Lecture Notes

(Electrical Current)

Intro:

- although many practical applications are based on static electricity, electricity did not truly become an inseparable part of our daily lives until scientists learned how to control the flow of electric charges

- electric currents power our lights, radios, TV's AC's, and refrigerators

- electric currents ignite the gas in our car engines and travels through the parts of our computers

Electric Current:

- a flow of charged particles is an electric current

- a more precise definition of current is the rate at which charge flows through a perpendicular surface of cross-sectional area A

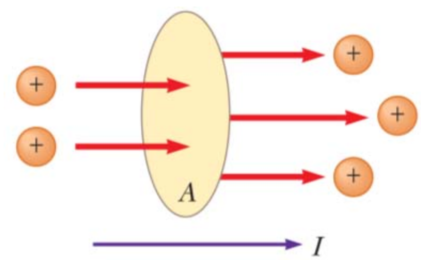


Figure 17.1 Charges in motion through an area *A*. The time rate of flow of charge through the area is defined as the current *I*. The direction of the current is the direction of flow of positive charges.

- in the last chapter we discussed the properties which determine how easily electrons to flow through a material

- we said that if a material has a chemical composition which leads itself to easily donating or receiving electrons it was called a conductor $\boxed{\text{Ex.}}$ metals, salt water

- materials that held tightly onto their electrons were called insulators $\boxed{\text{Ex.}}$ dry air, glass, plastic

- if the charge is great enough, however, even dry air will suddenly become a conductor, allowing a large amount of charge to shift through it

- the heat and light caused by the sudden rush of charge produces a spark; sparks were the first obvious evidence of moving charges

- until late in the eighteenth century, a significant flow of charge, that is, an electric current, could be produced only by discharging a highly charged object

- in studying electric currents, Benjamin Franklin believed the moving charges to be positive; because of this, he defined the direction of flow of an electric current to be the direction of flow of positive charges

- today, we know that the moving charges in a current can be positive or negative or both

- in most wires, the flowing charges are negative electrons

- however, ever since Franklin's early work, the direction of flow of an electric current is defined as the direction of flow of positive charges, regardless of the actual sign of the moving charges (this is called <u>conventional current</u>)

<u>Producing Electric Current</u>:

- charges flow when there is a potential difference (ΔV)

- a flow will stop when there is no potential difference

- in order to maintain a constant potential difference, charges must be pumped from one area to another

- this pump would have to increase the electric potential energy (U_e) of the charges, so it would require external energy to run

- some ways you could get this external energy are:
    1) batteries, 2) photovoltaic cells (solar cells), and 3) generators powered by steam, wind, or water

Batteries:

- in 1800, Alessandro Volta discovered a much better way of producing electric currents than using short-lived discharge devices

FIGURE 10.15 Alessandro Volta (1745–1827) was given his title of Baron by Napoleon in honor of his electrical experiments. He was Professor of Physics at the University of Pavia, Italy. Volta showed that the electric effects previously observed by Luigi Galvani, in experiments with frog legs, were due to the metals and not to any special kind of "animal electricity."

- Volta's method involved two different metals, each held with an insulating handle; when put into contact and then separated, one metal took on a positive charge and the other a negative charge

- Volta reasoned that a much larger charge could be produced by stacking up several pieces of metal in alternate layers; this idea led him to undertake a series of experiments that produced an amazing result

- Volta piled these metals in pairs, called cells, in a vertical arrangement known as a <u>pile</u>

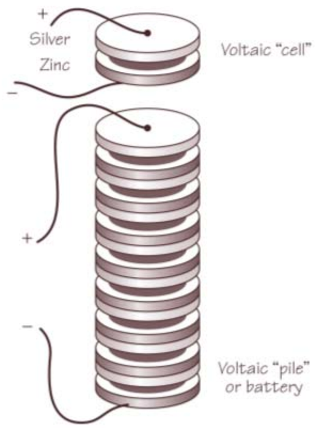


FIGURE 10.16 Voltaic cell and battery.

- Volta showed that one end, or terminal, of the pile was charged positive, and the other charged negative

- he then attached wires to the first and last disks of his apparatus, which he called a <u>battery</u>

- through these wires, he obtained electricity with exactly the same effects as the electricity produced by rubbing amber, or by friction in electrostatic machines

- most important of all, if the ends of the wires from Volta's battery were connected together, or attached to a conducting object, the battery produced a more or less steady electric current through the wires for a long period of time

- this arrangement is known today as a <u>circuit</u>

- the current, which flows through the wires of the circuit from the positive side of the battery to the negative side (by the earlier definition) is known as a <u>direct current</u>, or DC current

- a current that alternates in direction is known as an <u>alternating current</u>, or AC current; most household circuits around the world provide AC current

Electric Circuits:

- when charges move around in a closed loop, an electric circuit is formed

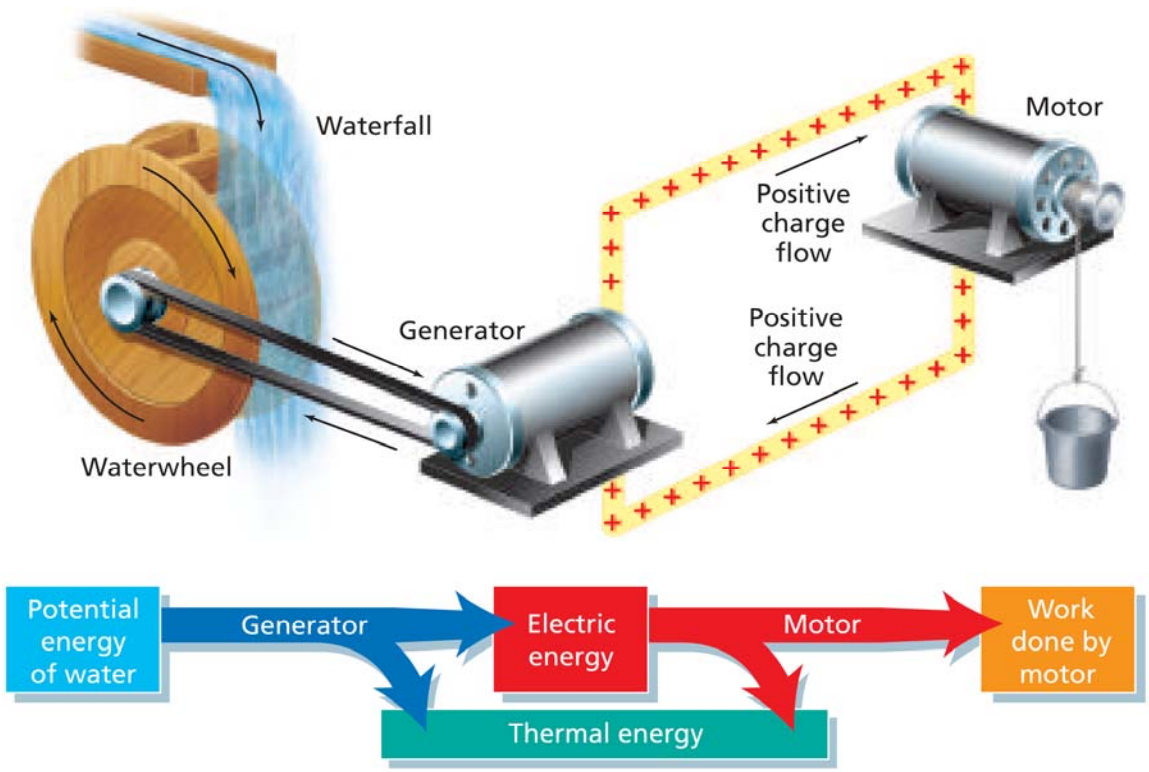
- circuits include a charge pump which increases the electric potential energy of the charges and also a device that reduces the U_e

- the device which reduces the U_e usually converts this energy into some other form such as kinetic, light, or heat

- from now on, the delta symbol (Δ) will be dropped from potential difference (ΔV) to just V; this is an historical convention

Water wheel Charge Pump:

- in this diagram, the kinetic energy (KE) of the water wheel will be converted into electric energy by the generator



- this electric energy will be added to charges in the wire connecting the generator to the motor; this will increase the potential difference in the wire and cause a flow of charges from high to low potential (a current is formed)

- as the current reaches the motor, the motor will reduce the U_e of the charges and convert the electric energy into kinetic energy

- remember that all machines lose some energy as heat, so not all the electric energy will be converted into kinetic energy

- also, the total amount of charges in the circuit cannot change, charges cannot be created or destroyed

- the potential difference increase in the wire caused by the generator is the same amount as the decrease in potential difference caused by the motor

<u>Rates of Charge Flow & Energy Transfer</u>:

- power measures the rate of energy transfer; and is measured in watts (W); one watt is equal to one joule per second

$$P = \frac{E}{t}$$

- the energy of an electric current is dependent upon the amount of charge transferred (q) and the potential difference (V) across which it moves:

$$E = qV$$

- the symbol for electric current is I and the units of current are amperes (A); where one ampere is equal to one coulomb per second

$$I = \frac{q}{t}$$

- devices that measure current are called <u>ammeters</u>

- the power of electrical devices can be found by multiplying the current by the potential difference:

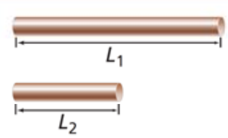
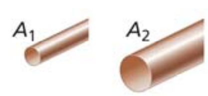
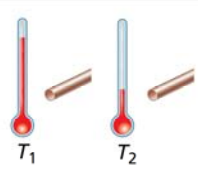
$$P = IV$$

<u>Resistance</u>:

- if you have two objects with a potential difference between them, a current will be produced if you connect the two objects

- the amount of current generated between the two objects depends on the material connecting them

- for example, if you connect the two objects with a copper rod, a large current will be created; if you connect the two objects with a glass rod, virtually no current will be produced

Table 22-1		
Changing Resistance		
Factor	**How resistance changes**	**Example**
Length	Resistance increases as length increases.	 $R_{L1} > R_{L2}$
Cross-sectional area	Resistance increases as cross-sectional area decreases.	 $R_{A1} > R_{A2}$
Temperature	Resistance increases as temperature increases.	 $R_{T1} > R_{T2}$
Material	Keeping length, cross-sectional area, and temperature constant, resistance varies with the material used.	R increases: Platinum, Iron, Aluminum, Gold, Copper, Silver

- the property which determines how much current will flow is called the resistance (R)

- resistance can be determined if you know the potential difference and the current:

$$R = \frac{V}{I}$$

- the units of resistance are ohms (Ω); one ohm is equal to one volt per amp

- the ohm was named after Georg Ohm (1787-1854), a German physicist

GEORG SIMON OHM (1787 – 1854)

Ohm, a high school teacher in Cologne and later a professor at Munich, formulated the concept of resistance and discovered the proportionalities expressed in Equation 17.6. But Henry Cavendish had earlier determined the proportionality of current to voltage that we call Ohm's law. (© Bettmann/CORBIS)

<u>Ohm's Law</u>:

- Ohm not only formulated the concept of resistance, but also discovered the proportionality called Ohm's Law

- Ohm's law states that the resistance is constant over a wide range of applied voltages (potential differences)

- most metallic conductors obey Ohm's law (at least over a limited range of voltages) and are called ohmic

- materials that do not obey Ohm's law are called non-ohmic

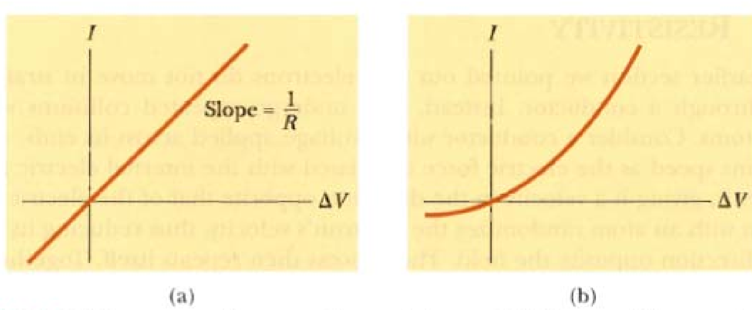


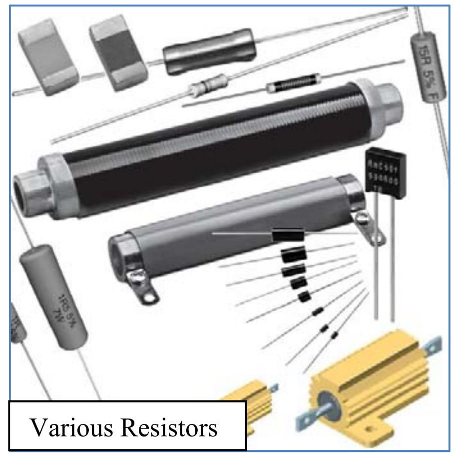
FIGURE 17.8 (a) The current-voltage curve for an ohmic material. The curve is linear, and the slope gives the resistance of the conductor. (b) A nonlinear current-voltage curve for a semiconducting diode. This device does not obey Ohm's law.

- it is common to express Ohm's law as:

$$V = IR$$

- wires used to connect electrical devices in homes have very little resistance (approx. 0.004 Ω/m of wire); when an object has this small resistance there is almost no loss of voltage

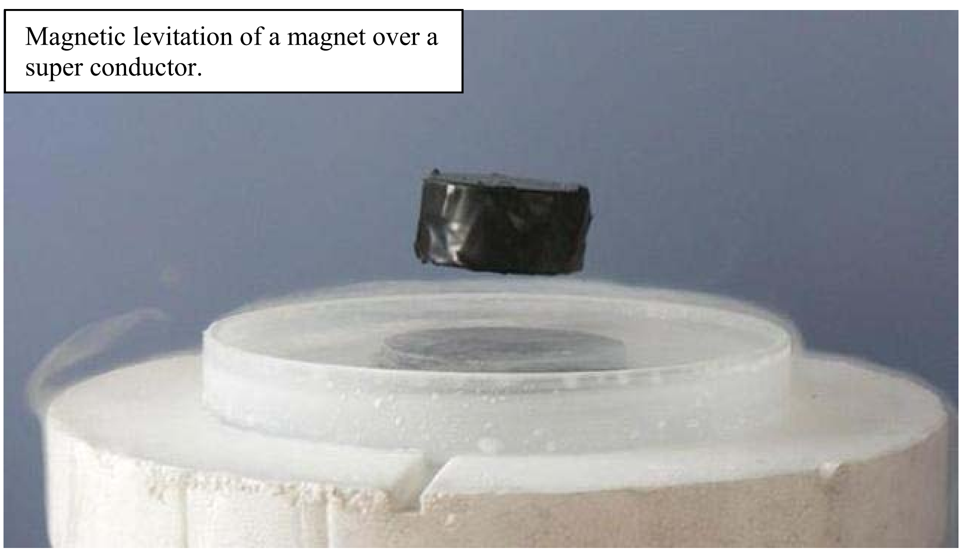
- to dramatically reduce voltage over short distances, resistors are used



Various Resistors

- a <u>resistor</u> is a conductor that provides a specified resistance in an electrical circuit; they may be made of long thin wires or semiconductors

- some materials have no resistance at all; they are called <u>superconductors</u>; superconductors can conduct electricity without loss of energy

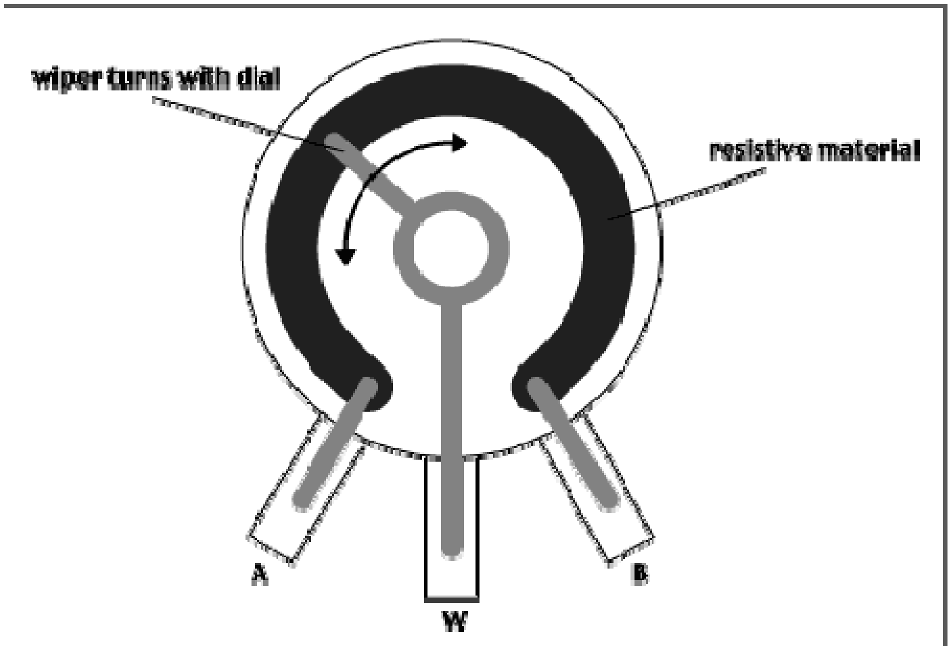


Magnetic levitation of a magnet over a super conductor.

- resistors are often used to control the amount of current flowing in a circuit or a part of a circuit

- sometimes a continuous variation of current is desired; a variable resistor may be used for this purpose

- a variable resistor is called a potentiometer; one type is the rotary potentiometer seen below



- the wiper (W) moves between two leads (A) and (B); resistance between wiper and lead determines resistance

- an example of a potentiometer is a lamp dimmer; it provides a smooth change in resistance in a circuit

- the human body is a moderately good electrical conductor and if enough current passes through your person your breathing or heart may stop

- if your skin is dry the resistance is high and currents passing through your body will stay low; conversely, if your body is wet, its resistance will decrease and the current will increase