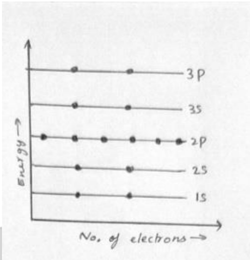
Assignment-1

Subject code: BECT 101

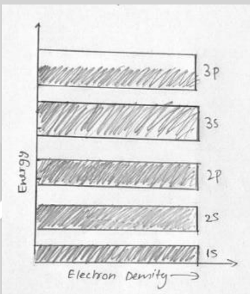
Answer the following question: -

1. On the basis of energy band gap theory, explain the formation of valance band in solid silicon. Classify solids on the basis of energy band theory.

If we consider energy diagram for electrons in different orbitals for isolated silicon atom with electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^2$:



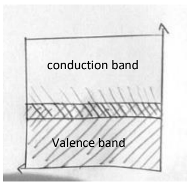
We get energy lines or energy levels, because in isolated state electrons of silicon atom only influenced by attractive force of nucleus and repulsive force of other electrons due to which electrons present in same orbital have same energy and have same energy level diagram for every atom considered in isolated state.



In case of solid silicon, atoms are closely packed due to which electrons present in orbital of atom of interest not only influence by its nucleus but also by the nucleus of other atoms. Due to energy level gets split into energy bands, this phenomenon is called splitting of energy levels. It happens because electrons belonging to same type of orbital belonging to different atoms differ in energy. Thus, energies of electrons present in valence shell gets split and form band called valence band.

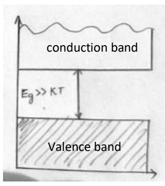
On the basis of Energy band diagram solids classified as:

Metals



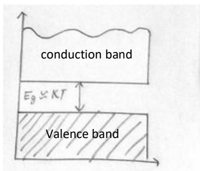
In metals conduction band and valence band overlap with each other.

Insulators



In insulators there is wide Energy gap between conduction and valence band.

Semiconductors



In semiconductors the energy gap is very less as compared to insulators.

2. Explain the difference between intrinsic and extrinsic semiconductor.

S.no.	Intrinsic semiconductor	Extrinsic semiconductor
1	These are pure semiconductor.	These are impure semiconductor.
2	Number of holes and electrons are equal.	Number of holes and electrons are not equal.
3	Conductivity is low	They have better conductivity then intrinsic.
4	Conductivity depends on temperature (i.e., conductivity $\propto$ temperature.)	Conductivity of extrinsic semiconduction depend on temperature and also the doped impurity.
5	E.g., Pure Si, pure Ge etc.	E.g., Si-As, Ge-Sb etc.

3. What happens to the conductivity of the SC with the rise in temperature?

In case of semiconductor increase in temperature increases collisions between electrons, due to which electrons gain enough energy so that it can jump to conduction band, which result in formation of new electron-hole pair. Thus, this phenomenon favours increase in conductivity.

But increase in temperature increases random motion of electron due to which conductivity decrease as temperature rises.

According to results it is seen that increase in conductivity is more prominent then decrease in conductivity. Hence, rise in temperature favours conductivity.

$$\text{Conductivity} \propto \text{Temperature}$$

4. Discuss in brief Drift Current, Diffusion Current and Mobility.

<u>Diffusion Current:</u> in p-n junction, concentration of holes is more in p-side and concentration of electron is more in n-side due to which a process called diffusion take place, in which electrons from n-side starts diffusing/moving from n-side to p-side, this movement of charge carriers is known as diffusion current, due to this movement a layer is formed between p-n junction called depletion layer.

<u>Drift current:</u> Due to temperature, as thermal collisions increase then occasionally an electron jumps to conduction band and an electron-hole crease. Also, as an electron from conduction band loses energy it jumps back to fill up hole, at this time electron-hole pair gets destroyed. These processes is common in material but, as electron jumps from depletion layer due to +ve charge on n-side it gets pulled towards n-side and hole due to -ve charge on p-side it gets pulled towards p-side and this is permanent. As electron-hole pair continuously created in depletion region this is regular flow of electron towards n-side and hole towards p-side. This makes current flow from n-side to p-side, this current is known as drift current.

<u>Mobility:</u> As external electric field is applied across p-n junction diode, then charge carriers (i.e., electrons and holes) start drifting across diode with some drift velocity which is directly proportional to applied electric field.

$$\text{i.e.,} \quad V_d \propto E$$

$$\text{or} \quad V_d = \mu E$$

$$\text{also,} \quad \mu = \frac{Vd}{E}$$

Here, μ is called mobility of charge carrier.

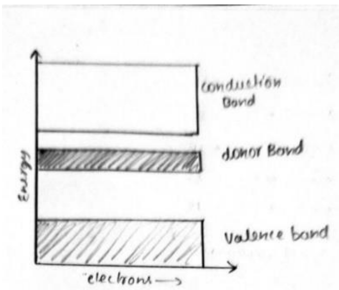
Thus, mobility can be defined as the ration of drift velocity and External applied electric field.

For electron, $\mu_e = V_e/E$

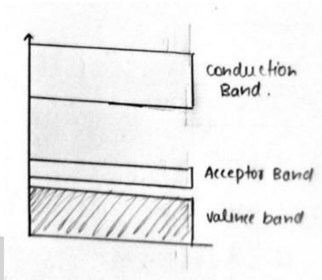
For holes, $\mu_h = V_h/E$

5. Sketch the Energy Band structure for (i) N type (ii) P type Extrinsic SC. Indicate the position of donor and accepter levels.

N-Type semiconductor



P-Type semiconductor



6. Why Si is preferred over Ge in semiconductors?

1. <u>Less back current:</u>

Si diode have range of back current in nano-amps where as back current in germanium diode have range in micro-amps, due to which Si based diode can tolerate high power (over 50W) and Ge diode barely survive on high power application (around 10W).

2. <u>High reverse breakdown voltage:</u>

Si diodes have significantly more breakdown voltage then Ge based diode.

3. <u>Temperature stability:</u>

Si diodes are more stable at high temperatures where as Ge diode are sensitive to temperature and can withstand up to 70degrees C.

4. <u>Large forward current:</u>

Si diodes may have forward current in the range of 10 amps, where as Ge-diodes have very less forward current as compared to Si-diodes, which make Si-diodes useful for high current application.

5. <u>Abundancy:</u>

Si is fairly more abundant in nature as compared to Ge, due to which it is easy to accessible.

6. <u>Cost effective:</u>

Si is cheaper than Ge due to its more abundancy.

7. Explain the formation of depletion layer in p-n junction diode.

In p-n junction diode, p-side of junction have holes as majority charge carrier and electrons are minority charge carrier and n-side of junction have electrons as majority charge carrier and holes as minority charge carrier.

Due to this difference in concentration of charge carrier electrons start diffusing (or moving) from n-side to p-side of diode and holes starts diffusing from p-side to n-side.

Initially p-side and n-side of diode is neutral but, as diffusion continues, -ve charge on p-side and +ve charge on n-side starts developing and a potential between both the diode develops. This potential start slowing down the diffusion of charge carrier by repealing charge carrier, as diffusion process continues this potential keeps on increase till it acquires maximum value called as barrier potential, beyond this potential no further diffusion occurs and a region consisting of immobile charge carriers is formed between p-n junction diode called depletion layer or region.

8. Explain the V-I characteristics of p-n junction Diode. Explain the effect of temperature on V-I characteristics of a diode.

VI characteristics of PN junction diodes is a curve between the voltage and current through the circuit. Voltage is taken along the x-axis while the current is taken along the y-axis. The above graph is the VI characteristics curve of the PN junction diode. With the help of the curve, we can understand that there are three regions in which the diode works, and they are:

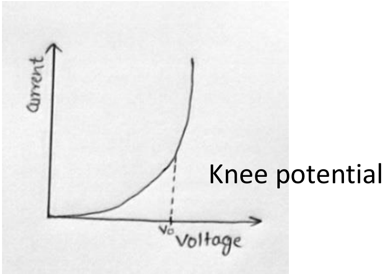
1. Zero Bias:

When the PN junction diode is under zero bias condition, there is no external voltage applied and this means that the potential barrier at the junction does not allow the flow of current.

2. Forward Bias

When the PN junction diode is under forward bias condition, the p-type is connected to the positive terminal while the n-type is connected to the negative terminal of the external voltage. When the diode is arranged in this manner, there is a reduction in the potential barrier.

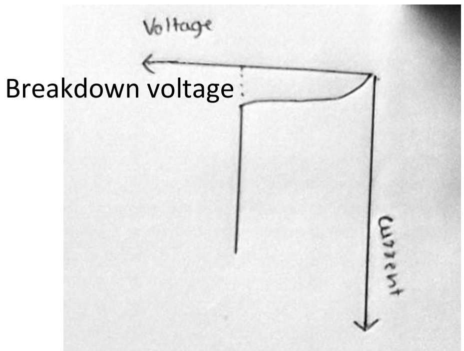
When the diode is in forward bias, the current increases slowly and the curve obtained is non-linear as the voltage applied to the diode is overcoming the potential barrier. Once the potential barrier is overcome by the diode, the diode behaves normally and the curve rises sharply as the external voltage increases and the curve obtained is linear.



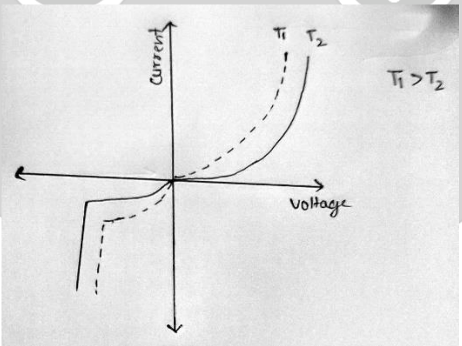
3. Reverse Bias

When the PN junction diode is under negative bias condition, the p-type is connected to the negative terminal while the n-type is connected to the positive terminal of the external voltage. This results in an increase in the potential barrier. Reverse saturation current flows in the beginning as minority carriers are present in the junction.

When the applied voltage is increased, the minority charges will have increased kinetic energy which affects the majority charges. This is the stage when the diode breaks down.



Effect of Temperature on V-I characteristic of p-n junction diode:



The forward characteristics shifts upwards with increase in temperature.

The reverse characteristics shifts downwards with the increase in temperature.

9. List the various Diode ratings and explain.

S.no.	Type of diode	Explanation	Ratings
1	Light Emitting Diode (L.E.D.)	When a conduction electron jumps back from conduction band to valence band, it emits some energy as photon, and if the	Current: 10mA – 30mA Voltage: 1.2v – 3.6v

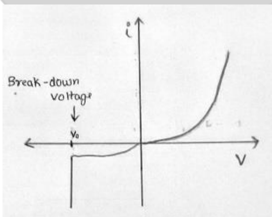
		wavelength of this photon is in the visible range (i.e., 400nm-800nm), then observer can see the emitted light or photon, such p-n junction diode is called **L.E.D.**	
2	Photodiode	**Photodiode** is a p-n junction which is controlled by the light intensity allowed to fall on it. When such light falls on the junction, new hole-electron pairs are created. The number of charge carriers increases; hence conductivity enhances.	Wavelength sensitivity: 940nm Reverse breakdown voltage: 32v Reverse Light current: 40μA
3	Zener diode	**Zener diode** is a special type of p-n junction, it works under breakdown condition to limit the voltage drop across it.	Voltage: 3v – 200v Current: 5mA – 10mA
4	Schottky Diode	A **Schottky diode** also known as the hot-carrier diode or Schottky barrier diode is a semiconductor diode formed by the junction of a semiconductor with a metal. Schottky diodes have a low forward voltage drop and a very fast switching action.	Forward voltage:150mV – 450mV

10. Explain Zener diode application as a shunt voltage regulator.

If the reverse bias voltage across p-n junction increased, at a particular voltage the reverse current show sudden increase to a large value, when this phenomenon happen it is said that **breakdown** of diode occurred.

A diode meant to operate in the breakdown region is called **avalanche diode** or **Zener diode**. Once the breakdown occurs, the potential difference across the diode does not increases even after the applied battery potential is increased. Such diodes are used to obtain constant voltage output.

The V-I characteristic of Zener diode as follows:



When Zener diode connected in parallel with a variable voltage source so that it is reverse biased, Zener diode conducts when the voltage reaches the diode’s reverse break-down voltage and voltage across Zener diode remain fixed. This property is very helpful to limit the voltage across a device by connecting it in parallel across Zener diode. Thus, voltage sensitive devices are connected in parallel across Zener diode to prevent from blowing up.