Lecture 1. **Voltage, Current, Power, Series Resistance, Parallel Resistance, and Diodes**

When you start to deal with electronics there are three main concepts to start with:

Name	Symbol	Unit
Voltage	V	volt
Current	I	ampere
Power	W	watt

Voltage is defined as the amount of work done or the energy required (in joules) in moving a unit of positive charge (1 coulomb) from a lower potential to a higher potential. Voltage is also called potential difference (PD) or electromotive force (emf). When you measure voltage you must have two points to compare, one of them being the reference point. When measuring the voltage drop on a circuit component it is sometimes called measuring the potential across that component.

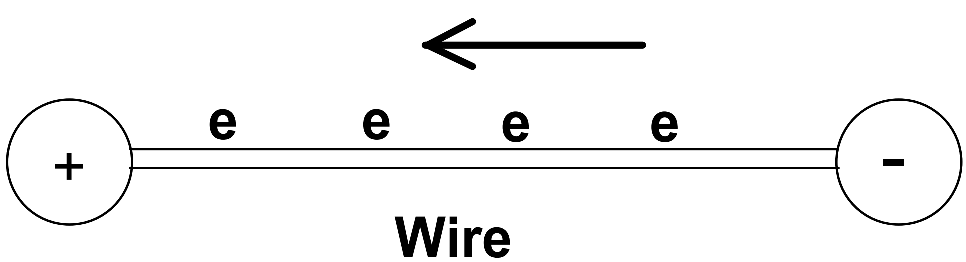
1 volt = 1 joule/coulomb

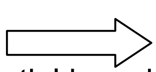
Voltage may be considered electrical pressure. It is analogous to water pressure in a municipal water supply. A battery is to voltage as a pump is to water pressure.

Current is the amount of electric charge (coulombs) flowing past a specific point in a conductor over an interval of one second.

1 ampere = 1 coulomb/second

Electron flow is from a lower potential to a higher potential.

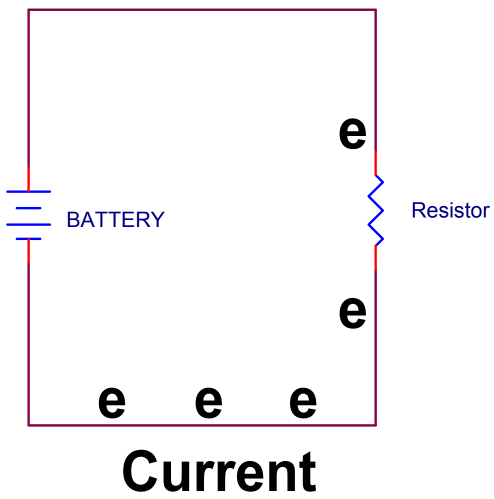


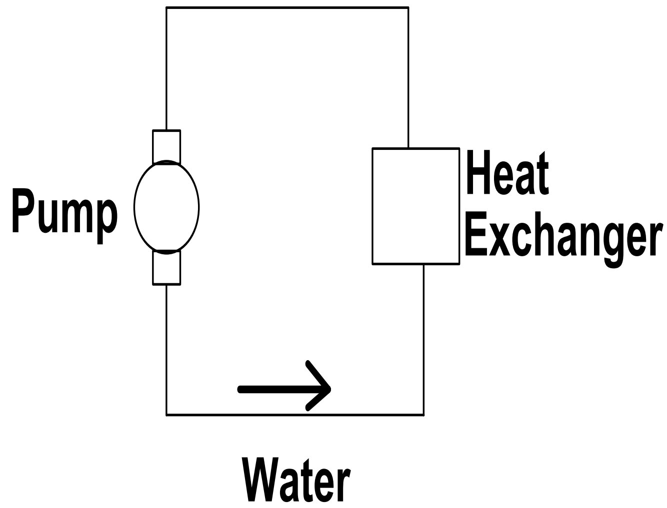
Current flow  is conventionally thought to flow from the positive to the negative potential in a circuit. This is due to belief of earlier scientists.

Power is the rate at which energy is used in an element.

1 watt = 1 joule/second

Voltage can be considered to be electrical pressure. You can think of a pump and a battery as equivalent.





Voltage is the pressure used to push the current through the circuit. Current is the charge that moves through the circuit.

Making voltage measurements requires two points of reference.

Basic Electrical Laws

Ohm's Law $$V = I * R$$

Ohm's Law is the basis for which all the other parameters may be determined.

Kirchoff's Voltage Law $$\sum V = 0$$

Kirchoff's Voltage Law is derived from the laws of the conservation of energy. In a circuit if you trace a path from a known starting point and include all the components necessary for an analysis and end at the starting point, this is called a loop. If you sum all the voltages in that loop the sum will equal zero volts. Typically in a circuit there is a power supply, either AC or DC. For Kirchoff's Law to be valid the sum of the voltages across each component must equal the power supply value. This is why it is important to make sure the polarities on the components are accurate.

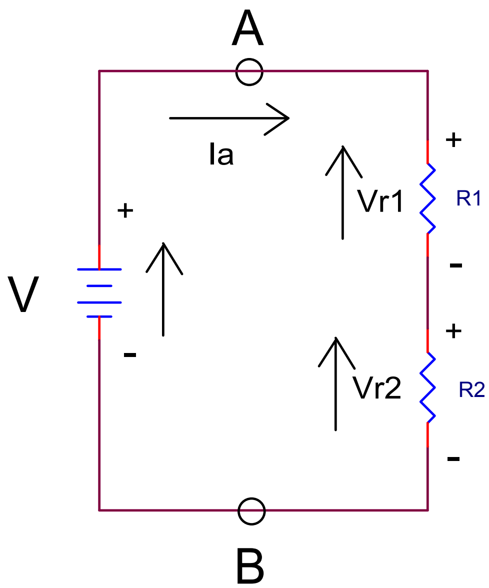
Kirchoff's Current Law $$I = I_1 + I_2 + I_3 + \cdots I_n$$

The point in a circuit where components are connected together is called a node. Kirchoff's Current Law says that the value of the current flowing into a node is equal to the sum of the currents flowing out of the node. Again this preserves the conservation of energy.

Circuits

Series

$$R_{eq} = R_1 + R_2 + R_3 + \cdots R_n$$



$$V_{R_{TOTAL}} = V_{R_1} + V_{R_2}$$

$$V = V_{R_{TOTAL}}$$

$$V = V_{R_1} + V_{R_2}$$

From Kirchoff's Law

$$V - V_{R_1} - V_{R_2} = 0V$$

From Ohm's Law

$$V_{R_1} = I_a R_1$$

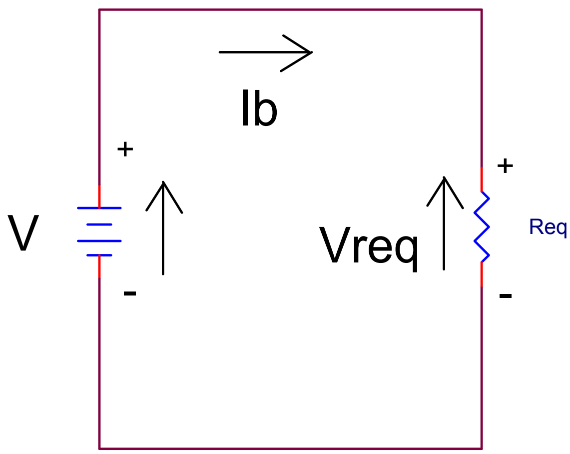
$$V_{R_2} = I_a R_2$$

Substituting in the above equation gives

$$V - I_a R_1 - I_a R_2 = 0V$$

$$I_a = \frac{V}{R_1 + R_2}$$

Equivalent Circuit



$$I_b = \frac{V}{R_{eq}}$$

Since we have the same current in each circuit we can say

$$I_a = I_b$$

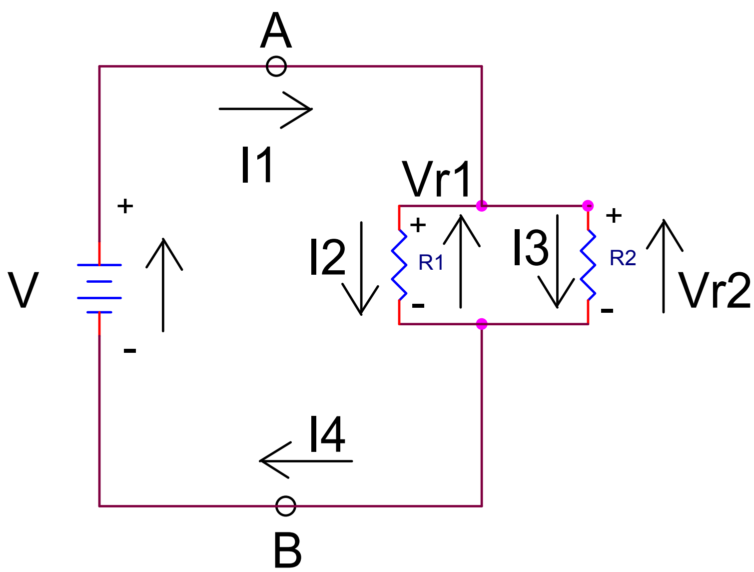
Substituting for I_a and I_b gives

$$\frac{V}{R_1 + R_2} = \frac{V}{R_{eq}}, \therefore \; R_{eq} = R_1 + R_2$$

since we have an equality and both the numerators and denominators are equal.

Parallel Resistance

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$$



By inspection you can see that $I_1 = I_4$.

From Kirchoff's Current Law

$$I_1 = I_2 + I_3$$

From Kirchoff's Voltage, using a loop from the battery, through the R_1 resistor and back to the battery gives

$$V - V_{R_1} = 0V, \;\therefore\; V - I_2 R_1 = 0V$$

$$I_2 = \frac{V}{R_1}$$

Taking a loop from the battery through R_2 gives

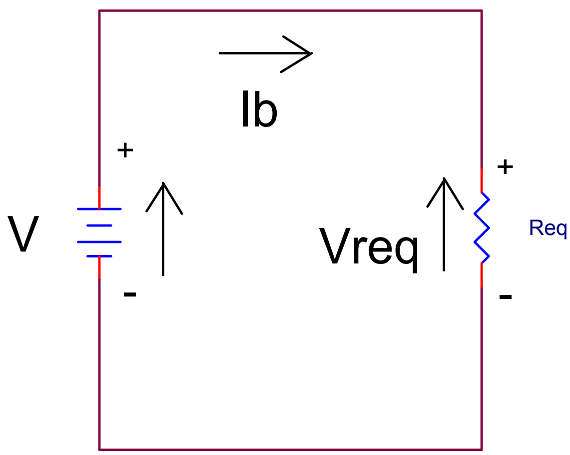
$$V - I_3 R_2 = 0V$$

$$I_3 = \frac{V}{R_2}$$

Substituting I_2 and I_3 in $I_1 = I_2 + I_3$ gives

$$I_1 = \frac{V}{R_1} + \frac{V}{R_2}$$

Equivalent Circuit



$$I_b = \frac{V}{R_{eq}}$$

Since $I_1 = I_b$ we can equate the two equations giving

$$\frac{V}{R_1} + \frac{V}{R_2} = \frac{V}{R_{eq}}$$

Again, due to the equality, since the numerators are equal the denominators are equal and we get

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

To simplify this fraction find the LCD

$$\frac{1}{R_{eq}} = \frac{\frac{R_1 R_2}{R_1} + \frac{R_1 R_2}{R_2}}{R_1 R_2}$$

$$= \frac{R_1 + R_2}{R_1 R_2}$$

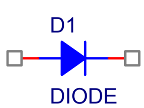
What you really want is R_{eq} so just invert the above equation to get the more easily recognized equation for parallel resistance

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

DIODES

A diode can be considered an electrical one-way valve. They are usually made from silicon (SD), germanium (GE), or gallium arsenide (GaAs). They each have their own operating characteristics. For our discussion we will assume we are working with silicon diodes.

A diode is a two terminal device.

ANODE 

CATHODE

It is made from two types of material called P and N. The anode is made from P material, which has been doped to have an excess of positive ions. The cathode has been doped to have an excess of negative ions.

Current conducts easily from the anode to the cathode and not easily from the cathode to the anode.

The diode you will get in the lab has a stripe on one end. This is the cathode.
V-I Curve

the majority carrier flow will increase exponentially with increasing forward bias as indicated in Fig. 1.27.

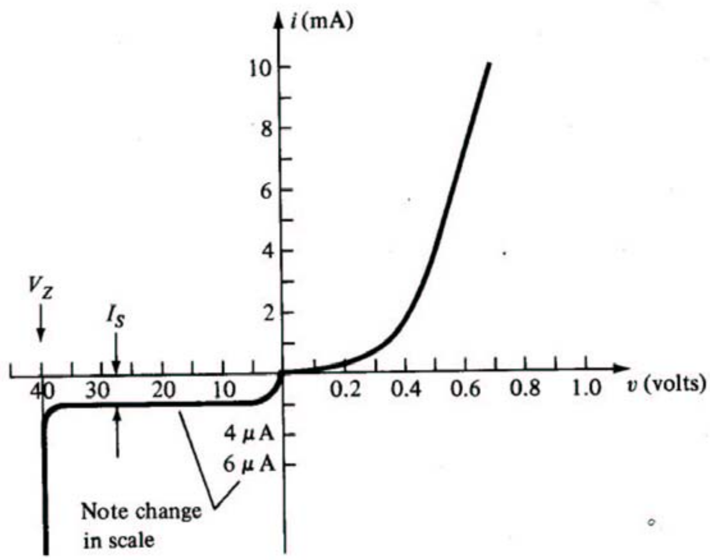
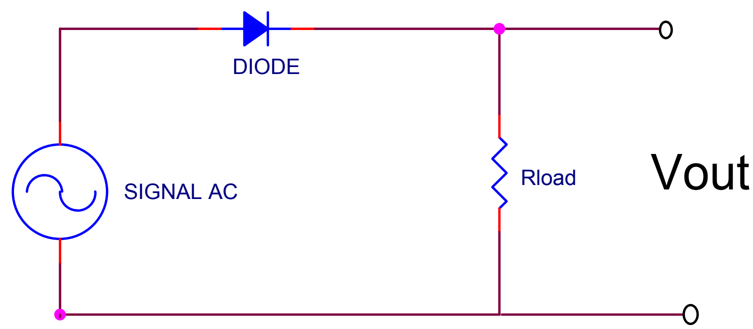


FIG. 1.27
Semiconductor diode characteristics.

As the potential across the diode increases it is easier for the current to flow from the P to the N region. At the point where the current flows exponentially is called V_T, the threshold voltage. Current will flow in the reverse direction when you reach the Reverse Breakdown Voltage, V_Z. In this region you are literally ripping electrons away from the N ions and forcing them to combine with the P material. Usually this occurs by applying 100 volts or more to the diode.

Diodes can be used to convert AC voltage to DC voltage. This is called rectification. You will study a half wave rectifier in lab.



HALF WAVE RECITIFIER CIRCUIT

Since a diode can only conduct when V_T is > 0.6V the output looks like

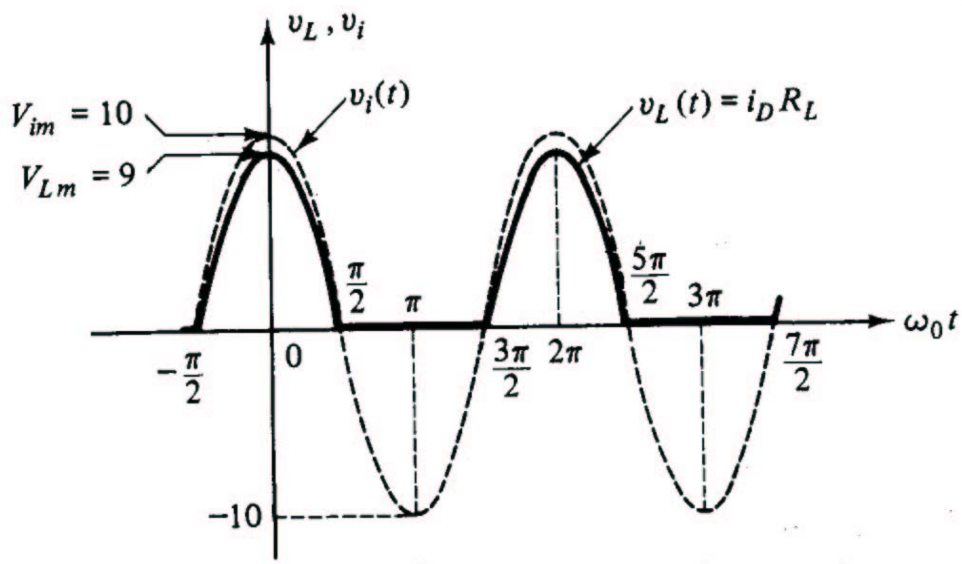


Figure 1.1-5 Waveforms in the rectifier circuit of Example 1.1-1.