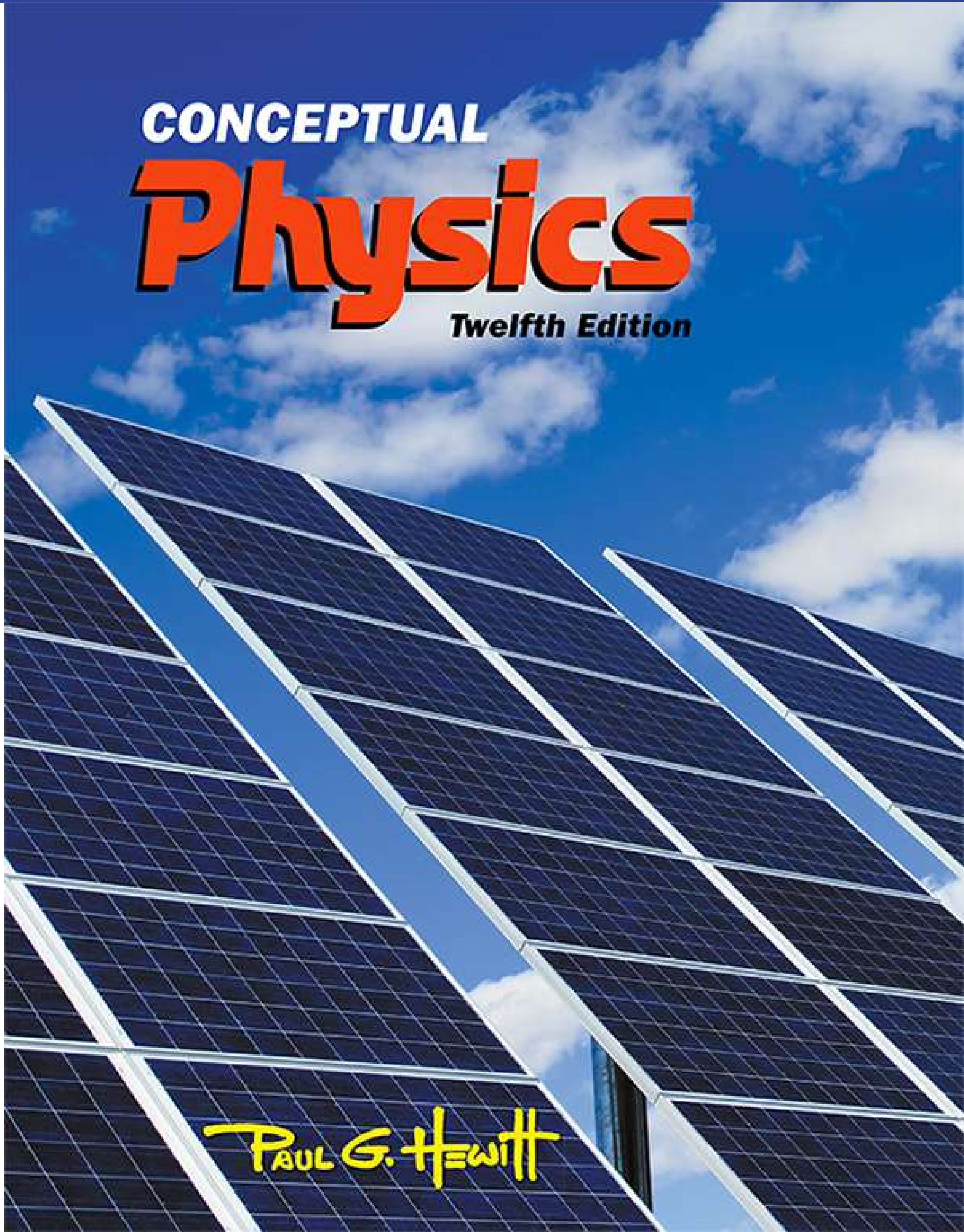
Lecture Outline

Chapter 22: Electrostatics



- Sections 4, 5 and 6:

- Coulomb's Law
- Conductors, Insulators, and Superconductors
- Charging

22.4: Coulomb's Law

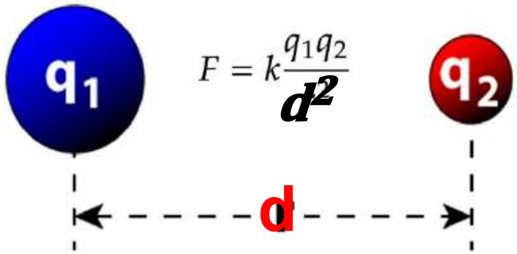
– Relationship among electrical force, charge, and distance discovered by Charles Coulomb in the 18th century:

For a pair of charged objects that are much smaller than the distance between them, the force between them varies:

1) *directly*, as the product of their charges, and

2) *inversely*, as the **square** of the separation distance

Coulomb's Law, Continued



- Coulomb's law (continued)
  - If the charges are alike in sign, the force is repelling; if the charges are opposite, the force is attractive.
  - In equation form:

direct

$$F = k\frac{q_1q_2}{d^2}$$

inverse square

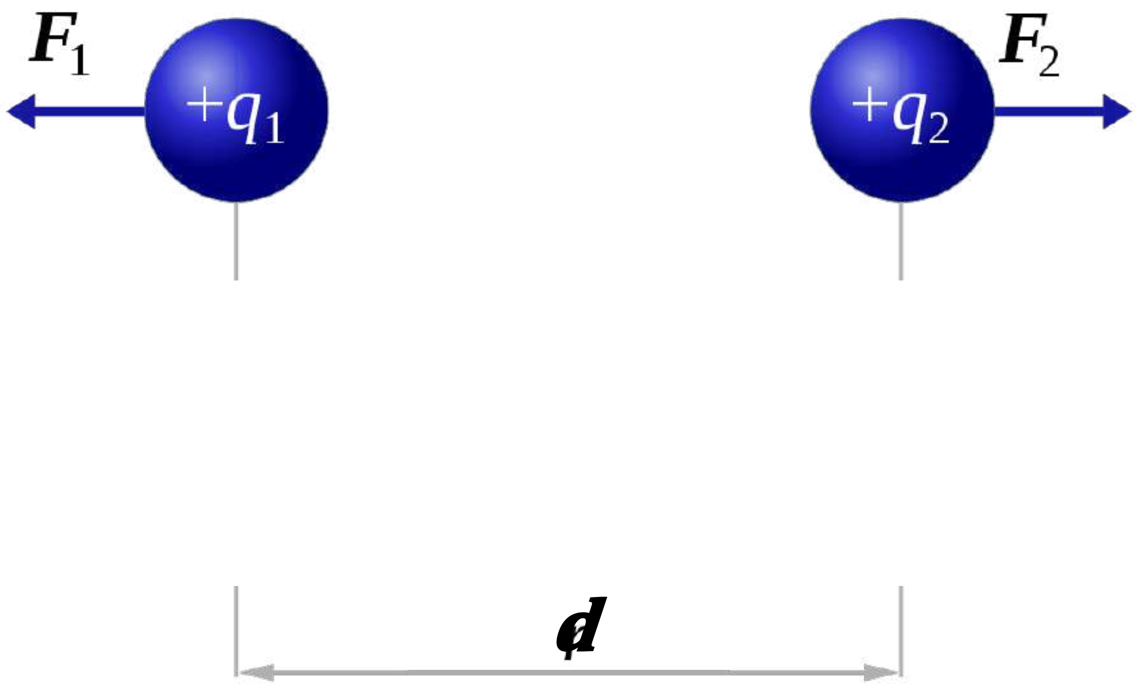
$k = 9{,}000{,}000{,}000 \text{ Nm}^2/\text{C}^2$

  - q = the charges
  - d = the distance between them
  - Unit of charge is the coulomb, C
  - **1 C = 6.25 billion billion electrons (or protons)**
  - Similar to Newton's law of gravitation for masses

Newton's 3rd Law: Neither q pushes harder!

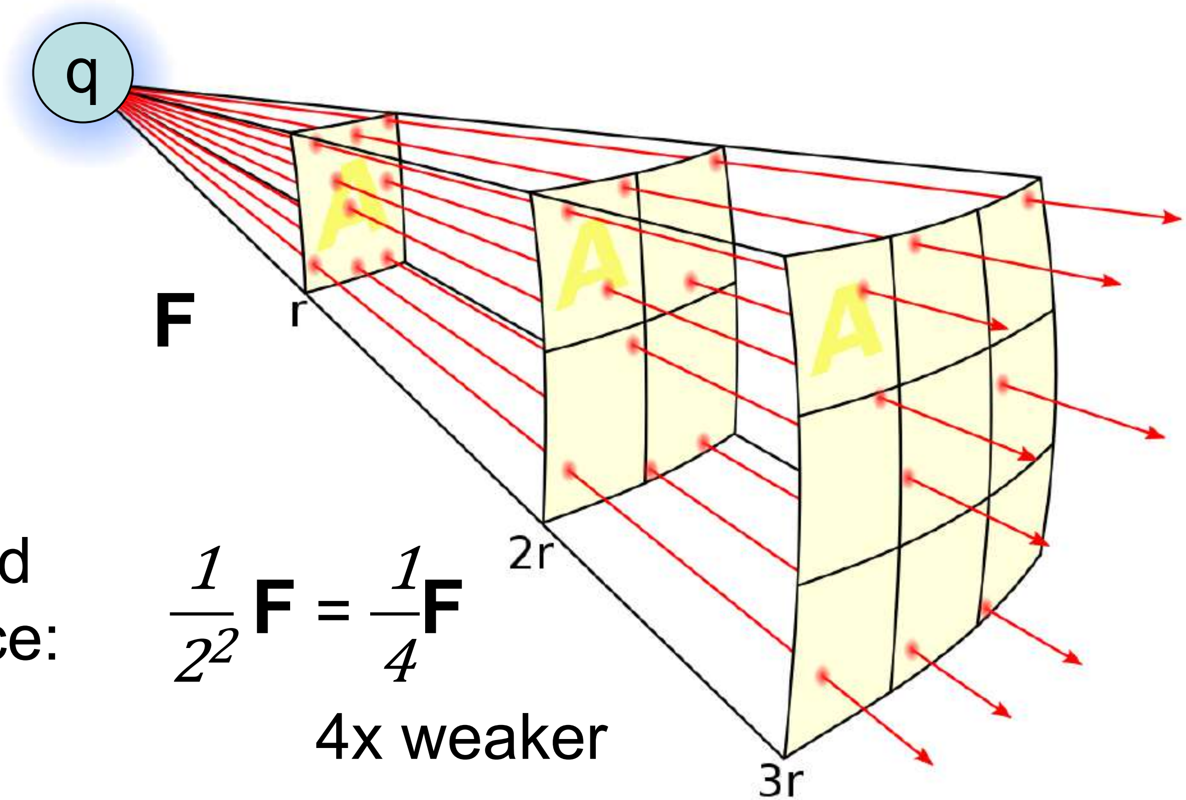
like charges:

opposite charges:



$$|F_1| = |F_2| = k_e \frac{|q_1 \times q_2|}{d^2}$$

Coulomb's law is an inverse squared law:



doubled distance: $\frac{1}{2^2}\mathbf{F} = \frac{1}{4}\mathbf{F}$

4x weaker

tripled distance: $\frac{1}{3^2}\mathbf{F} = \frac{1}{9}\mathbf{F}$ 9x weaker

Coulomb's Law
CHECK YOUR NEIGHBOR

According to Coulomb's law, a pair of particles that are placed twice as far apart will experience forces that are

A. half as strong.
B. one-quarter as strong.
C. twice as strong.
D. 4 times as strong.

Coulomb's Law
CHECK YOUR ANSWER

According to Coulomb's law, a pair of particles that are placed twice as far apart will experience forces that are

B. one-quarter as strong.

CHECK POINT

1. The proton that is the nucleus of the hydrogen atom attracts the electron that orbits it. Relative to this force, does the electron attract the proton with less force, with more force, or with the same amount of force?

2. If a proton at a particular distance from a charged particle is repelled with a given force, by how much will the force decrease when the proton is three times farther away from the particle? When it is five times farther away?

3. What is the sign of the charge of the particle in this case?

Gravity vs Electricity

$$F_g = G\frac{m_1 m_2}{d^2} \qquad F_e = k\frac{q_1 q_2}{d^2}$$

- **Similarities:**
- -both are *inverse square* with distance: $\frac{1}{d^2}$
- -mass *m* (gravity) is like charge *q* (electricity)
- **Differences:**

  -Electrical forces may be attractive or repulsive.
  - Gravitational forces are only attractive.
  - Gravity is much, much weaker: k >>> G

Section 22.5: Conductors and Insulators

- **Conductor**: Materials in which one or more of the electrons in the atoms are not anchored to the nuclei, but are *free to wander* in the material.
- → Conduct both electricity and heat.
  - Example: Metals such as copper and aluminum

Conductors and Insulators

Insulators: Materials in which electrons are tightly bound are not free to wander about the material.

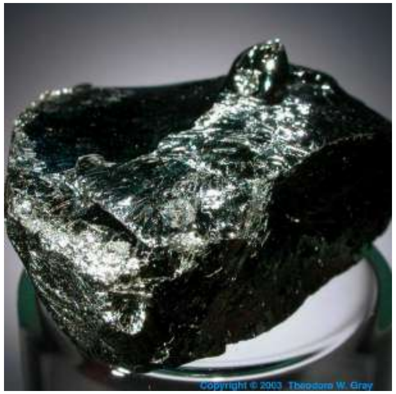
→ They resist the motion of electrons.

→ Do not conduct electricity or heat.

Example: Rubber, glass, paper:

Semiconductors…:

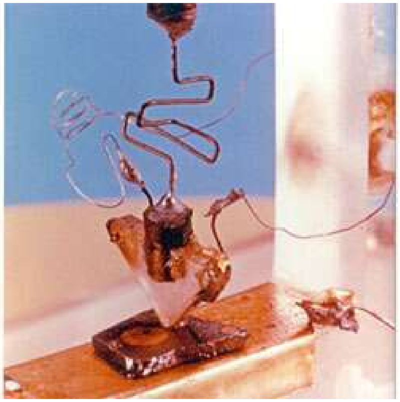
- …are materials that can be made to behave sometimes as an insulator and sometimes as a conductor.
  - In the middle of electrical resistivity between insulators and conductors.
  - They are insulators in their pure state.
  - They are conductors when they have impurities.
  - Examples: Silicon (Si) and germanium (Ge)



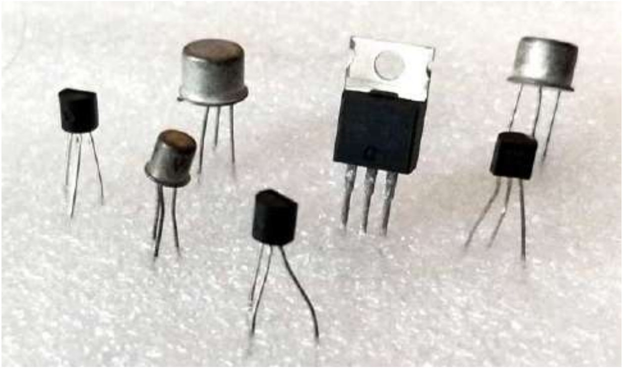
Semiconductors:

- Thin, semiconducting layers make up a **transistor**:

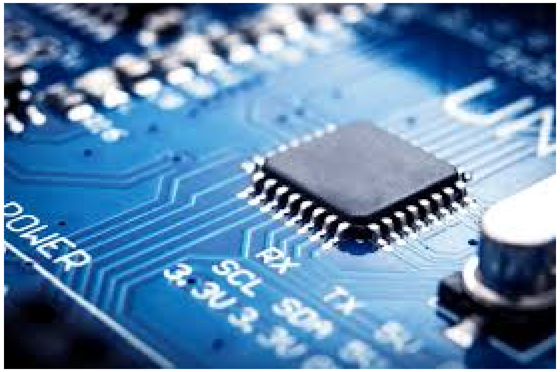
first one



old style



nowadays:

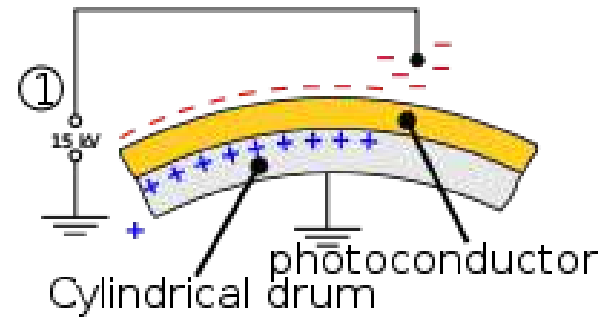


Transistors are used :

1) to control the flow of electrons in circuits
2) to detect and amplify radio signals
3) to produce oscillations in radio transmitters
4) as digital switches → chips in computers

More about semiconductors:

- Semiconductors conduct when light shines on it.
  - If a charged selenium plate is exposed to a pattern of light, the charge will leak away only from the areas exposed to light.
  - When toner (powdered ink) is applied, it only sticks to the charged areas.
  - Paper is rolled across, and the ink sticks to the paper.
  - This is how photocopiers work.



Conductors and Insulators
CHECK YOUR NEIGHBOR

When you buy a water pipe in a hardware store, the water isn't included. When you buy copper wire, electrons

A. must be supplied by you, just as water must be supplied for a water pipe.
B. are already in the wire.
C. may fall out, which is why wires are insulated.
D. None of the above.

Conductors and Insulators
CHECK YOUR ANSWER

When you buy a water pipe in a hardware store, the water isn't included. When you buy copper wire, electrons

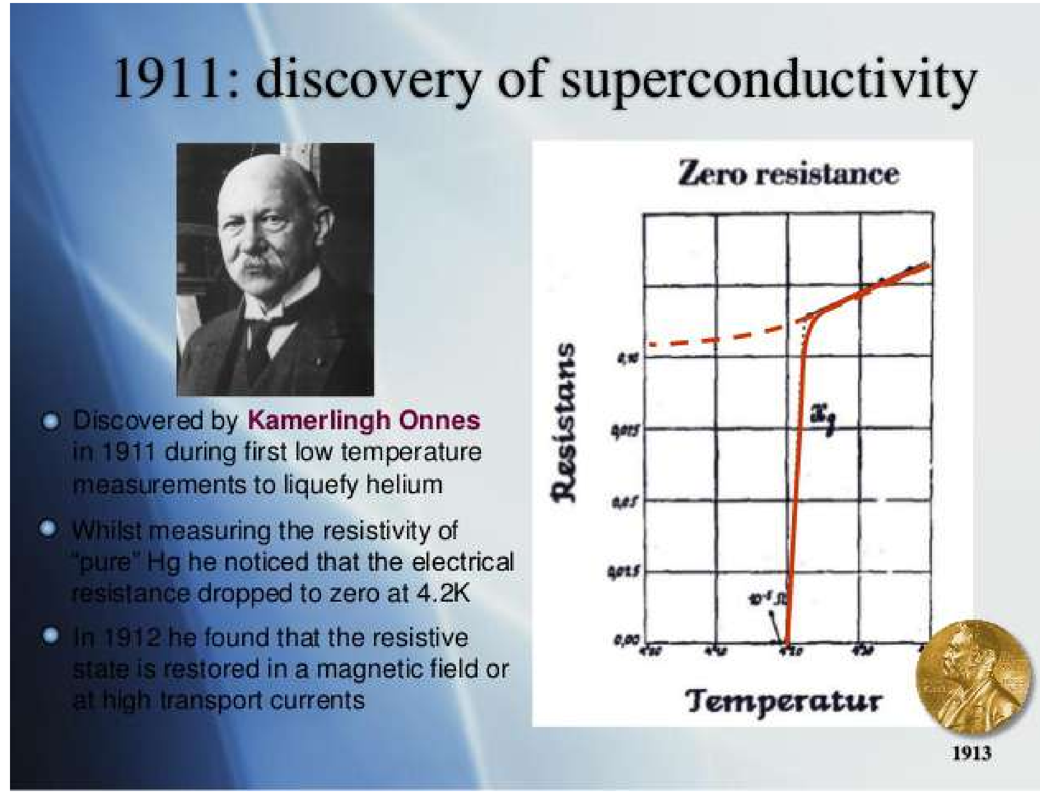
B. are already in the wire.

Superconductors

- Superconductors: Materials acquire zero resistance (infinite conductivity) to the flow of charge.
  – Once electric current is established in a superconductor, the electrons flow indefinitely.
  – With no electrical resistance, current passes through a superconductor without losing energy.
  – No heat loss occurs when charges flow.

Superconductivity has changed:

Originally, only occurred in metals near absolute zero.



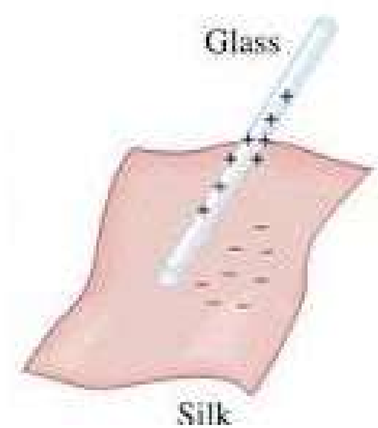
Nowadays, superconductors are made from a mixture of materials and can be used at much higher temperatures for many uses.

3 Types of Charging

1. Charging by **Friction**

Example: Stroking cats fur, combing your hair, rubbing your shoes on a carpet

- Electrons transfer from one material to another by simply touching.

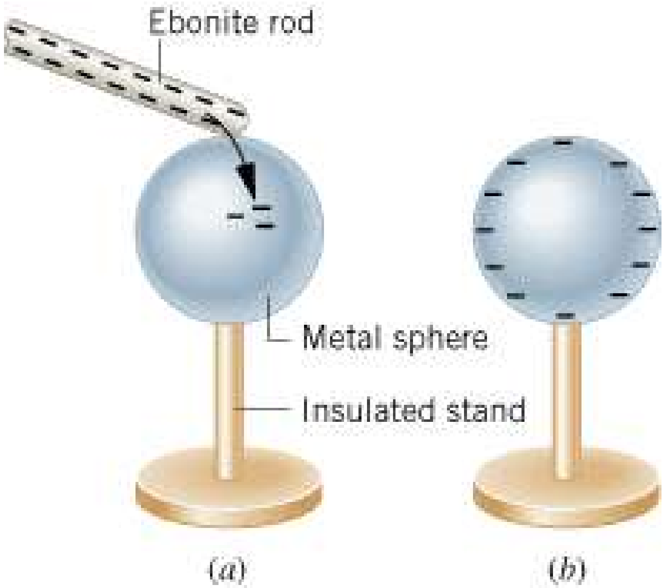


2. Charging by contact.

– Electrons transfer from one material to another by simply touching.

Example: When a negatively charged rod is placed in contact with a neutral object, some electrons will move to the neutral object.

Works best if the objects are metals.

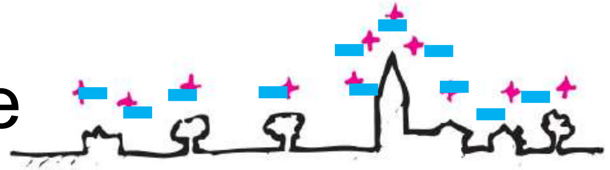


Charges repel each other and spread out on sphere.

3. Charging by **induction**

If you bring a charged object *near a conducting surface*, *electrons are made to* move in the surface material, even without physical contact.

Example: The negative charge at the bottom of the cloud induces (causes) a positive charge on the buildings below it by repelling electrons away.



This occurs in thunderstorms. **Lightning** is the discharge of electrons from cloud to ground.

Ben Franklin: Charge flows easily to or from sharp metal points → Lightning rods

Lightning rods prevent lightning strikes by allowing charge to leak to the ground.

If enough charge does not leak away and lightning occurs, it is diverted to ground.

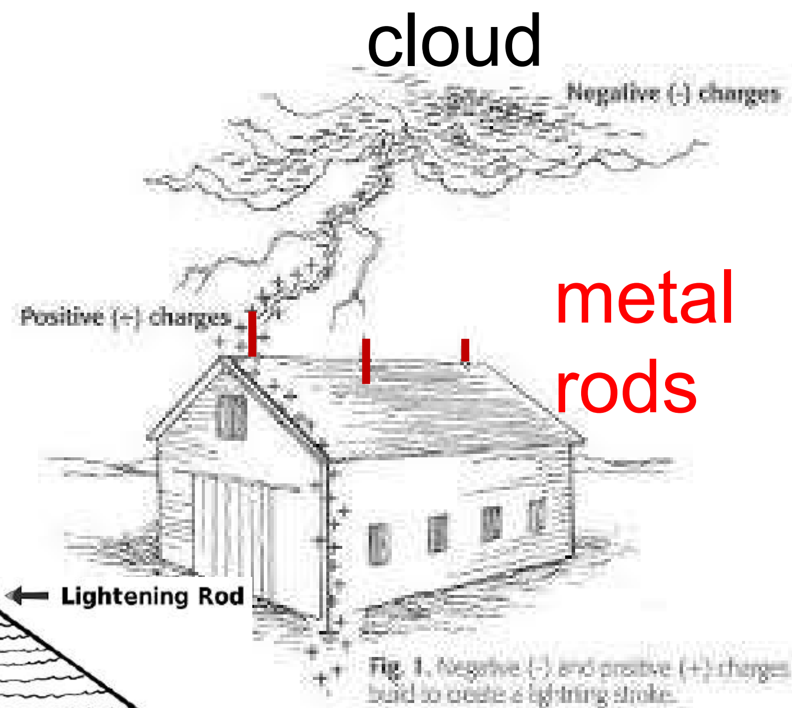
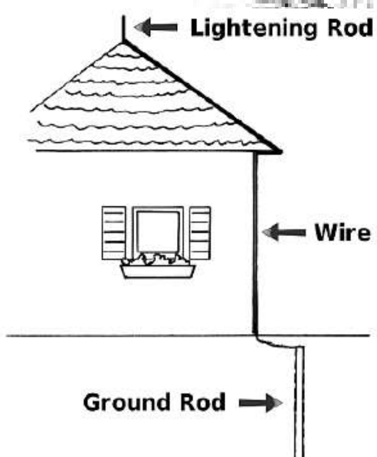
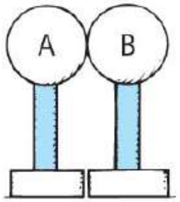


Fig. 1. Negative (-) and positive (+) charges build to create a lightning stroke.



- Induction: Consider two insulated metal spheres A and B.

a. They touch, so in effect they form a single uncharged conductor.
b. When a negatively charged rod is brought near A, electrons in the metal, being free to move, are repelled as far as possible until their repulsion is enough to balance the influence of the rod. The charge is redistributed.
c. If A and B are separated while the rod is still present, each will be equal and oppositely charged.
d. If the rod is removed, the charges spread out.



(a)

Classwork: Take out your book. Take out sheet. Write name at top. Write: Page 425: # 10-20

10. How does one *coulomb* of charge compare with the charge of a *single* electron?

11. How is Coulomb's law similar to Newton's law of gravitation? How is it different?

12. Why are metals good conductors both of heat and of electricity?

13. Why are materials such as glass and rubber good insulators?

14. How does a semiconductor differ from a conductor or an insulator?

16. How does the flow of current differ in a superconductor compared with the flow in ordinary conductors?

17. What happens to electrons in any charging process?

18. What kind of charging occurs when you slide your body across a plastic surface?

19. What kind of charging occurs during thunderstorms?

15. What is a transistor composed of, and what are some of its functions?

20. What is the primary purpose of a lightning rod?