

charges, and inversely as the square of the separation distance. The force acts along a straight line:

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

where  $q_1$  and  $q_2$  are the charges,  $d$  is the distance between the charges,  $C$  is the unit of charge, known as a coulomb, and  $k$  is the proportionality constant, like  $G$  in the gravitational equation. But where  $G$  is a very small number,  $k$  is a large number indeed;  $k$  is equal to  $9,000,000,000 \text{ N}\cdot\text{m}^2/\text{C}^2$ . This is an amazingly large number in newtons. If like charges of 1 coulomb each were 1 meter apart, the force of repulsion of the two charges would be 9 billion newtons—about 10 times the weight of a battleship. In our everyday existence, we do not see forces like this.

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### Conductors and Insulators

As with heat, some materials transmit electric charge well, and others do not. We call those that can transmit electric charge easily conductors, while those that seem to inhibit electric charge are called insulators. The same materials that transmit heat well seem to transmit electric charge well—metals, for instance—while rubber, ceramics, and woods inhibit transmission of charge.

On rare occasion, some substances can be tricked into being good conductors. Silicon, which is neither a good conductor nor a good insulator, can, if it is sandwiched in layers, create transistors through which electric charge can flow. All modern computers contain silicon chips, for instance. These chips, and a few other materials like them, are known as *semiconductors*.

Things are charged by the movement of electrons. We can do this by physical contact—rubbing a balloon on your hair negatively charges the balloon—or by **induction**. To induct a charge, a charged object is brought near a conducting surface, although no physical contact is made. An example of induction in nature is a thunderstorm. Negatively charged clouds induce a positive charge on the surface of the earth. Lightning is an electrical discharge between the clouds and the oppositely charged ground, or between two oppositely charged clouds.