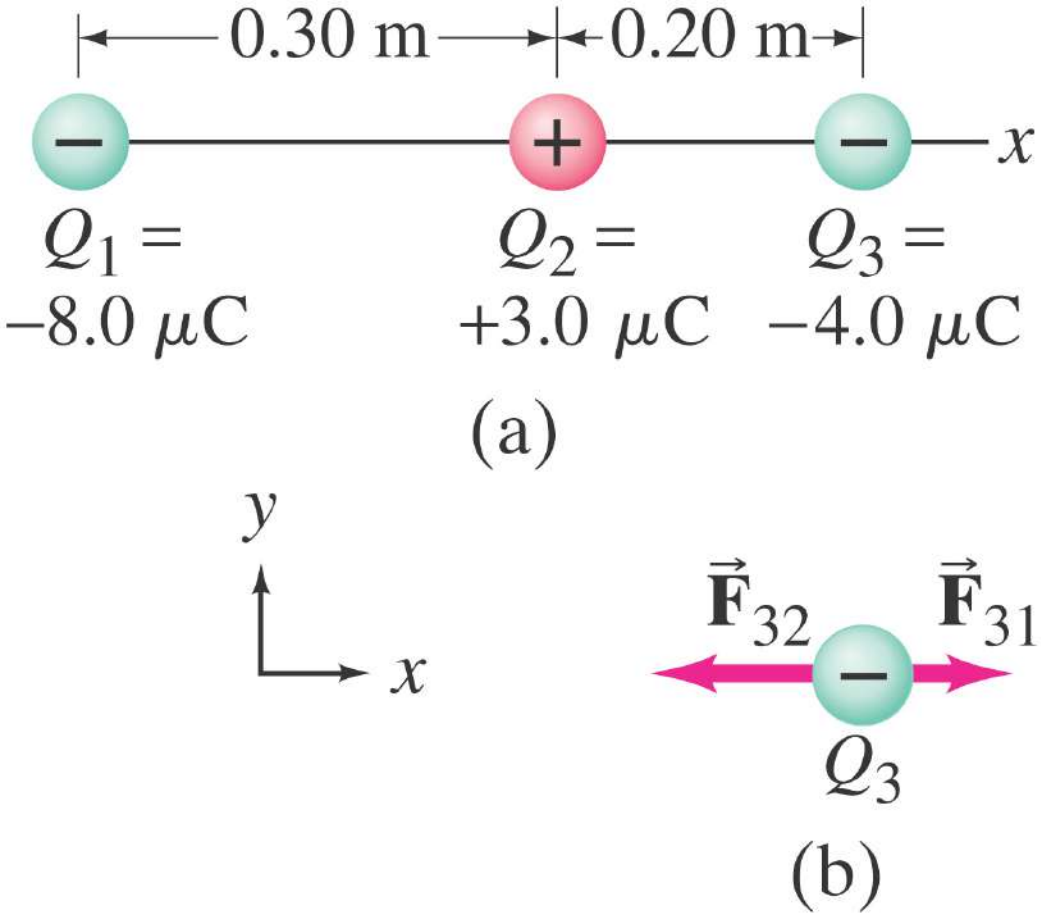


16.6 Solving Problems Involving Coulomb's Law and Vectors

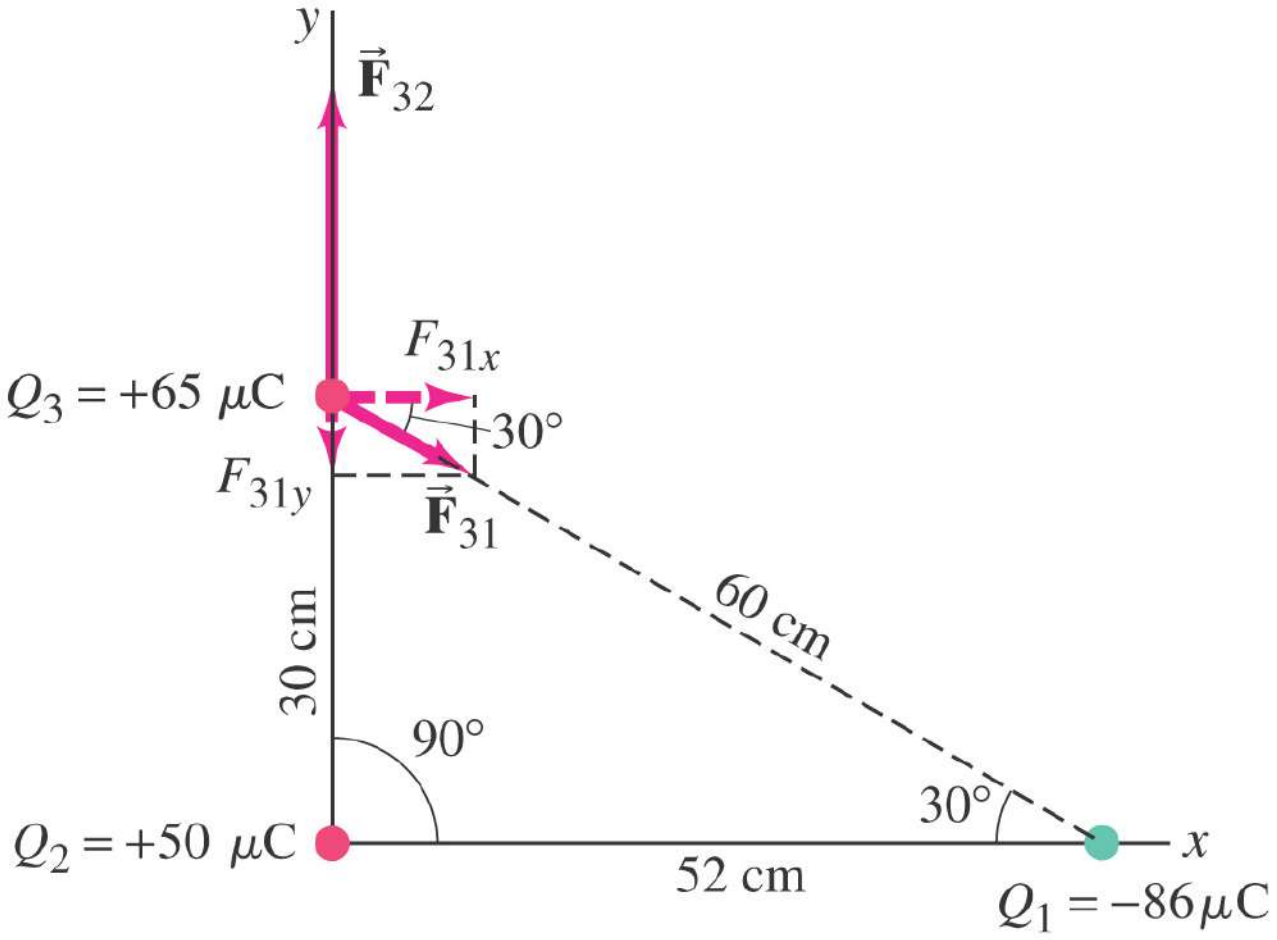
The net force on a charge is the vector sum of all the forces acting on it.

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

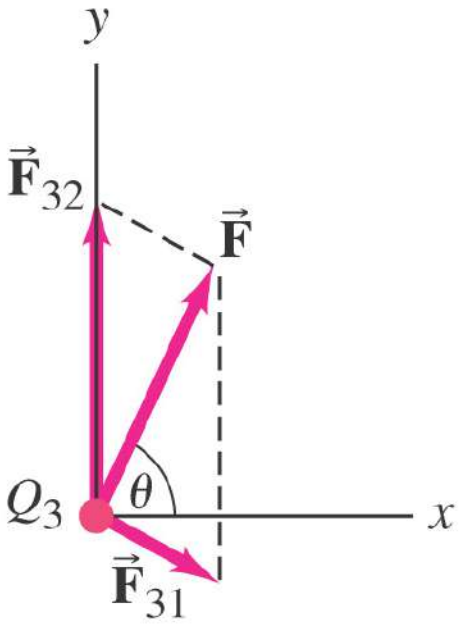
Calculate F_{net} on Q_3



Calculate F_{net} on Q_3



(a)



(b)

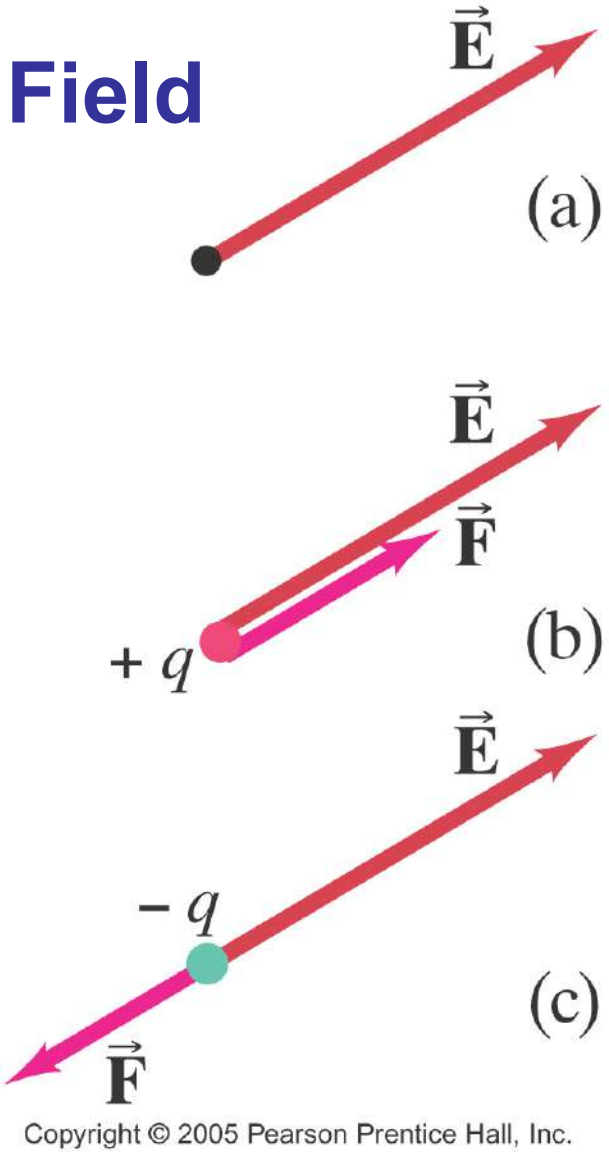
16.7 The Electric Field

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

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

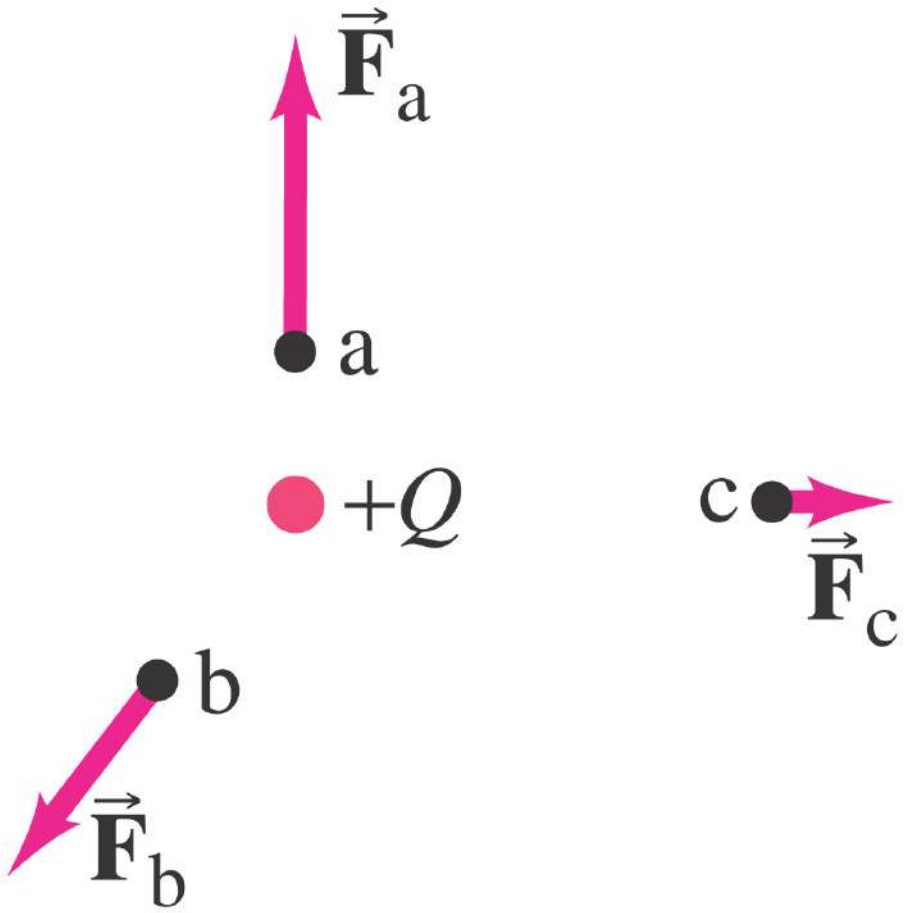
(on formula sheet)

Units are N/C



If q is positive, F and E will point in the same direction. If q is negative, F and E will point in opposite directions.

Force exerted by charge +*Q* on a small test charge, *q*, placed at points a, b, and c. What would be different if the charge was –*Q*?



16.7 The Electric Field

For a point charge:

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

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

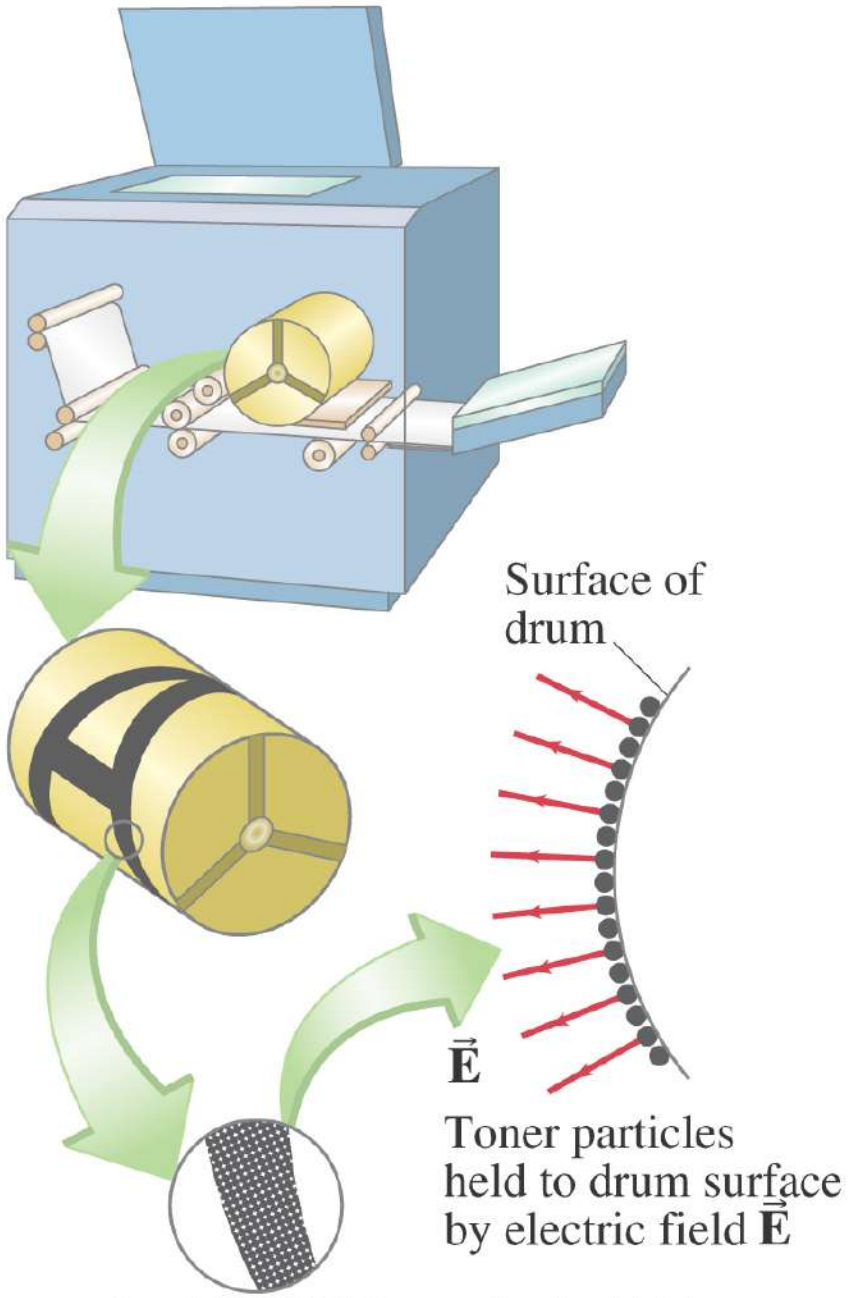
16.7 The Electric Field

Force on a point charge in an electric field:

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

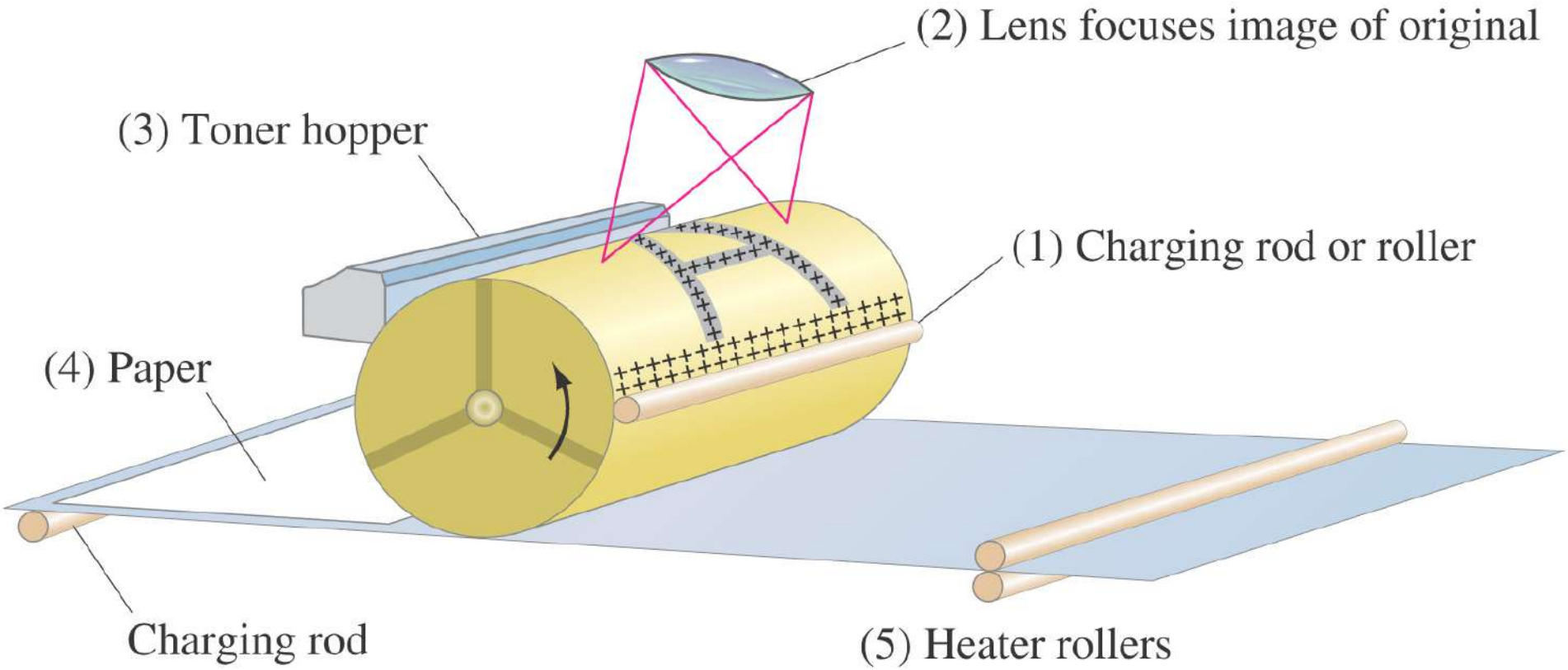
Superposition principle for electric fields:

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



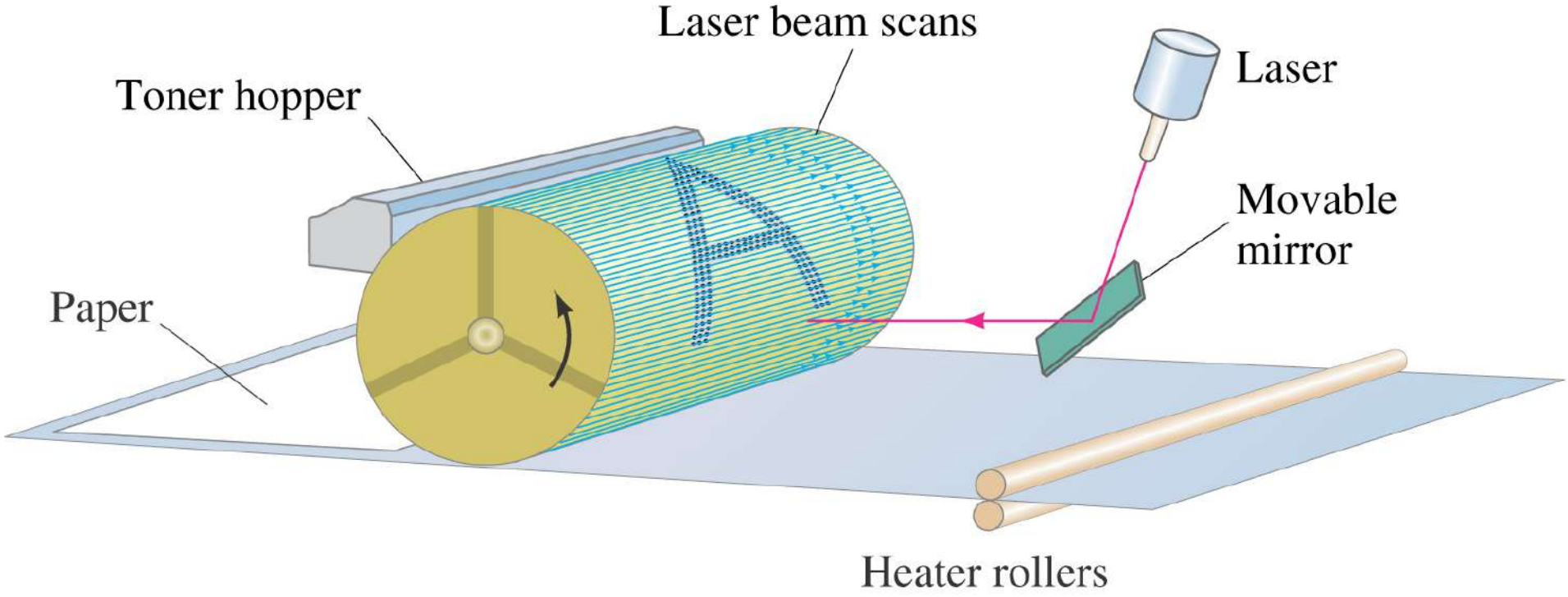
A copier works by arranging positive charges in a pattern on the surface of a drum. The negative toner particles stick to the pattern on the drum and are later transferred to paper and melted to produce the copy.

Photocopy Machines and Computer Printers Use Electrostatics

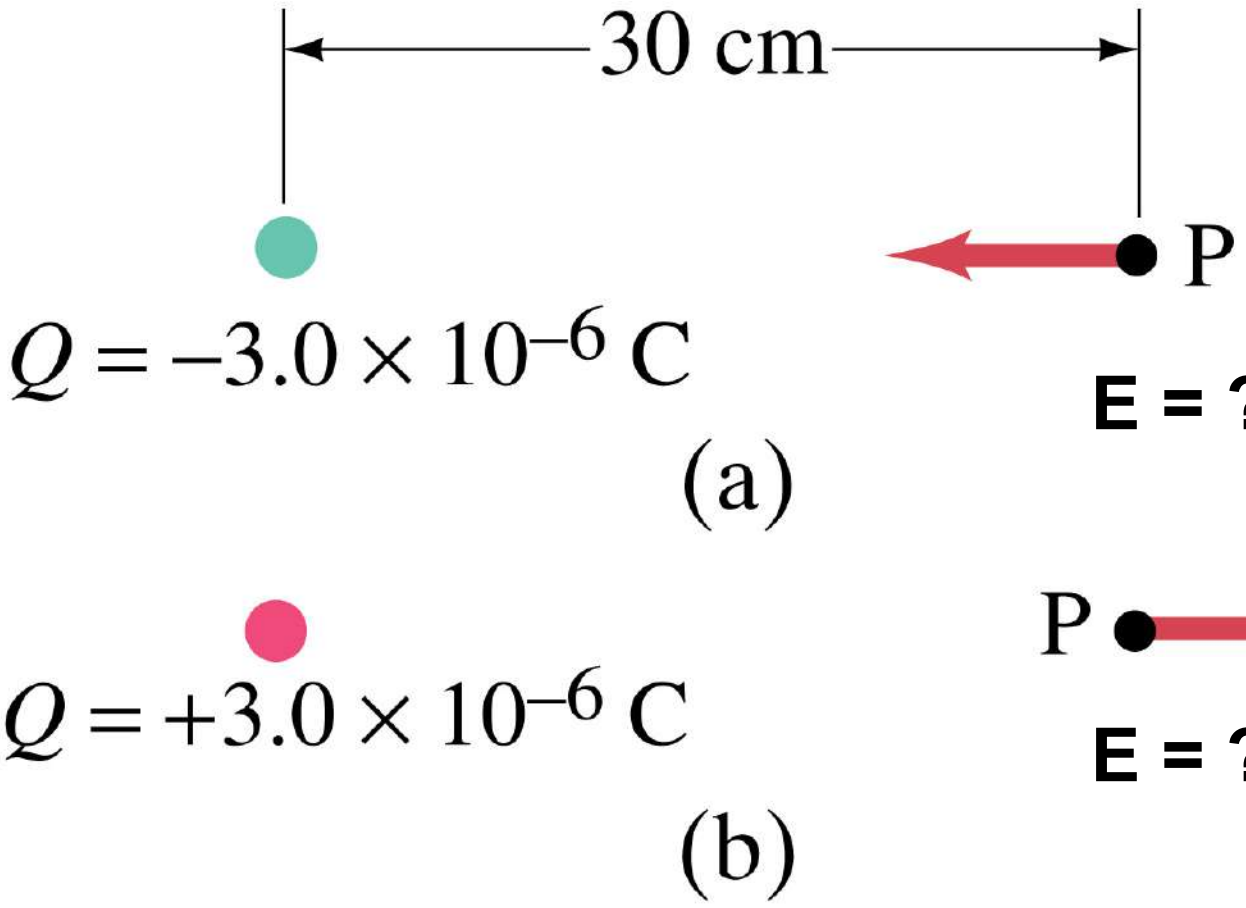


Photocopy Machines and Computer Printers Use Electrostatics

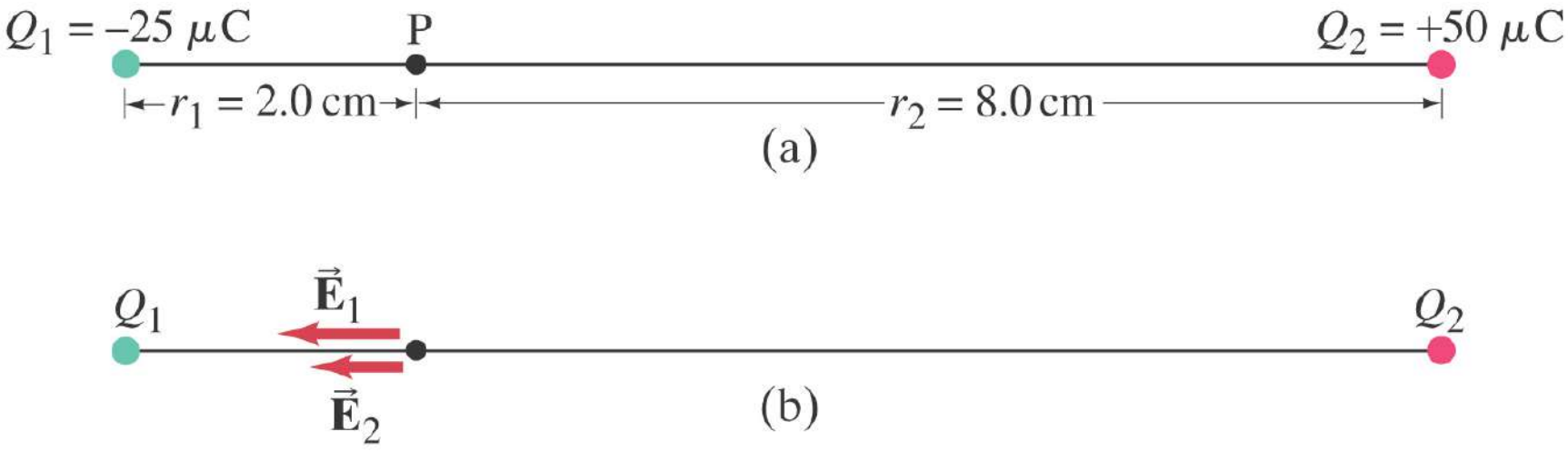
Laser printer is similar, except a computer controls the laser intensity to form the image on the drum



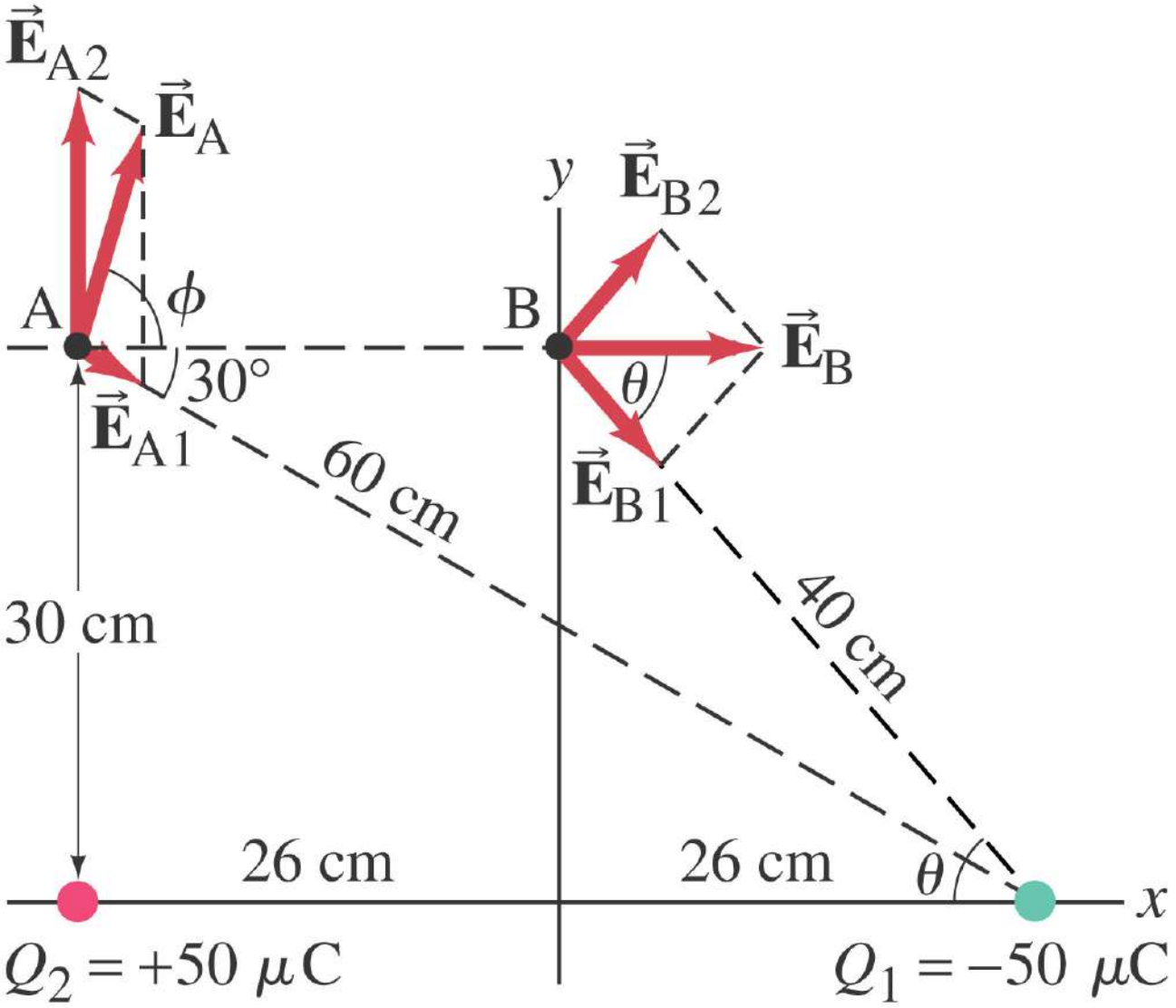
Calculate the magnitude and direction of the electric field at point P.



Determine the direction and magnitude of the electric field at point P. If an electron is placed at rest at P and then released, what will be its initial acceleration?

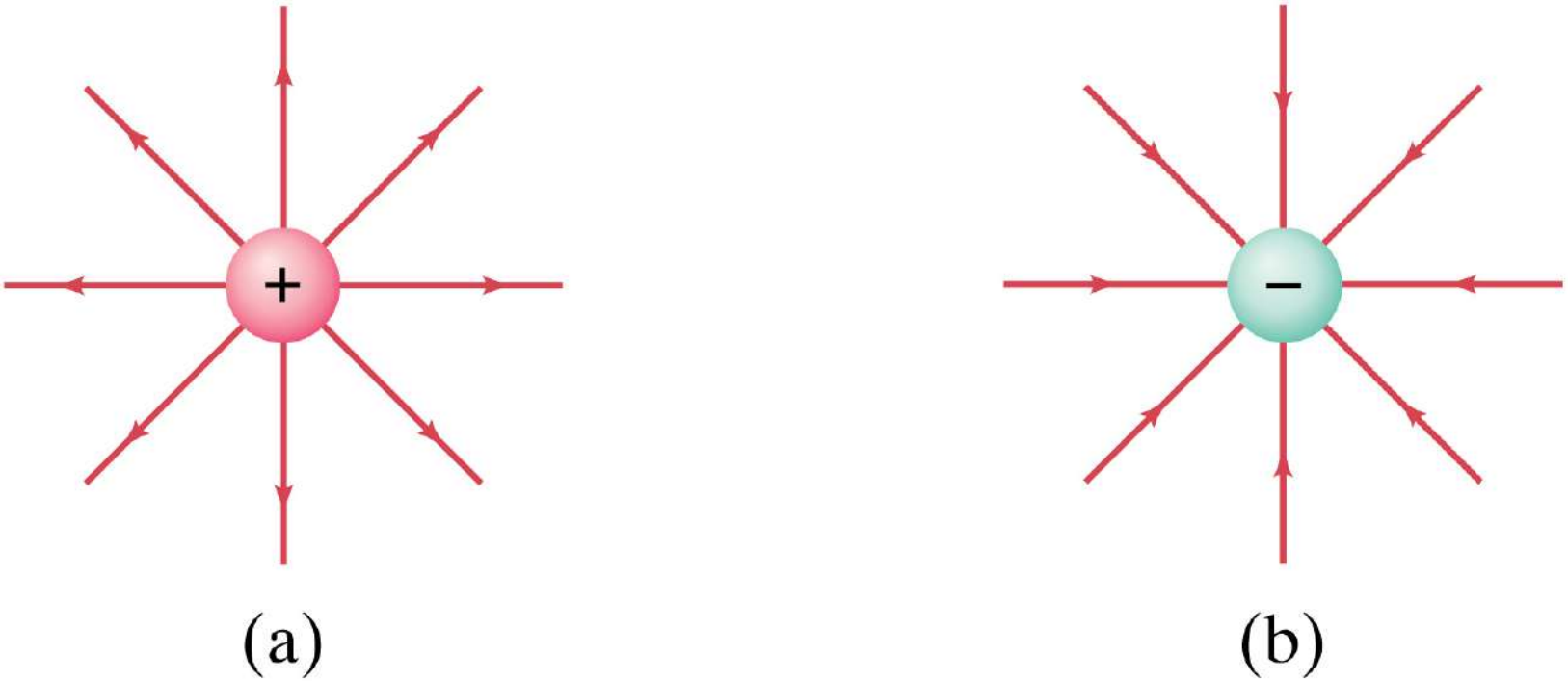


Calculate the electric field at points A and B.



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.



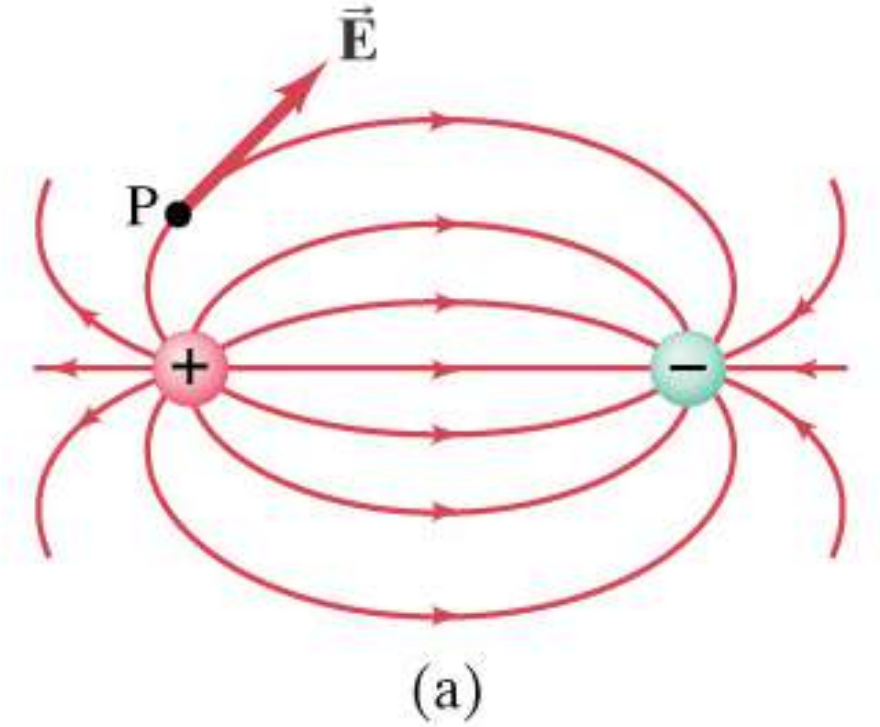
16.8 Field Lines

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.

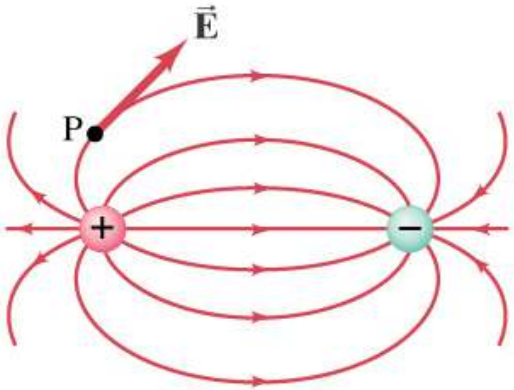
16.8 Field Lines

Electric dipole: two equal charges, opposite in sign:

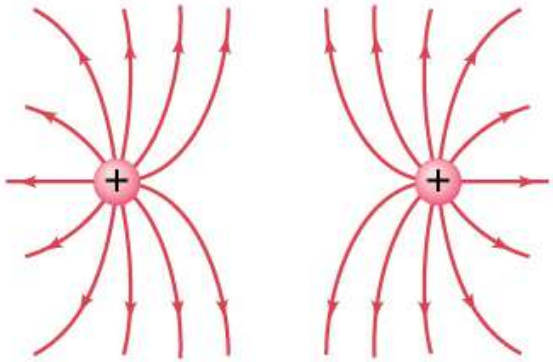


(a)

Electric field lines for four arrangements of charges.



(a)



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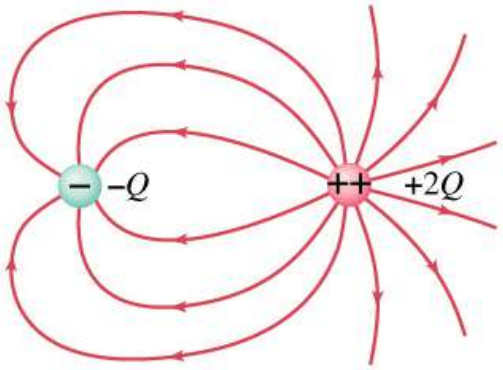
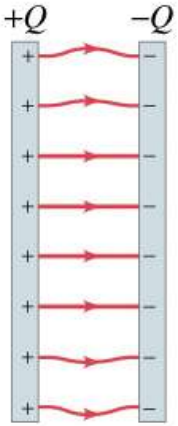
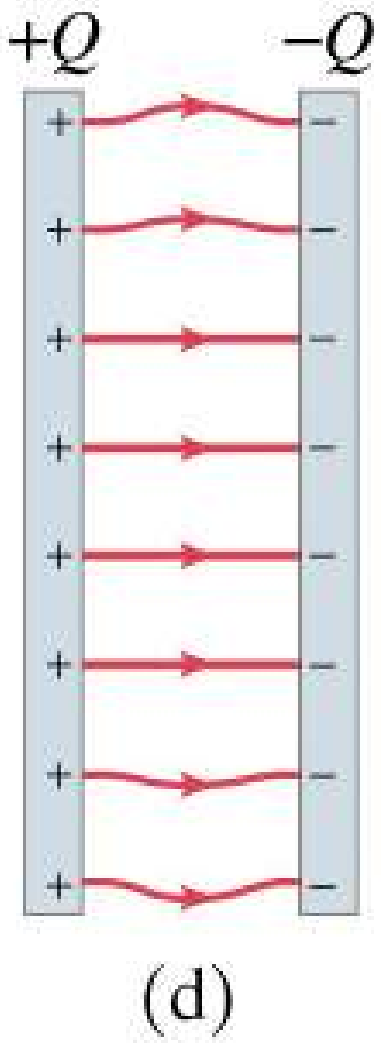


(c)



(d)

16.8 Field Lines



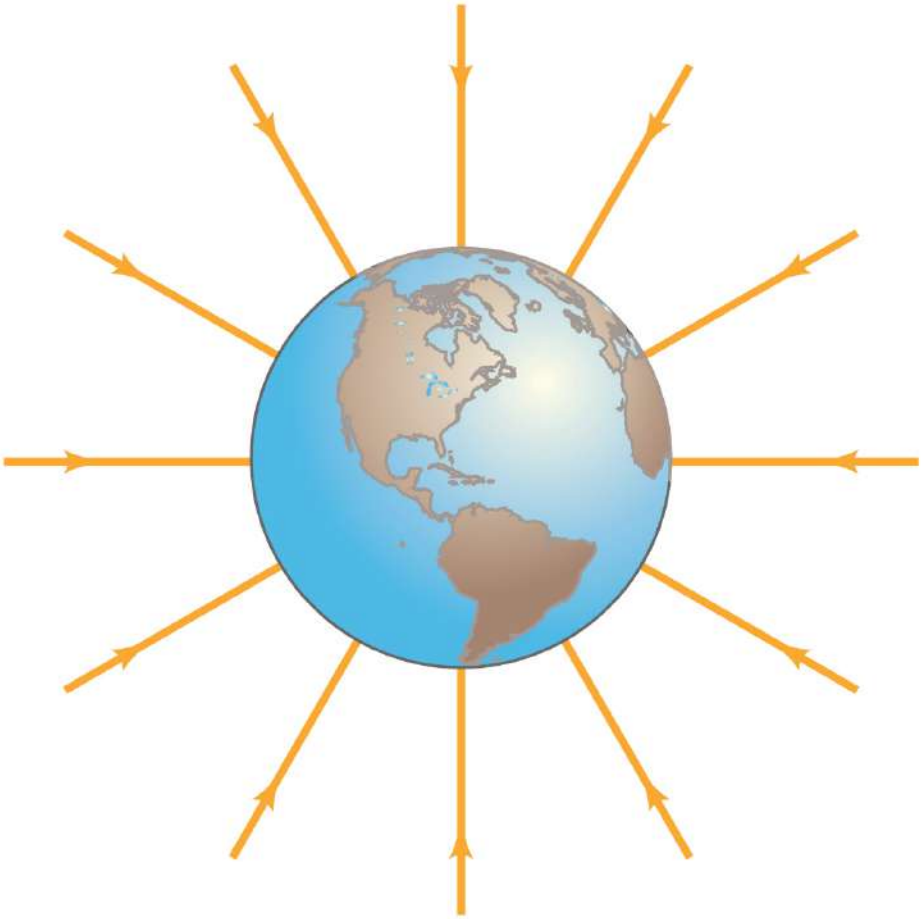
The electric field between two closely spaced, oppositely charged parallel plates is constant.

16.8 Field Lines

Summary of field lines:

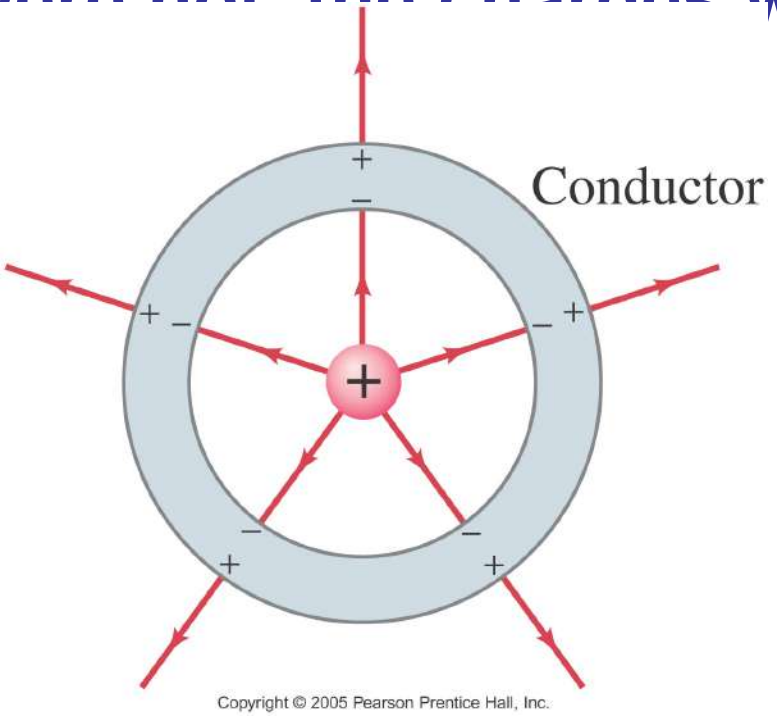
1. **Field lines indicate the direction of the field; the field is tangent to the line.**
2. **The magnitude of the field is proportional to the density of the lines.**
3. **Field lines start on positive charges and end on negative charges; the number is proportional to the magnitude of the charge.**

The Earth's gravitational field



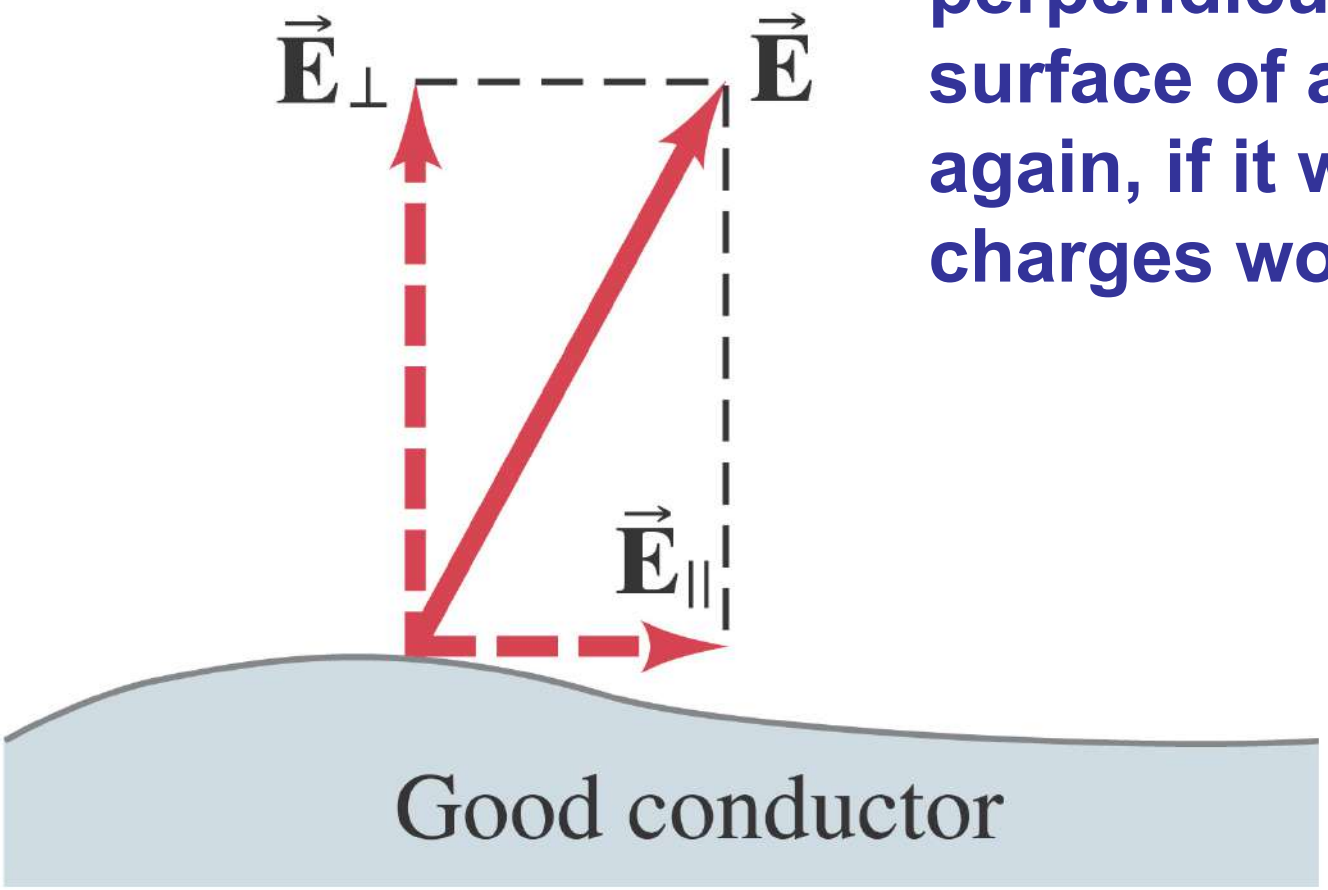
16.9 Electric Fields and Conductors

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



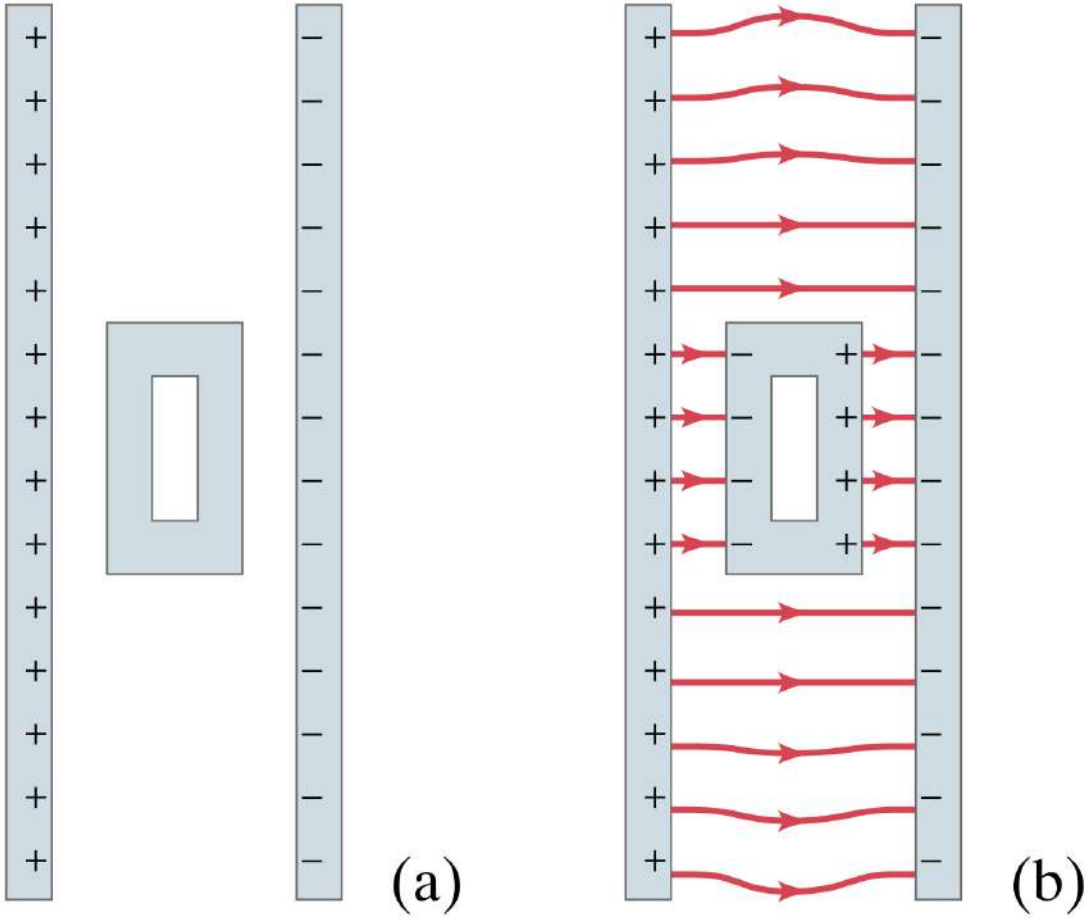
The net charge on a conductor is on its surface.

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.

What is the field like inside the metal box?
This applies to safety in a storm.



Electric Forces in Molecular Biology: DNA Structure and Replication

Replication: DNA is in a "soup" of A, C, G, and T in the cell. During random collisions, A and T will be attracted to each other, as will G and C; other combinations will not.