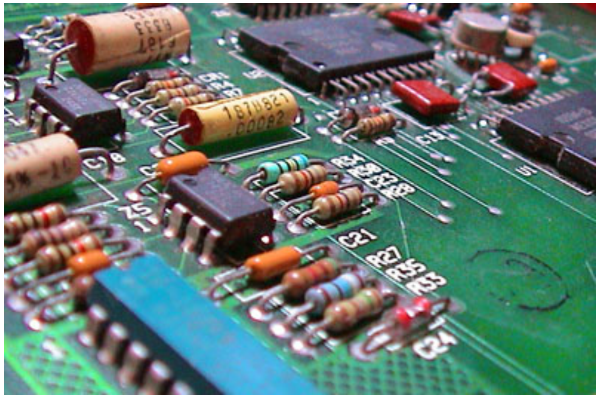
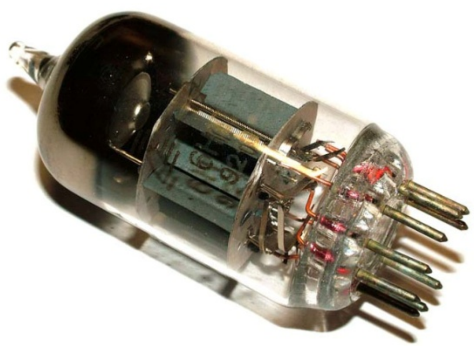
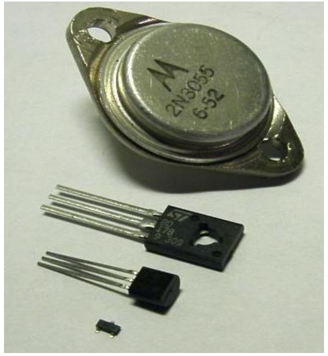
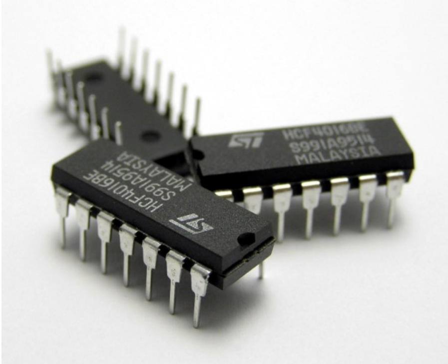
# Electronics

***Electronics means….“The branch of physics and technology concerned with the design of circuits using transistors and microchips , and with the behaviour and movement of electrons in a semiconductor , conductor, vacuum or gas .”***



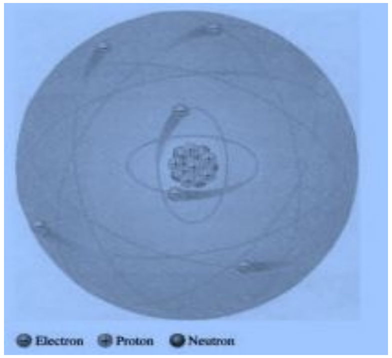






# Atomic structure

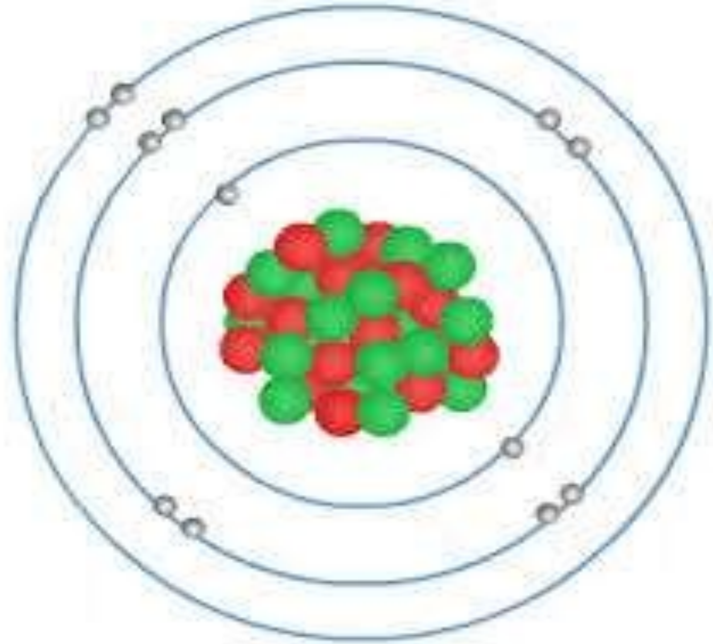
- An atom is the smallest particle of an element that retains the characteristics of that element.
- Each element has unique atomic structure
- Atoms have planetary structure consists of

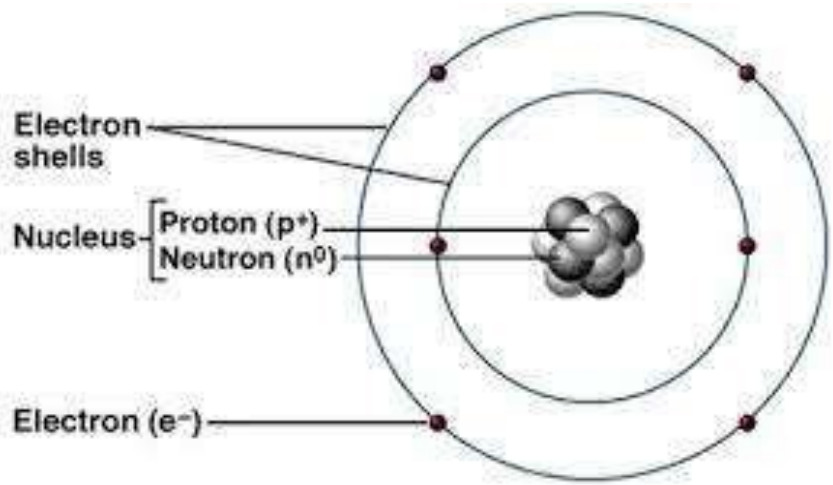



Central nucleus

- Surrounded by orbiting electrons (negatively charged),
- Consists of protons (positively charged) and
- Neutrons (uncharged)

- Orbit Electrons orbit the nucleus at certain discrete distances from the nucleus.
- Electrons near the nucleus have the less energy than those of the more distant orbits.
- Energy level: Each distance orbit from nucleus corresponds to a certain energy level

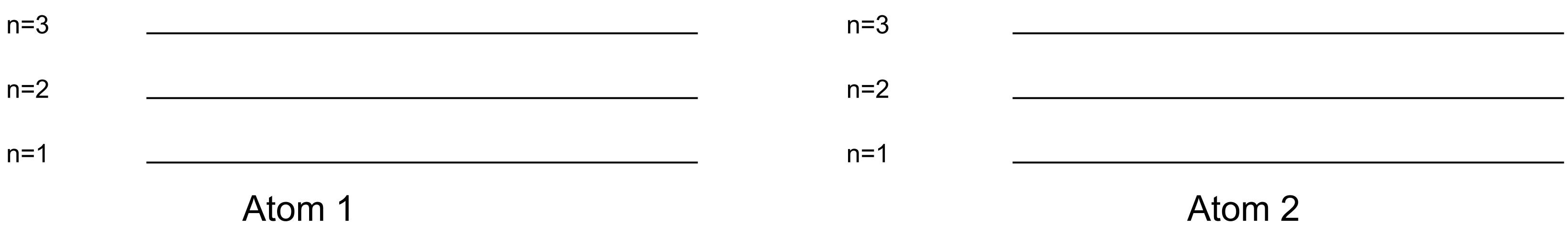



Electron shells
Nucleus
Proton (p+)
Neutron (n0)
Electron (e−)

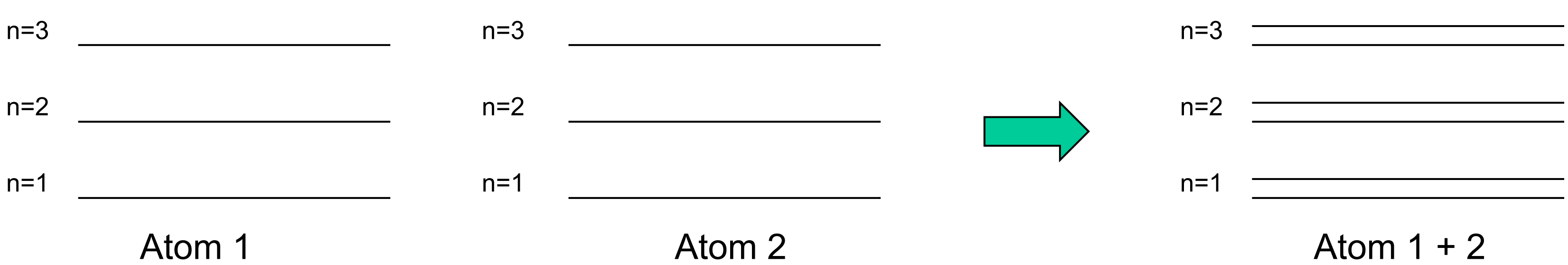
- Shells : orbits are grouped in to energy bands shells are designated 1,2,3 and so on. . .Or K,L, M…
- Force of attraction between positively charged nucleus and negatively charged electrons decreases with increasing distance from nucleus.
- Higher energy level electrons are loosely bounded whereas electrons close to nucleus are tightly bounded.
- The no of electrons(Ne) in each shell of an atom can be expressed by the formula : $Ne = 2n^2$
- Electrons jump to higher orbit by gaining energy and fall back to lower orbit by emitting light or heat.

# Energy band theory of crystal

- A solid is formed by bringing together isolated single atoms.
- Consider the combination of two atoms. If the atoms are far apart there is no interaction between them and the energy levels are the same for each atom. The numbers of levels at a particular energy is simply doubled.




- If the atoms are close together the electron wave functions will overlap and the energy levels are shifted with respect to each other.



# Energy band theory of crystal

- In single isolated atom, there are single energy levels, in solids, the atoms are arranged in a systematic space lattice and hence atoms are generally influenced by neighbouring atoms.
- The closeness of atoms results in intermixing of electrons of neighbouring atoms, i.e. for the valence electrons in the outermost shell which are not strongly bound by the nucleus.
- According to Pauli exclusion principle, no two electrons can have same energy. So electrons in orbit have slightly different energies.
- Due to inter mixing, the number of permissible energy levels increases. Hence in case of solids, instead of single energy levels there will be bands of energy levels.
- A solid will have millions of atoms close together in a lattice so these energy levels will creates bands each separated by a gap.
- **The range of energies possesed by an electron in a crystal is called as energy band.**

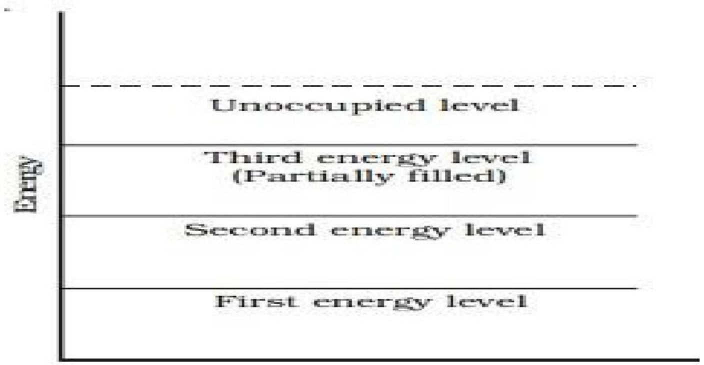



Fig a Energy levels of a single isolated atom

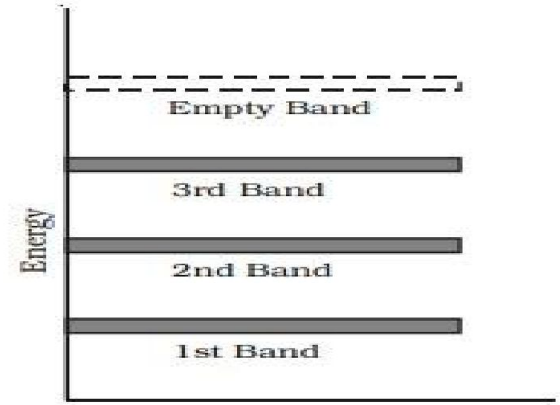
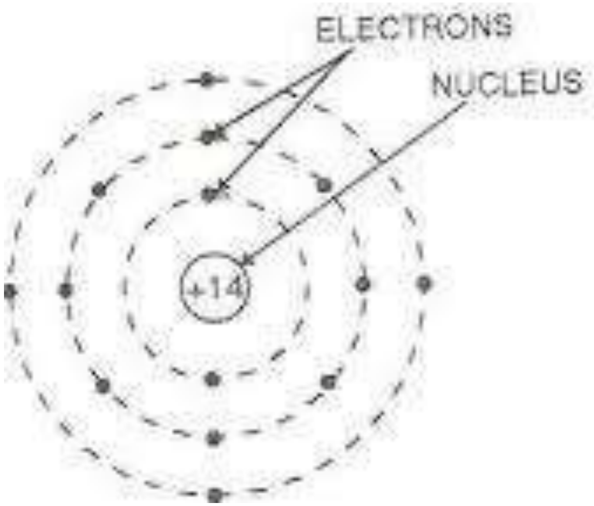
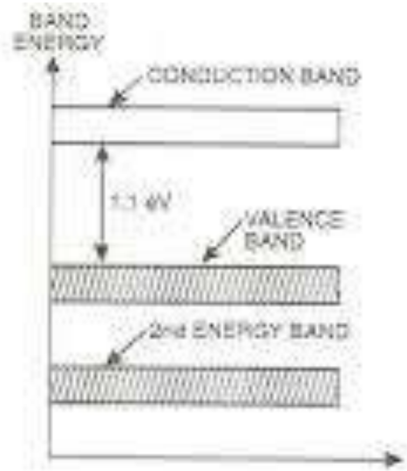
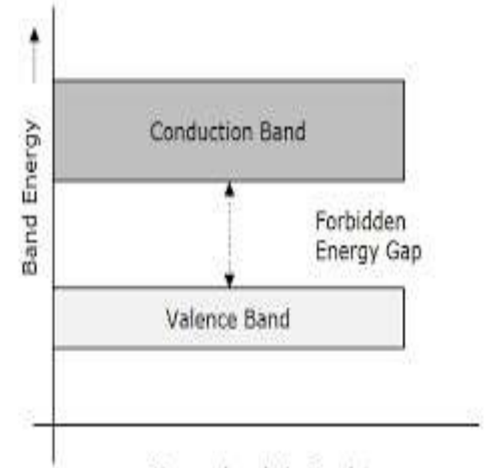



Fig b Energy bands in a solid

# Energy Band



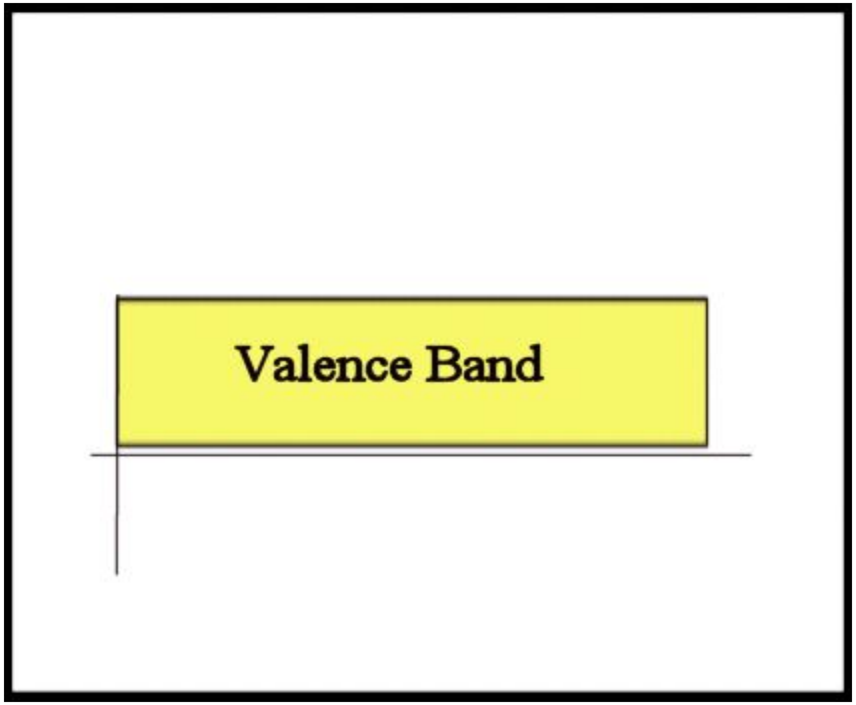

Energy bands in Insulators

- The range of energies possesed by valance electrons are known as Valance energy band (V.B).

- The range of energy possesed by free/conduction electrons are known as conduction energy band (C.B).

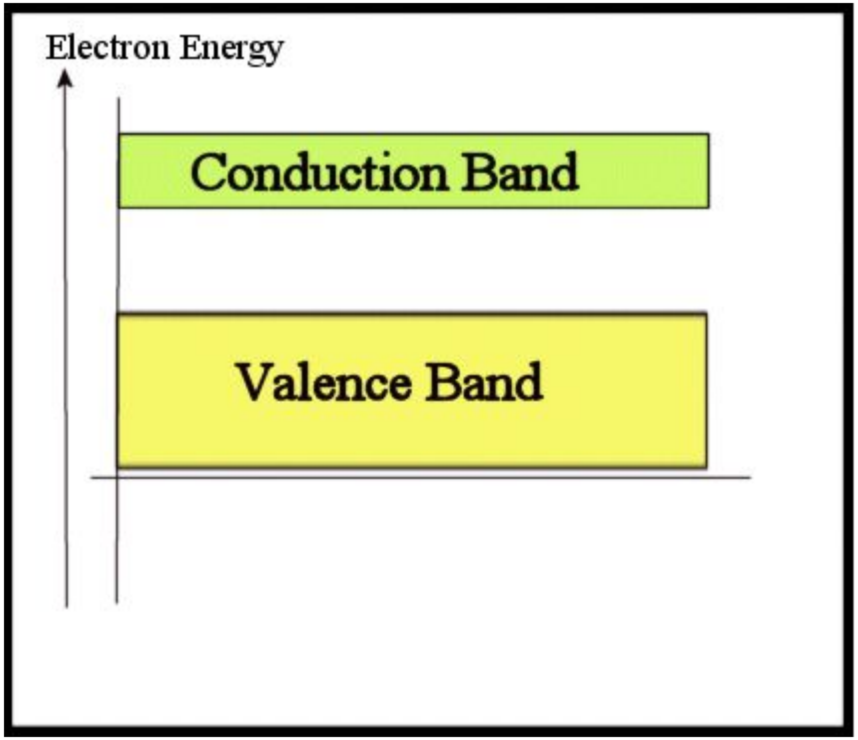
- The separation between conduction energy band and valance energy band is known as forbiden energy band gap (Eg).

# Valance band



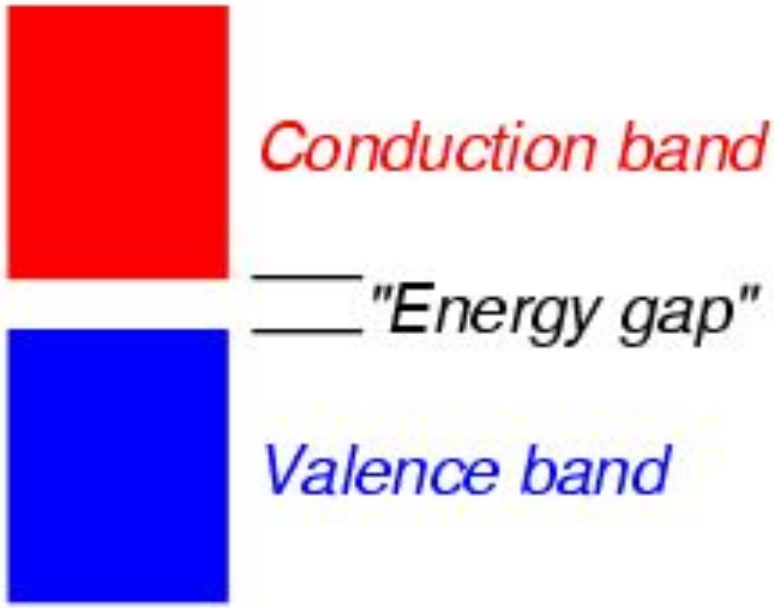

The highest occupied energy band is called the valence band. Most electrons remain bound to the atoms in this band.

# Conduction band



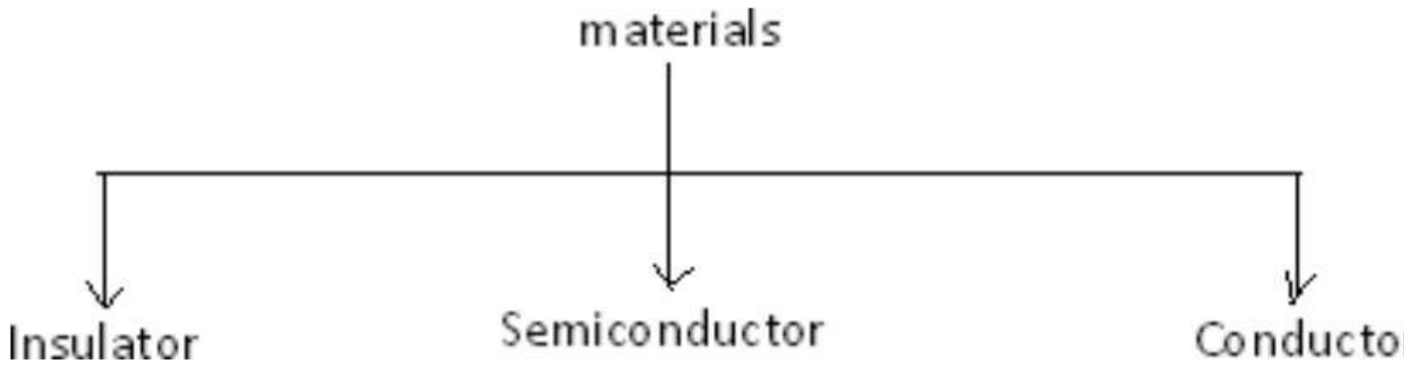

The conduction band is the band of orbitals that are high in energy and are generally empty.It is the band that accepts the electrons from the valence band.

# Energy Gap



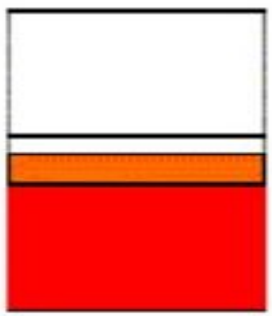

The “leap” required for electrons from the Valence Band to enter the Conduction Band is called as forbidden energy gap.

# Classification of Solids



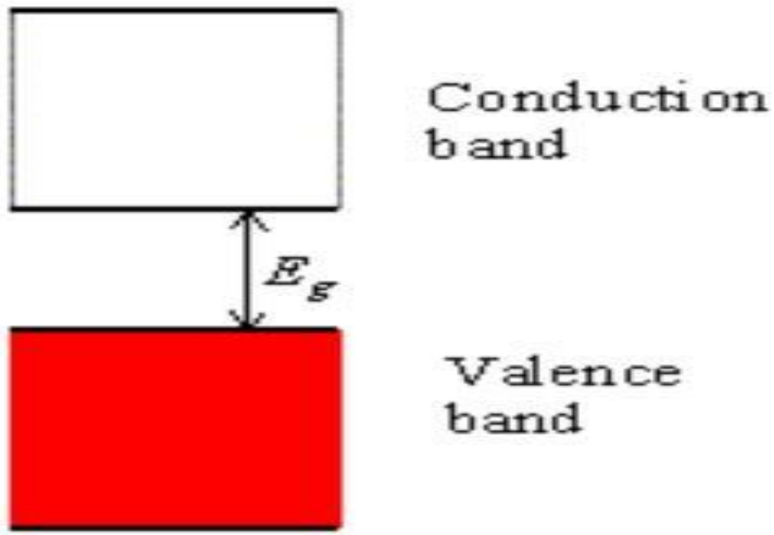
# Conductor

- Conductor: In this case the easily detached valance electrons are given up by the atoms and create more free electrons which easily allow the flow of current through them under the influence of applied voltage. Example: copper, gold etc
- A large number of free electrons are available in conduction band.
- Conduction band and valance band are overlapped.
- A slight potential difference across material cause the flow of carrier to constitute current in it.
- Conductor shows positive temperature coefficient of resistance



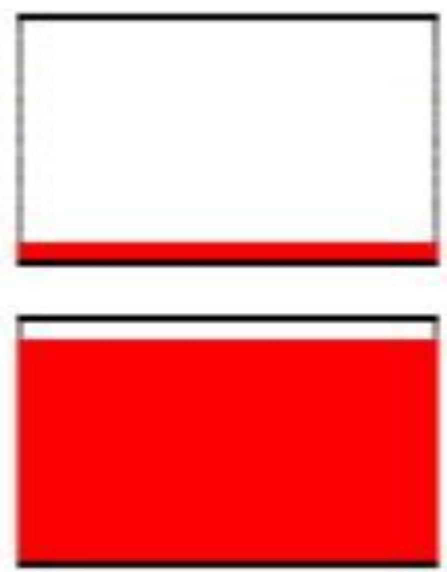
# Insulator

- The valance shell electrons are so strongly attached to the atoms that no charge carrier are available for current flow.
- Example: Diamond, Glass, wood, paper etc
- In this type of materials V.B are full and C.B is empty.
- Energy gap is very large

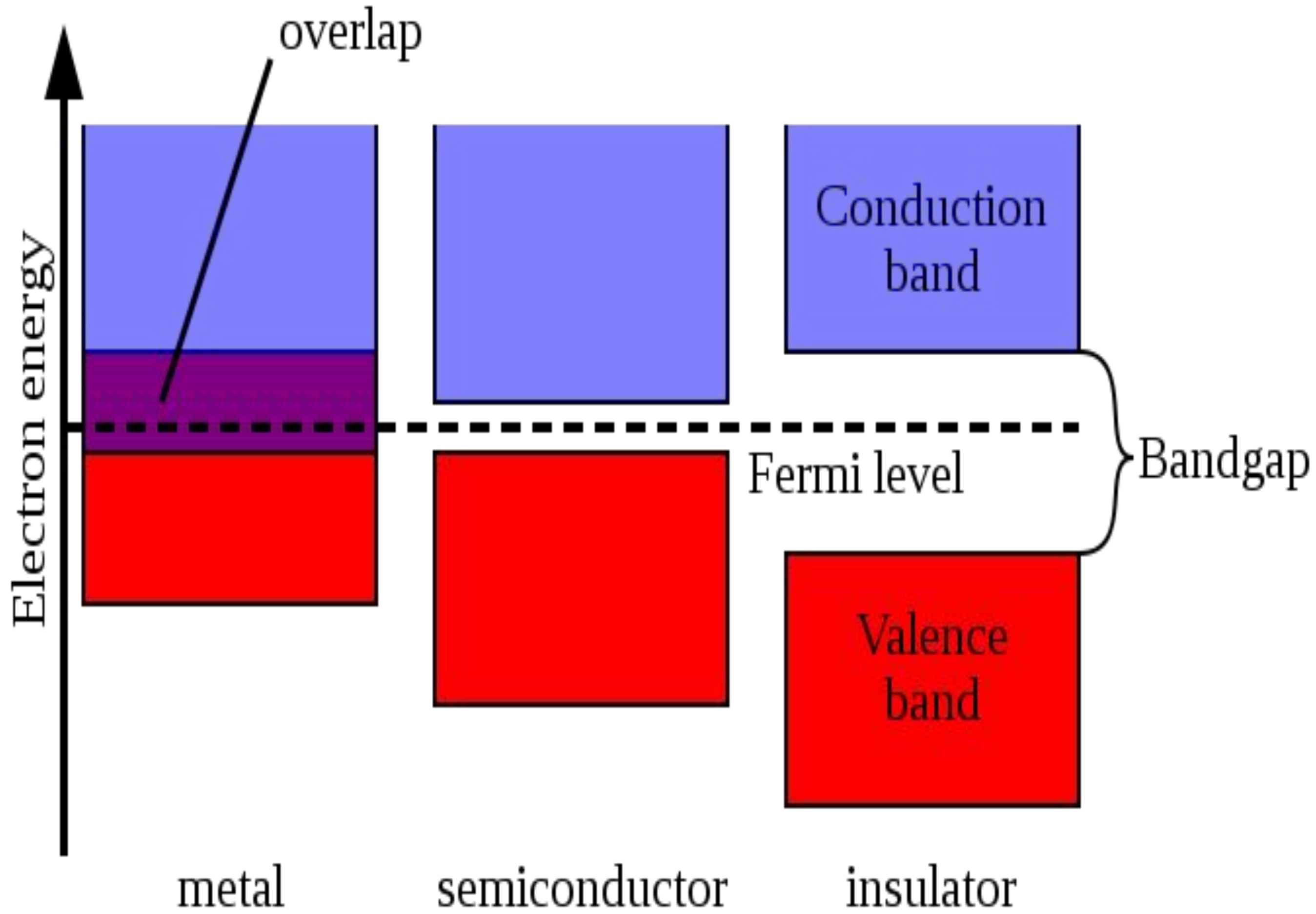


# Semiconductor

- Those substances which have conductivity lies between conductor and insulator.
- Example: Graphite, Silicon, Germanium, GaAs, GaP
- The energy gap between C.B and V.B are very less.
- Very small energy is required to move electrons from V.B to C.B.
- Semiconductor shows negative temperature coefficient of resistance

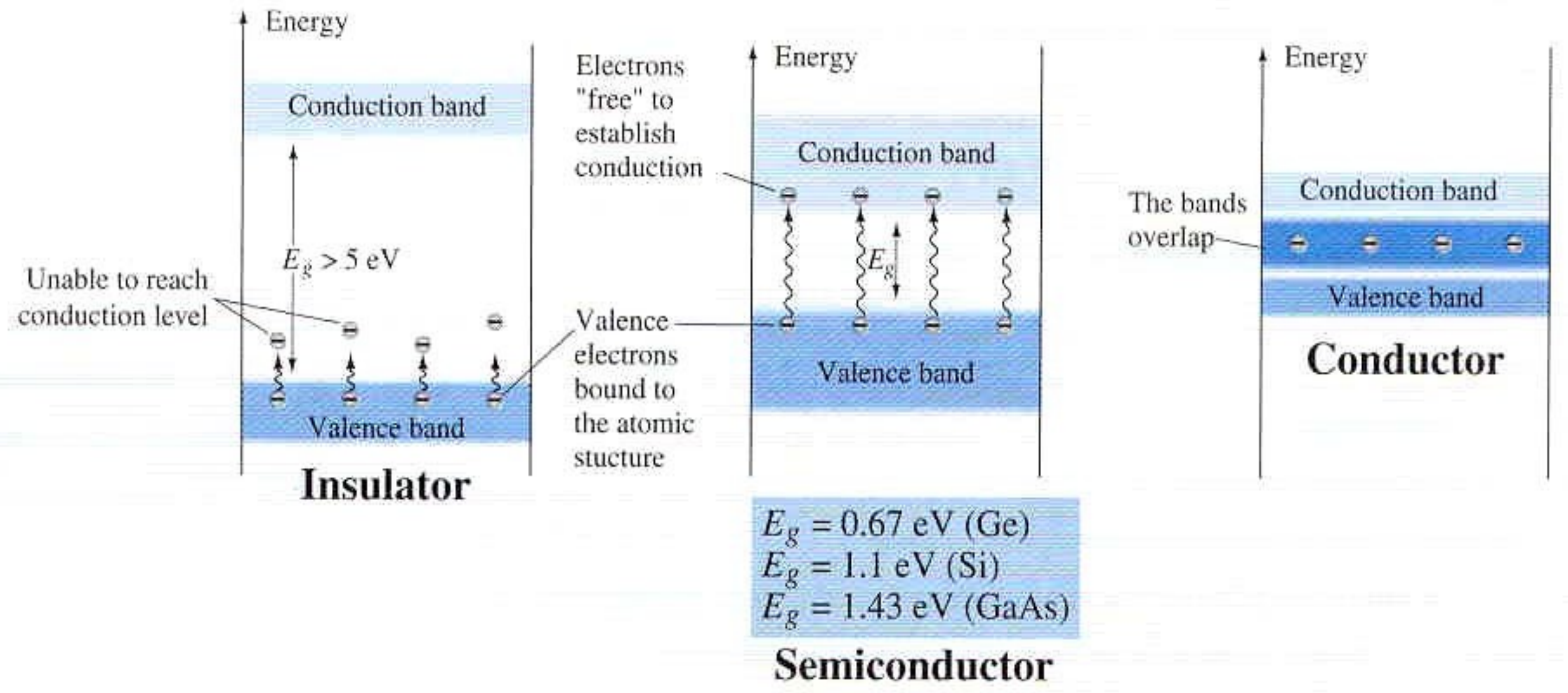


# Conductors,Insulators,Semiconductors



# Introduction to Semiconductor Theory

## Energy level diagrams

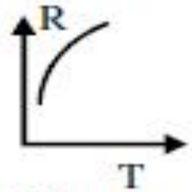
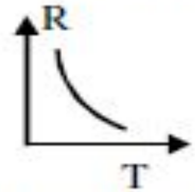
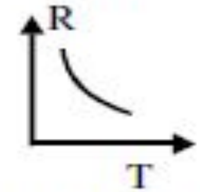



(b)

Eg is the energy required to shift the electros from valance band to conduction band

eV(electronVolt)= It is unit of energy, equal to the energy acquired by an electron accelerating through a potential difference of one volt.

# Comparison of Metal, Semiconductor and Insulator

| S. No. | Parameters of comparison | Metals (Conductors) | Semiconductors | Insulators |
|---|---|---|---|---|
| 1. | Forbidden gap ($E_G$) | $E_G = 0$<br>No gap | $E_G < 3$ eV<br>Medium gap | $E_G > 5$ eV<br>Large gap |
| 2. | Effect of temperature on resistance | <br>R-increases as T increases | <br>R-decreases as T increases | <br>R-decreases as T increases |
| 3. | Temperature coefficient of resistance | Positive | Negative | Negative |
| 4. | Conductivity ($\sigma$) at room temperature (300 °K) | Very high<br>$\sigma \geq 10^3/(\Omega m)$ | Moderate<br>$\sigma = 10^{-8}$–$10^3/(\Omega m)$ | Very low<br>$\sigma < 10^{-8}/(\Omega m)$ |
| 5. | Resistivity | Very low | Moderate | Very high |
| 6. | Number of electrons for conduction | Very large<br>($>10^{23}$ cc) | Moderate<br>($10^{11}$–$10^{20}$/cc) | Almost zero or very less |
| 7. | Applications | As conductors, wires, bus bars | Semiconductor devices | Capacitors insulation for wires |
| 8. | Examples | Al, Cu | Si, Ge, GaAs, InP, etc. | paper, mica, glass, etc. |

- Unit of Energy: An electron moving through 1Volt potential difference will gain some kinetic energy which is expressed in eV.
- $1eV = 1.6\times10^{-19} \times 1V = 1.6\times10^{-19}$ Joule