Chapter 21 Coulomb's Law

Electric Charge

- **Electric charge** is an intrinsic characteristic of the fundamental particles making up objects; that is, it is a property that comes automatically with those particles wherever they exist.

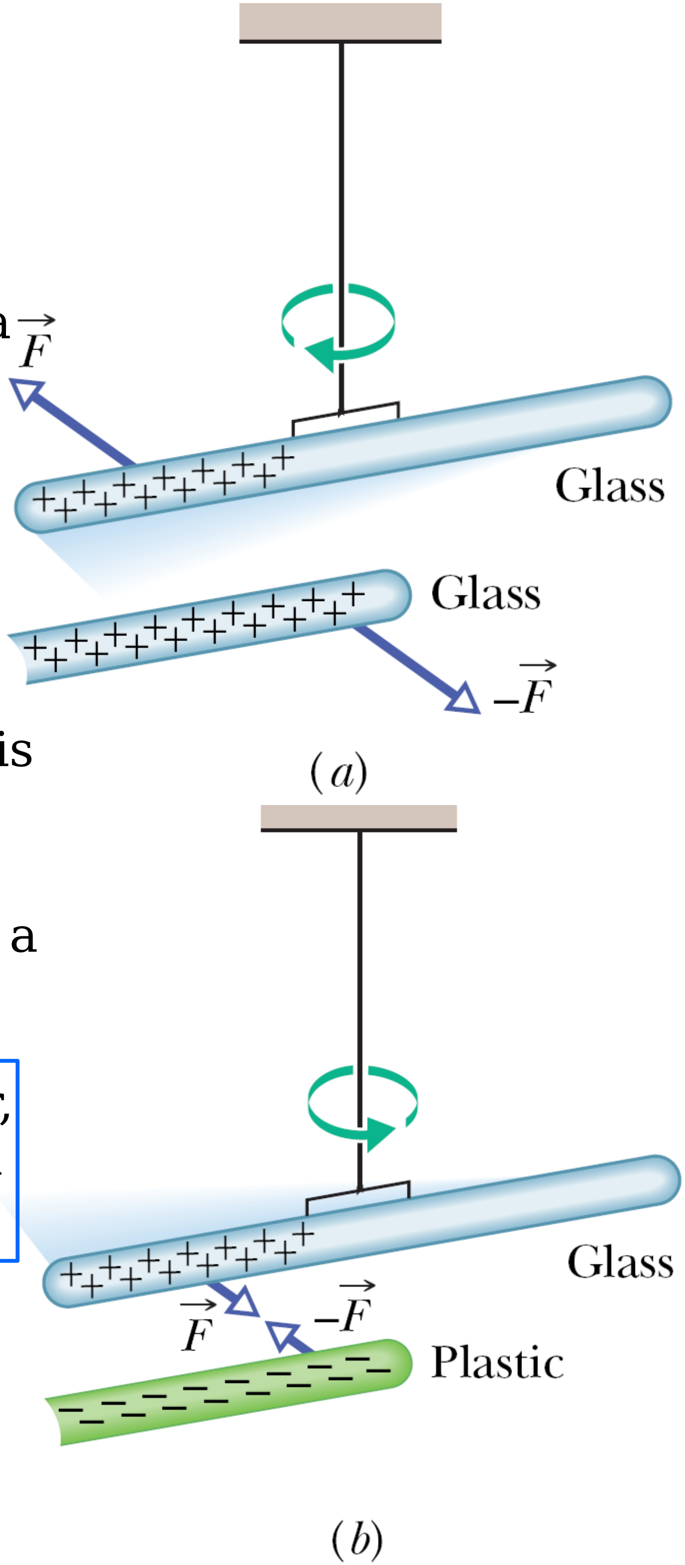
- the 2 kinds of charge: *positive charge* and *negative charge*.

- With an equality – or *balance* – of charge, the object is *electrically neutral*.

- an object is said to be charged to indicate that it has a charge imbalance, or net charge.

Charges with the same electrical sign repel each other, and charges with opposite electrical signs attract each other.

- *electrostatic*: the charges are either stationary or moving only very slowly relative to each other.



Conductors and Insulators

Conductors: materials through which charge can move rather freely;

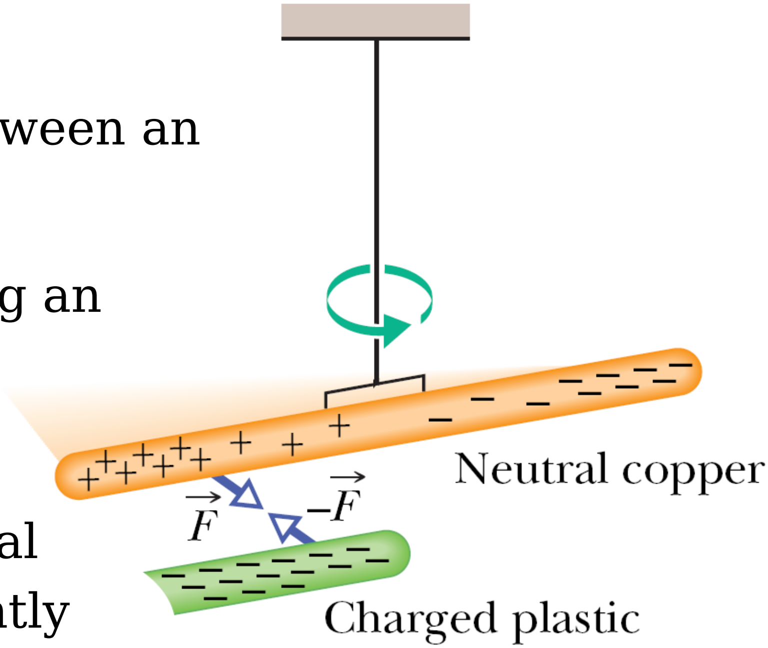
Insulators: materials through which charge cannot move freely;

Semiconductors: materials that are intermediate between conductors and insulators;

Superconductors: materials that are perfect conductors, allowing charge to move without any hindrance.

Ground: In setting up a pathway of conductors between an object and Earth s surface.

Discharge: in neutralizing the object by eliminating an unbalanced positive or negative charge.



- Atoms consist of positively charged *protons*, negatively charged *electrons*, and electrically neutral *neutrons*. The protons and neutrons are packed tightly together in a central *nucleus*.

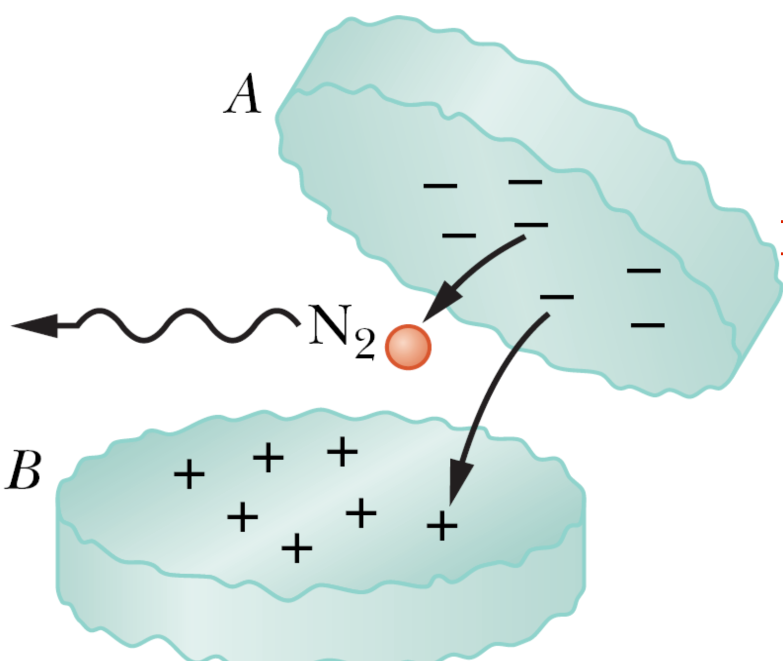
- The charge of a single electron and that of a single proton have the same magnitude but are opposite in sign. An electrically neutral atom contains equal numbers of electrons and protons.

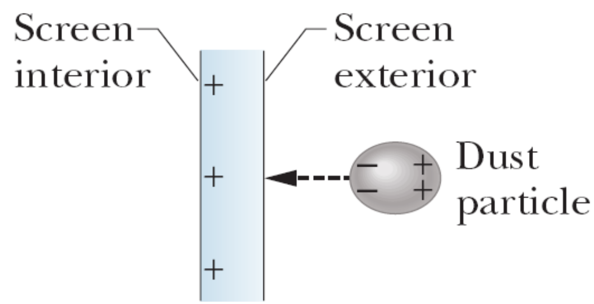
- For atoms of a conductor like copper, some of their outermost (and so most loosely held) electrons become free to wander about within the solid, leaving behind positively charged atoms (*positive ions*). We call the mobile electrons *conduction electrons*. There are few free electrons in a nonconductor.

- *induced charge*: some of the positive and negative charges in a material have been separated due to the presence of a nearby charge.

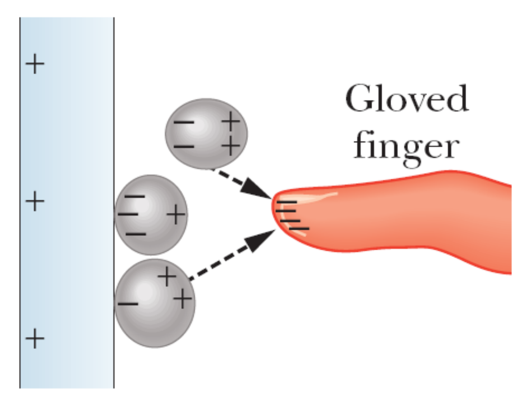
- only conduction electrons, with their negative charges, can move; positive ions are fixed in place. Thus, an object becomes positively charged only through the *removal of negative charges*.

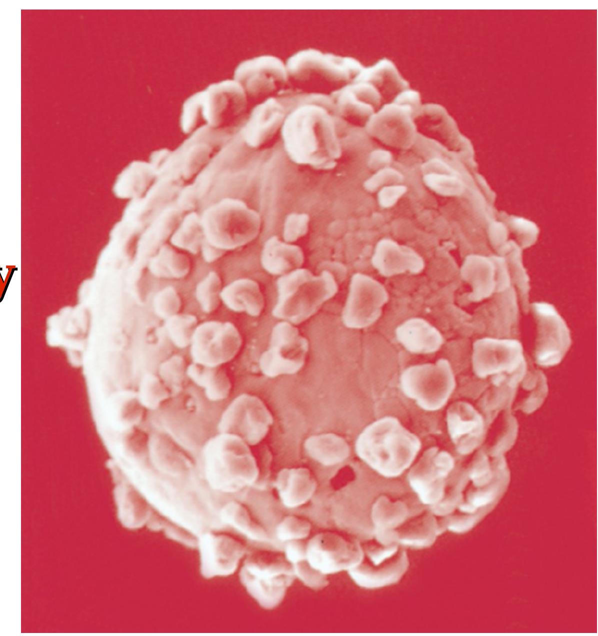
Blue Flashes from a Candy





Bacterial Contamination During Endoscopic Surgery

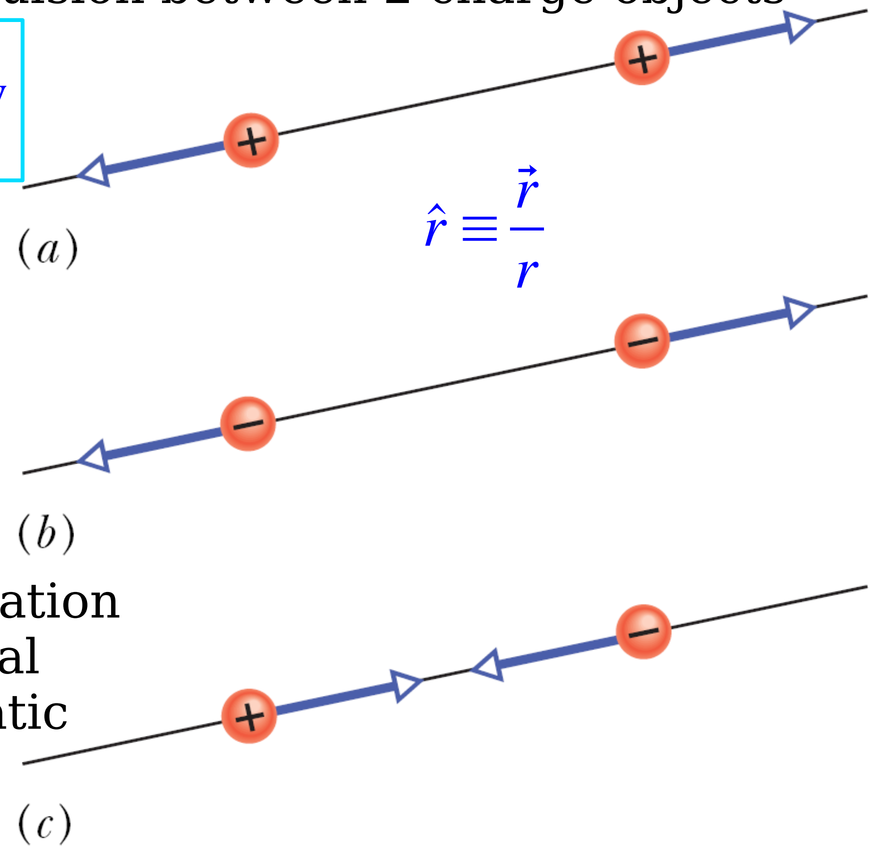




Coulomb's Law

- The **electrostatic force** of attraction or repulsion between 2 charge objects

$$\vec{F} = \kappa \frac{q_1 q_2}{r^2} \hat{r} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r} \qquad \text{Coulomb's Law}$$



$$\hat{r} \equiv \frac{\vec{r}}{r}$$

where the **electrostatic constant**

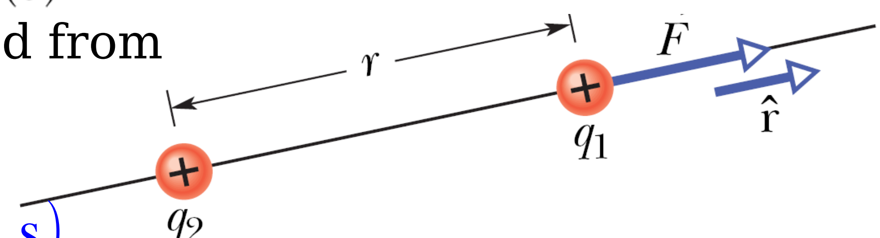
$$\kappa = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \ \mathrm{N \cdot m^2 / C^2}$$

and the **permittivity constant**

$$\varepsilon_0 = 8.85 \times 10^{-12} \ \mathrm{C^2 / (N \cdot m^2)}$$

- Its form is the same as that of Newton's equation for the gravitational force. But the gravitational forces are always attractive and the electrostatic forces may be either attractive or repulsive.

- The SI unit of charge is the **coulomb**, derived from the SI unit *ampere* for *electric current* i,



$$i = \frac{dq}{dt} \qquad \text{electric current} \qquad \Rightarrow \qquad 1\,\mathrm{C} = (1\,\mathrm{A})(1\,\mathrm{s})$$

- the principle of superposition stands

$$\vec{F}_{1,\,\mathrm{net}} = \vec{F}_{12} + \vec{F}_{13} + \cdots + \vec{F}_{1n} = \sum_{i=2}^{n} \vec{F}_{1i} \qquad \Rightarrow \qquad \vec{F}_1 = \int d\vec{F}$$

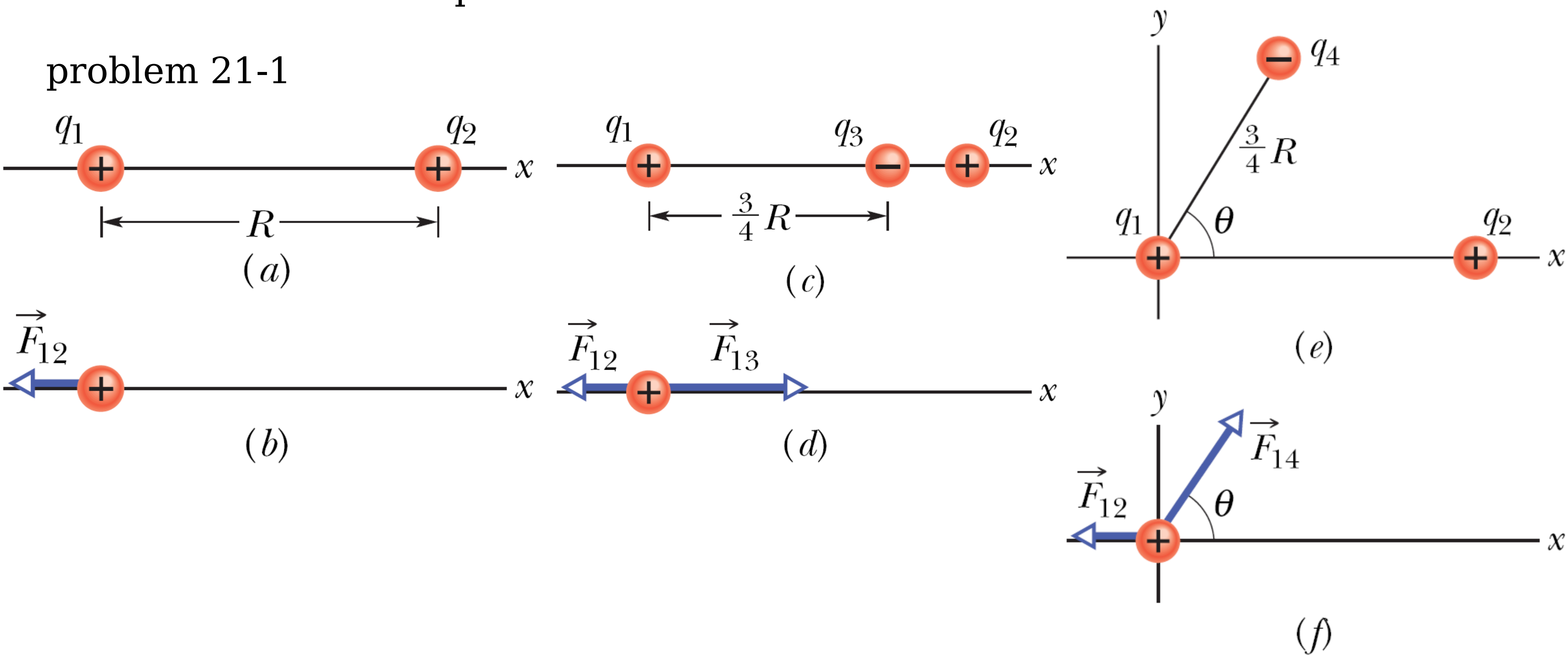
- the shell theorem also stands

> A shell of uniform charge attracts or repels a charged particle that is outside the shell as if all the shell's charge were concentrated at its center.
>
> If a charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell.

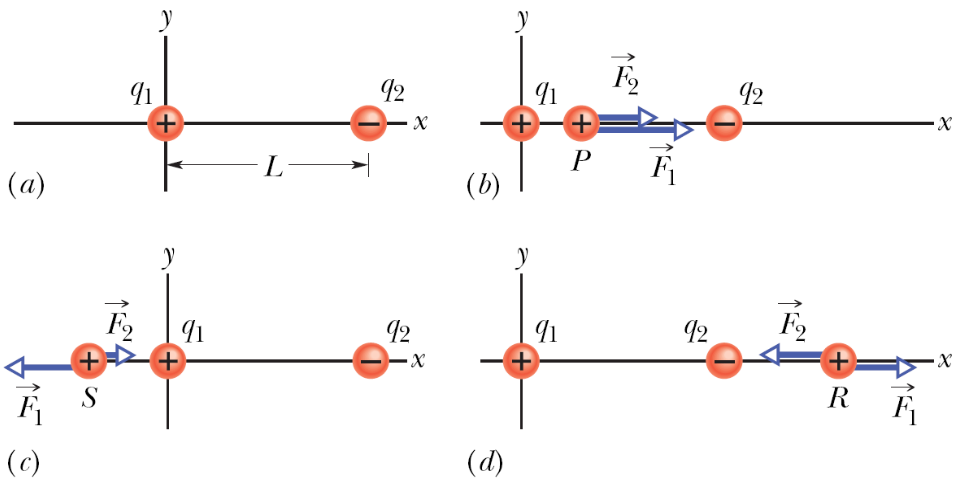
Spherical Conductors

- If excess charge is placed on a conducting spherical shell, the excess charge spreads uniformly over the (external) surface. The arrangement maximizes the distances between all pairs of the excess electrons.

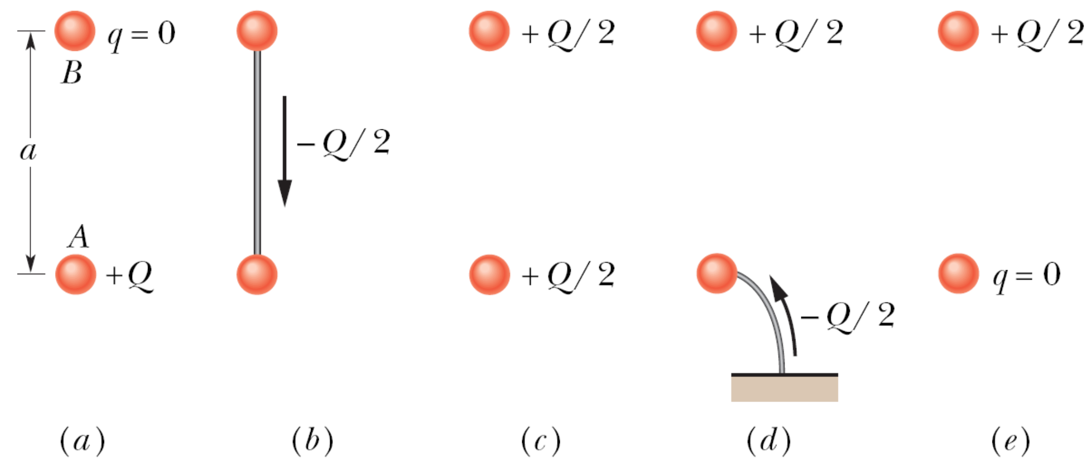
problem 21-1



problem 21-2



problem 21-3



Charge Is Quantized

- Any positive or negative charge q can be written as

$$q = n\,e\,, \qquad n = \pm 1, \pm 2, \pm 3, \cdots$$

in which e is the **elementary charge**, $e = 1.602 \times 10^{-19}$ C .

- Quarks have charges of $\pm e/3$ or $\pm 2e/3$, but they apparently cannot be detected individually.

- When a physical quantity such as charge can have only discrete values rather than any value, we say that the quantity is quantized.

The Charges of Three Particles

Particle	Symbol	Charge
Electron	e or e$^-$	$-e$
Proton	p	$+e$
Neutron	n	0

problem 21-4

Charge Is Conserved

- The hypothesis of **conservation of charge** has stood up under close examination for different scales.

- in the *radioactive decay* of nuclei, a nucleus transforms into a different type of nucleus, $^{238}U \rightarrow {}^{234}Th + {}^{4}He$

- In an *annihilation process*, an electron and its antiparticle, the positron transform into 2 gamma rays

$$e + e^{+} \rightarrow \gamma + \gamma \quad \text{pair annihilation}$$

- In *pair production* a gamma ray transforms into an electron and a positron:

$$\gamma + \gamma \rightarrow e + e^{+} \quad \text{pair production}$$

Selected problems: 10, 24, 26, 36