LECTURE 3

Metals, Semiconductors and Insulators

Metals are good conductors of electricity because they have electrons that are 'free'. We are normally used to thinking of electrons as attached to the nucleus - each nucleus has it's own set of electrons. This picture is strictly correct only for insulators. In metals the electrons are free to roam about pretty much throughout the piece of metal. However the atoms (i.e. the ions) that are left behind stay and vibrate with the vibration increasing in amplitude as the temperature raises. This vibration provides a hindrance to the motion of electrons thus causing 'resistance'.

In semiconductors the gap between the allowed bands of energies is small and is comparable to $k_B T$ the thermal energy. Therefore an increase in temperature enables the electrons to jump this energy gap and collect in the energy band where there are empty states available. An increase in the the kinetic energy of these electrons when a voltage is applied is possible because the electrons can get into these empty states.

Q: Should we be worried about using semiconductor chips outside in a frost ?

In an insulator there are no empty electron energy states available. Consequently application of a voltage produces no extra motion of the electrons.

In a superconductor there is no resistance to the motion of electrons.

POWER - Hindrance to the motion of a mechanical object arises because of friction. For instance in the case of a block sliding down an inclined plane we know that the kinetic energy is lost and converted to heat. The same analogy works for the motion of electrons in a resistive material. The kinetic energy of the electrons is converted to heat. This is the principle behind room heaters, toaster ovens etc. Such gadgets are normally rated by their POWER. Power is simply the rate at which electrical energy is dissipated or generated. For the time being we will simply state that power P is given by the equation:

$$\mathbf{P = V \cdot I}$$

The unit of power is a watt; 1 watt = 1 amp x 1 volt.

Using Ohm's law we can rewrite Power in terms of the resistance R:

$$\mathbf{P = (R.I) \cdot I = I^2 R = V^2 / R}$$