Conventional Current Flow vs Electron Current Flow

In the atomic theory section that we studied earlier, we discovered that electrons move away from the negative and are drawn towards the positive. In short, this means that ***current flows from negative to positive. This is called electron current flow.***

In the early days of electricity, it was believed that current was the of movement of positive charges, and that these charges moved around the circuit from the positive terminal of the battery to the negative. Based on this, all laws, formulas, and symbols of circuit theory were developed. ***Current flow from positive to negative is called conventional current flow.***

Conventional current flow is well established. This course and further courses that you will take later, will continue to use conventional current flow. ***We assume that current flows from the positive terminal to the negative terminal.***

Ohm's Law

Ohm's Law simply states that ***current in a resistive circuit is directly proportional to its applied voltage and inversely proportional to its resistance.***

These three simple equations describe Ohm's law

$$I = \frac{E}{R} \text{ [amps, A]} \qquad R = \frac{E}{I} \text{ [ohms,]} \qquad E = IR \text{ [Volts, V]}$$

E is the voltage in volts
R is the resistance in ohms
I is the current in amperes

Ohm's Law

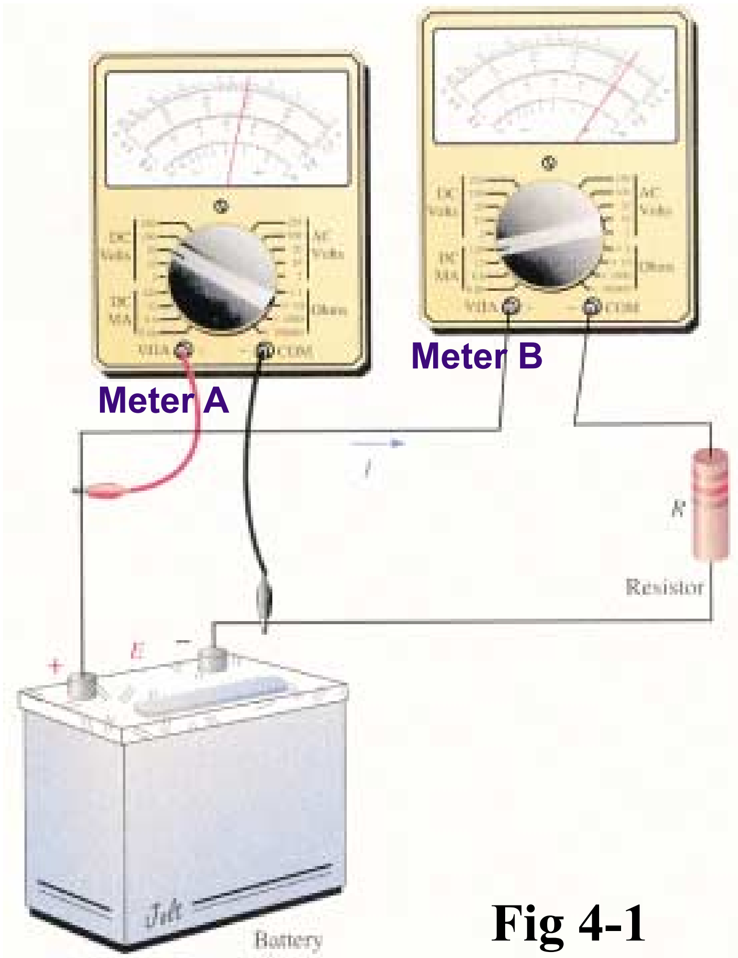


Fig 4-1

Figure 4-1 shows a simple circuit. Meter (A) is across the battery and measures the voltage (pressure). Meter (B) is installed in such a way that the current flowing in the circuit must also flow through the meter. The resistor R limits the total current flowing in the circuit.

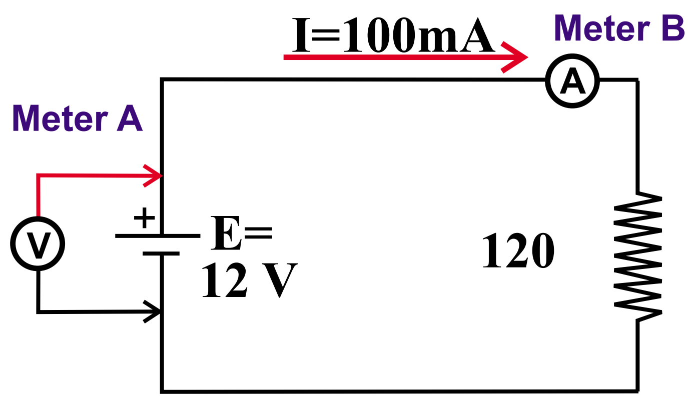


Fig 4-2

If the voltage is 12 V, and resistor R is 120 then by calculation the current will be 12V/120 100 mA. This is the reading that the ammeter should show in the circuit above.

Figure 4 -2 shows the schematic diagram of the circuit. Meter (A) is across the battery and meter (B) is an ammeter that is inserted into the circuit to read the current.

Ohm's Law

Fixed Resistance - Changing Voltage

The circuit in Figure 4-3 (a) is the same as the circuit shown in figure 4-2 except that the voltage has doubled to 24 volts from 12 V. Note that the current has also doubled to 200 mA.

The circuit shown in figure 4-3 (b). has the voltage tripled to 36 V from 12 V. Note that the current has tripled and is now 300 mA.

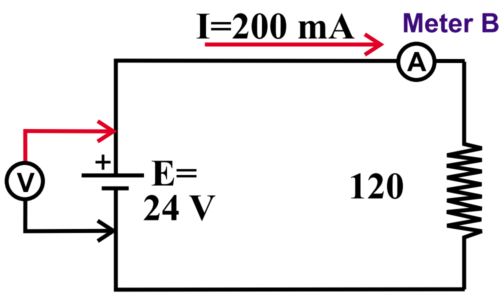


Fig 4-3 (A)

The voltage is doubled to 24V
The current doubles to 200 mA

$$I = \frac{E}{R} = \frac{24V}{120} = 200\ mA$$

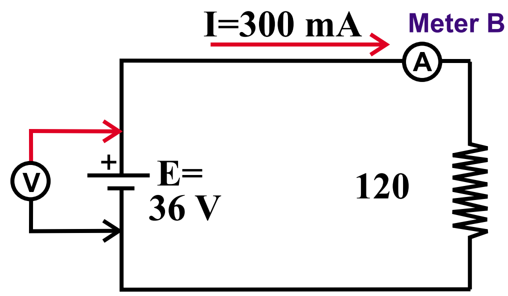


Fig 4-3 (B)

The voltage is tripled to 36V
The current triples to 300 mA

$$I = \frac{E}{R} = \frac{36V}{120} = 300\ mA$$

This proves that for a ***fixed resistance, current is directly proportional to voltage.*** Thus doubling the voltage doubles the current and tripling the voltage triples the current and so on.

Fixed Voltage - Changing Resistance

The inverse relationship between resistance than current is shown in Fig. 4-4. Look at figure 4-4(a). Here, we have fixed the voltage at 36 volts. With our resistance still at 120 , the current remains at 300 mA.

In figure 44 (b),we have fixed the voltage at 36 volts. We have doubled the resistance to 240 he current drops in half from 300 mA to 150 mA.

Ohm's Law

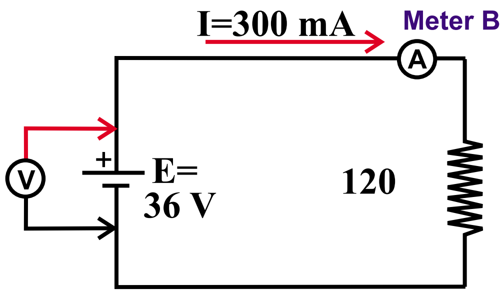


Fig 4-4 (A)

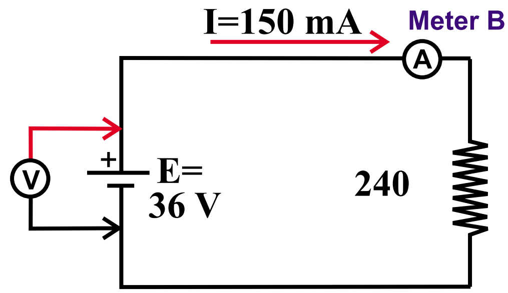


Fig 4-4 (B)

The voltage is constant at 36 V
The current is 300 mA

$$I = \frac{E}{R} = \frac{36\ V}{120} = 300\ mA$$

The voltage is constant at 36 V
The resistance doubles to 240
The current drops to half or 150 mA

$$I = \frac{E}{R} = \frac{36\ V}{240} = 150\ mA$$

See examples 4-1 to 4-4 pages 98 and 99 of the text

Ohm's Law in Graphical Form

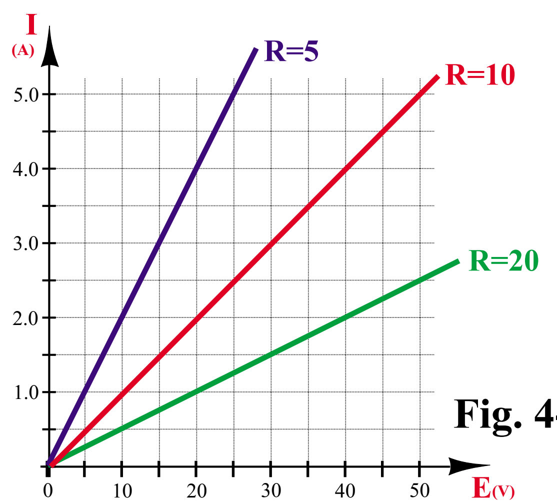


Fig. 4-5

Figure 4-5 shows a graphical representation of ohm's law. Three different resistances are plotted on the graph. Using the Ohm's law formulas, we can find any point on the line for each resistance.

Note that this slope of the line for R=5 is steeper than for R=20

For R= 0 the slope of the line would be vertical. For R= the line would be a horizontal.

Since every possible resistance exists between 0 and , we can see that every resistance is represented by the slope of the line.

The lower the resistance, the steeper the line.
The higher the resistance, the more horizontal line becomes.

An Open Circuit

Current can only exist where there is a conductive path (e.g. A length of wire). In the circuit shown in Figure 4- 6, I= 0 since there is no conductor between points a & b. We referred to this is an ***open circuit***.

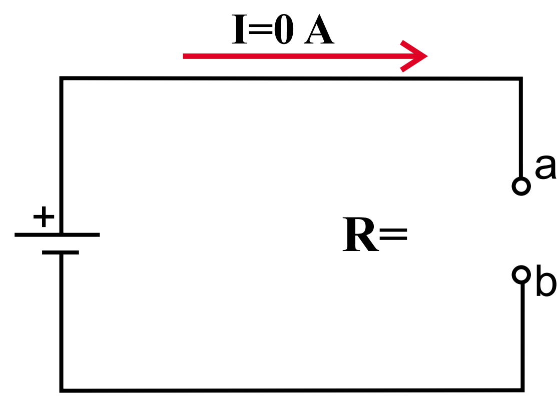


Fig 4-6 **An open circuit has infinite resistance**

Voltage Symbols

Two different symbols are used to represent voltage.

***For sources, use uppercase* E**
***For loads (and other components), use uppercase* V.**

Ohm's Law can be rewritten using the symbol V

$$I = \frac{V}{R} \text{ [amps, A]} \qquad R = \frac{V}{I} \text{ [ohms,]} \qquad V = IR \text{ [Volts, V]}$$

V is the voltage in volts
R is the resistance in ohms
I is the current in amperes

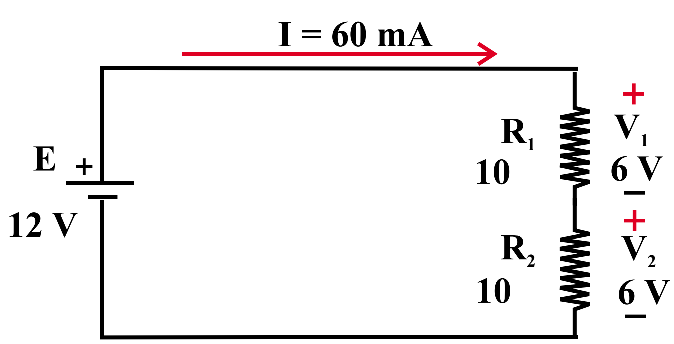


Fig 4-7

In figure 4-7,the voltage source is represented by E, and is 12 V.

There are two equal voltage drops in the circuit, V_1 and V_2.

Here we have the voltage source represented by E, and the voltage drops represented by V.

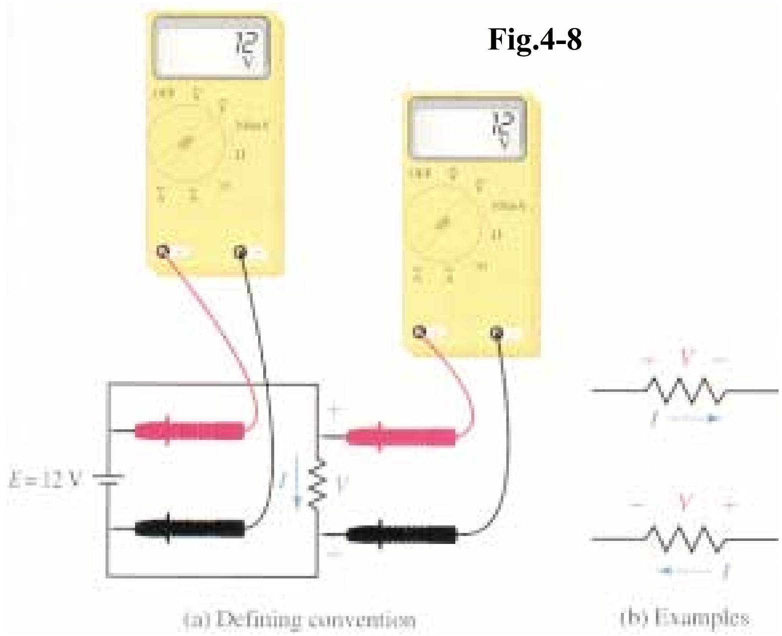
See examples 4-5 page 101 of the text

Voltage Polarity And Current Direction

For voltage across the resistor, always place the plus sign at the tail of the current reference arrow. An example is shown in Figure 4-8.

Since conventional current flow is from positive to negative, it should make sense that the positive sign will be at the tail end of the current arrow.

Fig.4-8



Current Direction (An Important Note)

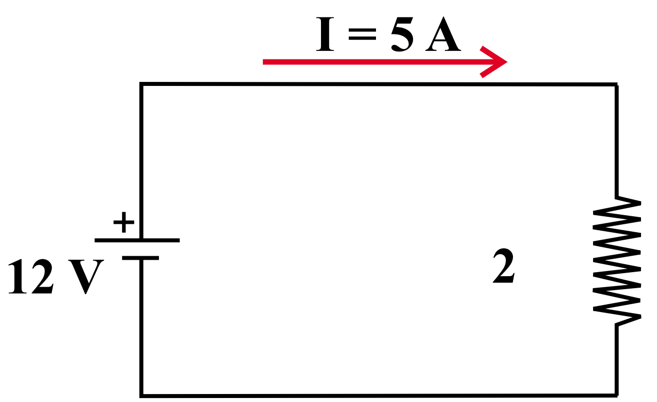
Figure 4-9 shows two representations of the same current. Polarity of current flow refers to direction.

In Figure (a), current is shown in the normal way. Figure (b), the current is shown going in the opposite direction, but it has a magnitude of - 5 amps.

Since the minus refers to the opposite direction in this case, the current is really travelling in the same direction as in Figure (a).

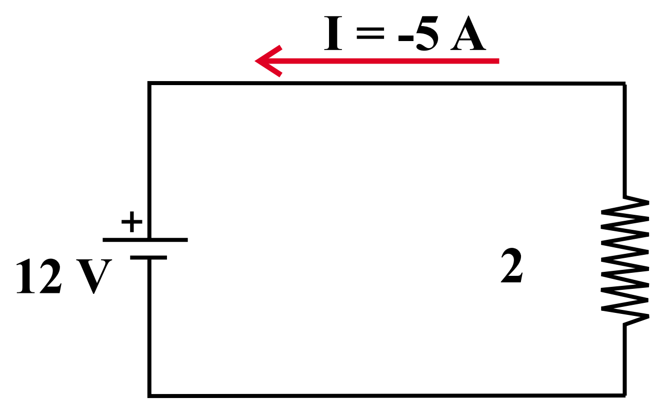
This may seem confusing in a simple circuit like the one shown, however in more complicated circuits, current direction can become very important.

Keep in mind that plus and minus refer to the direction of the current. When you solve problems and the resulting answer is negative, you will know which direction the current flowing.



Current shown in the normal way

Fig 4-9 (a)



Same current as (a)

Fig 4-9 (b)

Power

Power is a familiar word to us. We know that electric heaters and light bulbs are rated in watts. Most electric motors are rated in horsepower.

We also know that the higher the watt rating of the device the more energy we can get out of it per-unit time.

An example is a lightbulb. We all know that 100 watt lightbulb is brighter than 60 watt lightbulb.

Similarly, the greater the power rating of the heater, the more heat energy it can produce per second.

In the case of a motor, the larger the power rating, the more mechanical work that it can do per second.

Power

As you can see, power is related to energy, which is the capacity to do work. ***Power*** is defined as the ***rate of doing work*** or as the ***rate of transfer of energy.*** The symbol for power is **P**.

$$P = \frac{W}{t} \quad \text{[watts, W]}$$

where: W = work(or energy) in Joules
t = corresponding time interval in seconds

The SI unit of power is the watt.

1 watt = 1 joule per second.

Occasionally, you also need power in horsepower. To convert remember that ***1 hp = 746 watts..***

Power In Electrical And Electronic Systems

The equations listed below are very useful to us for finding power in electrical and electronic systems.

$$P = VI \quad \text{[watts, W]}$$

or, for a source

$$P = EI \quad \text{[watts, W]}$$

$$P = I^2 R \quad \text{[watts, W]}$$

$$P = \frac{V^2}{R} \quad \text{[watts, W]}$$

Example 4-6, 4-7, 4-8 Page 105 R & M

Power Rating Of Resistors

Resistors must be able to safely dissipate their heat without damage. For this reason resistors are rated in watts.

Composition resistors of the type that are commonly used in electronics are made with standard ratings of 1/8, ¼, ½, 1, and 2 watts.

To provide a ***safety margin, it is customary to select a resistor that is capable of dissipating 2 or more times its computed power.***
By over rating the resistor, it will run cooler.

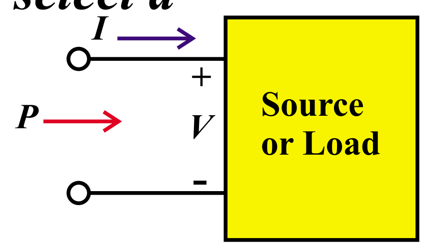


Fig 4-10 Power Direction Convention

Power Direction Convention

For circuits with one source and one load, energy flows from the source to load and the direction of power transfer is from source to load. This probably seems obvious.

For circuits with multiple sources and loads, however, the direction of energy flow in some parts of the network may not be at all apparent. We therefore need to establish a clearly defined power transfer direction convention.

The convention says: The power to a load is positive when both the current and the power direction arrows pointing into the load, both have positive values, and the load voltage as the polarity indicated in Figure 4-10.

For a more detailed description, see page 107 section 4.4 in the text and **example 4-9 on page 108.**

Energy

The formula for energy is:

W = Pt	**where: W is energy** **P is power** **t is the time interval**

The most familiar example of energy usage is in our homes. We use energy to our appliances and lights.

A 100 watt light bulb uses 100 watts of power. If we run the100 watt lightbulb for one hour , the energy consumed is

$$W = Pt = (100W)(1hr) = 100\ Wh\ (watthours)$$

If we run an 1500 watt electric heater for 12 hours, the energy consumed is:

$$W = Pt = (1500W)(12hr) = 18{,}000\ Wh\ (watthours)$$

This example illustrates that the watt power is too small unit for practical purposes. For this reason we use kilowatt-hours (kWh) A kilowatt-hour simply 1000 watt hours.

$$\text{energy}_{(kWh)} = \frac{\text{energy}_{(Wh)}}{1000}$$

For the example above W = 18 kWh. In our area, this is the unit that would appear on your utility bill.

Fig.4-11

A standard watt hour meter. Newer models are electronic and use digital readouts.

Example 4-10, 4-11
Page 109 R & M

Energy & Efficiency

The law of conservation of energy states that energy can neither be created nor destroyed, but instead converted from one form to another.

In our case, we've seen electrical energy converted into heat energy by a resistor. In the case of a motor, electrical energy is converted into several types of energy simultaneously. Mechanical energy is produced along with heat.

Efficiency

Poor efficiency results in wasted energy and higher costs. The heat produced by our motor in the example above is wasted energy.

An inefficient piece of electronic gear generates more heat than an efficient one, and this heat must be removed, resulting in increased costs for fans, heat sinks, etc.

Efficiency is simply the ratio of power output to power input and is usually expressed as a percentage.

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

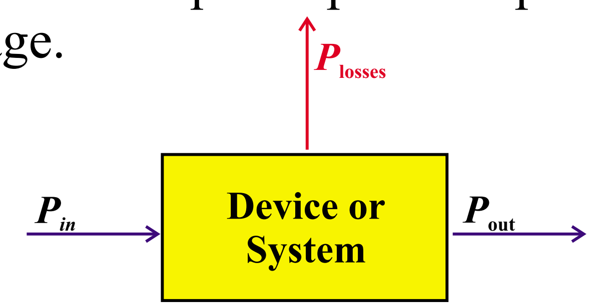


Fig. 4-11 Input power equals output power plus losses

The efficiency of equipment and machines varies greatly. Large power transformers can have efficiencies > 98 %. Some electronic amplifiers and have efficiencies lower than 50%.

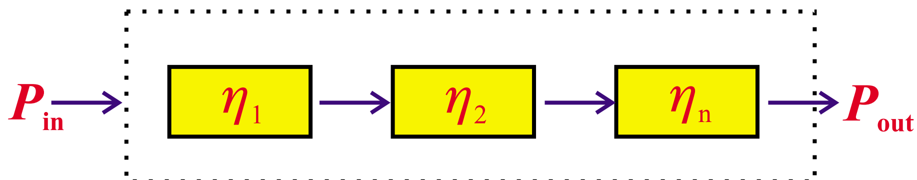
Note that efficiency will always be less than 100 %.

Examples 4-12, 4-13, Page 111-112 R & M

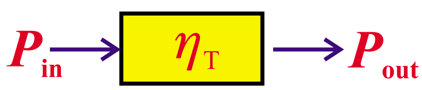
Efficiency Of Cascaded Systems

For systems with subsystems or components in cascade, we find the overall efficiency by multiplying the efficiencies of each individual part.

$$\eta_T = \eta_1 \text{ x } \eta_2 \text{ x } \eta_3 \text{ x } \ldots\ldots \text{ x } \eta_n$$



(a) cascaded system



(b) equivalent of (a)

Examples 4-14, 4-15, 4-16 Page 112-113 R & M