[APPLIED PHYSICS]

[MID-TERM]

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MID TERM ASSIGNMENT

Q1.

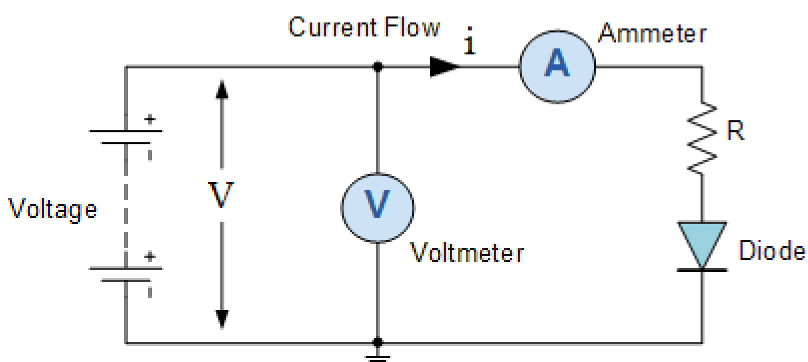
A). Discuss the significance of the knee of the characteristics curve in forward bias?

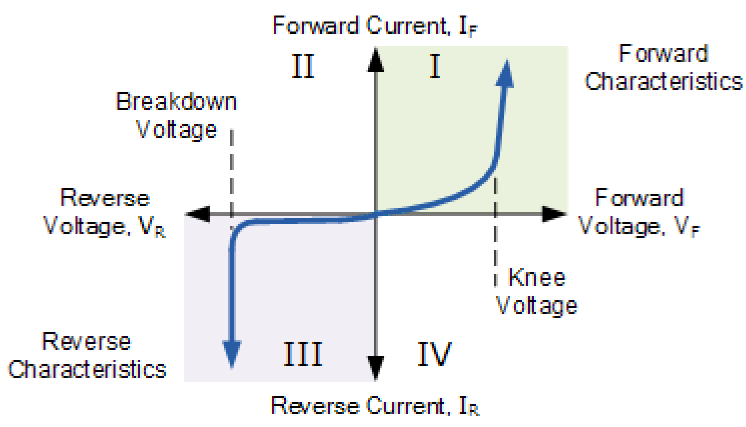
➢ **Characteristics curve in Forward Bias:**

The **significance** is the **knee of the characteristics curve in forward bias** is the point which the barrier potential is overcome and current will increase rapidly.

When the diode is forward biased, anode positive with respect to the cathode, a forward or positive current passes through the diode and operates in the top right quadrant of its I-V characteristics curves as shown. Starting at the zero intersection, the curve increases gradually into the forward quadrant but the forward current and voltage are extremely small.

When the forward voltage exceeds the diodes P-N junction's internal barrier voltage, which for silicon is about 0.7 volts, avalanche occurs and the forward current increases rapidly for a very small increase in voltage producing a non-linear curve. The "knee" point on the forward curve.





The **I-V Characteristic Curves** for a silicon diode are non-linear and very different to that of the previous resistors linear I-V curves as their electrical characteristics are different. Current-Voltage characteristics curves can be used to plot the operation of any electrical or electronic component from resistors, to amplifiers, to semiconductors and solar cells.

The current-voltage characteristics of an electronic component tells us much about its operation and can be a very useful tool in determining the operating characteristics of a particular device or component by showing its possible combinations of current and voltage, and as a graphical aid can help visually understand better what is happening within a circuit.

B). What happens to the barrier potential when the temperature increases?

- ## Temperature Effect on Barrie Potential:

As the temperature increases, the value of the potential barrier is decreasing. The potential barrier has the highest value when temperature is at 300K. At temperature 600K, the potential barrier has the lowest value. The temperature affects the kinetic energy of the carriers.

In semiconductors, there is a layer near the p-n junction which is partially devoid of free charge carriers. This layer is known as depletion layer.

For the diffusion of charge carriers from one region to another, there is a barrier across junction known as potential barrier. This is the amount of voltage which must be applied for the flow of free charge carriers.

This barrier potential is directly proportional to the concentration of free charge carriers.

Barrier potential is inversely proportional to the temperature. Higher the temperature, greater will be the mobility of charge carriers and lower potential difference across the junction can break the potential barrier. But as the temperature lowers, kinetic energy of charge carriers decreases and higher will be the value of potential barrier.

Q2.

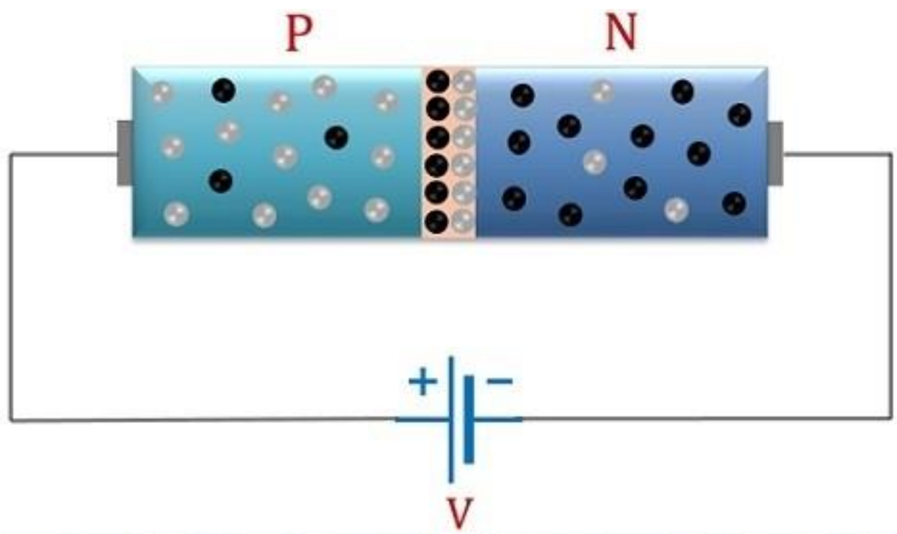
A). Compare the depletion regions in forward bias and reverse bias?

- ## Forward Biasing:

A PN junction device is said to be in forward biased condition when the p region forms the connection with positive terminal and n region forms the connection with the negative terminal of the battery.

in a p-type semiconductor material, holes are present as majority carriers and electrons are present as the minority carriers. While in case of n-type semiconductor material electrons are the majority carriers and holes are the minority carriers.

the representation of forward biasing applied to a PN junction diode:



Forward biased condition of pn junction diode

So, when forward biasing is provided to the device as shown above. Then the majority carriers from both sides, i.e., holes from p side and electrons from n side experience a repulsive force from the positive and negative terminal of the battery respectively.

the Coulomb's law of physics that **like charges repel each other and unlike charges attract each other**.

So, due to the repulsion from the externally provided supply, the majority carriers gain sufficient energy and overcome the barrier potential.

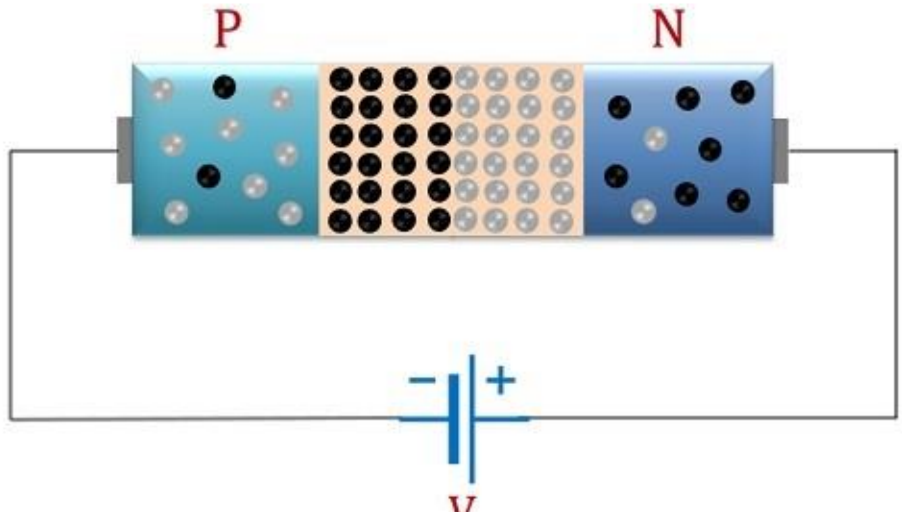
The **barrier potential is nothing but a region of neutral atoms** that get generated due to temperature difference when no external voltage is provided to it.

With the increase in the applied forward voltage, the width of the depletion region decreases. After completely overcoming the barrier potential, the depletion region diminishes and a sharp flow of current is noticed because a large number of majority carriers now crosses the junction region.

- **Reverse Biasing:**

A PN junction device is said to be in reverse biased condition when the p region is connected to the negative potential of the battery and n region is connected to the positive potential of the battery.

the reverse biased arrangement of a PN junction diode:



Reverse biased condition of pn junction diode

It is clear from the above figure that, the majority carriers present in p region i.e., holes attract towards the negative terminal of the battery. Similarly, electrons in the n region attract towards the positive side of the battery.

The majority carriers start moving away from the junction. Resultantly, this increases the depletion width. Due to the increase in the width of the depletion region, the flow of current due to majority carriers somewhat gets restricted.

However, the minority carriers in both the regions i.e., electrons in p side and holes in the n side experience repulsion from the battery terminals and move across the junction.

Due to this movement, a **very small reverse leakage current flows** through the device. This current is known as reverse saturation current.

As in reverse biased condition, no any current flows due to the majority carriers through the device. Thus, it is said that it behaves like an **insulator**.

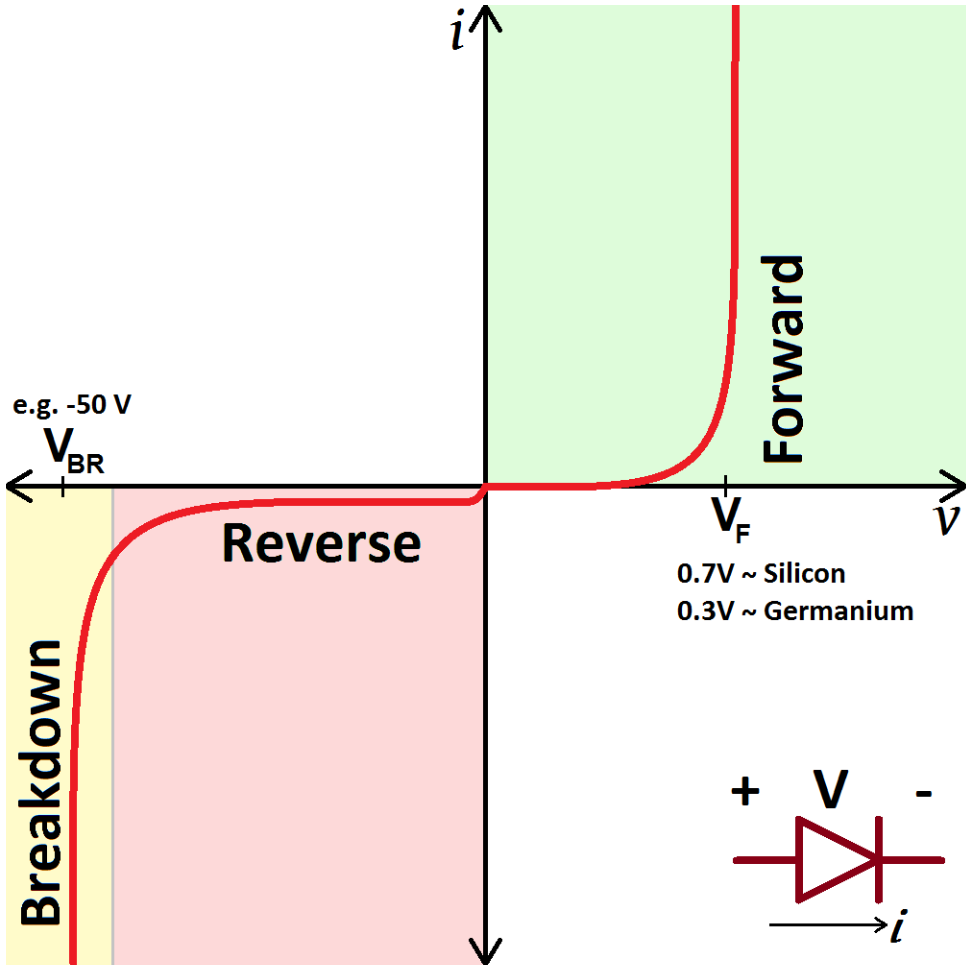
➢ <u>Differences between Forward Biasing and Reverse Biasing:</u>

1. The factor that generates a key difference between forward biasing and reverse biasing is that when a forward voltage is applied to a device then mainly the **current flow due to the movement of majority charge carriers**. On the contrary, when a reverse voltage is applied to a device then the **movement of only minority carriers generates small current**, known as leakage current.
2. On applying a forward voltage to a PN junction device the depletion width decreases with the increase in supplied voltage. While, when reverse biasing is provided to a PN junction device then the width of the depletion region increases with supplied voltage.

3. Due to **forward applied voltage pn junction device acts as a good conductor** after overcoming the barrier potential. Whereas, due to **reverse supplied voltage pn junction devices start behaving as an insulator** thus, allowing almost negligible current flow through it.
4. In case of forward applied potential, the PN junction device offers very low resistance. On the other side, in case of reverse applied voltage, pn junction device offers very high resistance.
5. It is basically understood that a **forward biased voltage permits a large flow of current** thus operates as a closed switch. While a **reverse biased voltage does not allow sufficient current flow** hence fundamentally termed as an open switched condition.
6. Due to the thin depletion region at the time of forward biasing, the barrier potential is low. However, due to the thick depletion width in case of reverse biasing, the barrier potential is high.
7. In case of **forward biasing, majority carriers experience repulsion** from the battery terminal. As against, in the case of **reverse biasing, majority carriers experience attraction** from the terminals of the battery.

B). When does reverse breakdown occur in a diode?

The **reverse** current in a **diode** is normally very small. If the external bias voltage is increased so on, the **reverse** current increases drastically at a particular value of the **reverse** bias voltage. This particular value of the **reverse** bias voltage is known as **breakdown** voltage. If a large enough negative voltage is applied to the diode, it will give in and allow current to flow in the reverse direction. This large negative voltage is called the **breakdown voltage**. Some diodes are actually designed to operate in the breakdown region, but for most normal diodes it's not very healthy for them to be subjected to large negative voltages. For normal diodes this breakdown voltage is around -50V to -100V, or even more negative.



If we keep on increasing the applied reverse voltage, the depletion width will increase accordingly. At a point which we can call as "breakdown point", the diode will get damaged. At this point, the diode behave more like a shorted wire and hence current flows through it easily. The internal resistance of diode at this stage is approximately near zero. According to Ohms Law, V = I/R and since resistance is very very low, current increases many folds with voltage. This is the reason we get a perpendicular line shoot in VI characteristics of reverse bias.

Q3.

A). Find the difference between electric potential energy and electric potential?

- **Electric Potential Energy:**

Electric Potential Energy is defined as the energy stored in the charge "q" because of its position in an electric field, Mathematically,

$$\text{Electric P.E} = U = q_o \Delta V$$

Electric potential energy is defined as the total potential energy a unit charge will possess if located at any point in the outer space. The SI unit of electric potential energy is the joule(J).

➢ Electric Potential:

The Potential energy of a charged particle in an electric field depends on the charge magnitude. However, the potential energy per unit charge has a unique value at any point in an electric field. Electric potential is a scalar, not a vector. Its unit is volt which is equal to joule per coulomb (J/C).

$$V = U/q$$

➢ Difference between electric potential energy and electric potential:

The basic difference between electric potential and electric potential energy is that Electric potential at a point in electric field is the amount of work done to bring the unit positive charge from infinity to that point, while electric potential energy is the energy that is needed to move a charge against the electric field.

The gravitational potential at a point in the gravitational field is the gravitational potential energy of a unit mass placed at that point. In this way, the electric potential at any point in the electric field is the electric potential energy of a unit positive charge at that point.

B). How to find the potential difference between any two points in the electric field lines?

➢ Potential Difference:

The potential difference between two points is defined as ***the work done in carrying a unit positive charge from one point to the other while keeping the charge in electrostatic equilibrium.***

Mathematically, if A and B be two points in electric field then,

$$\Delta V = V_B - V_A = W_{AB}/q_o$$

The potential difference between two points can also be defined as ***the difference of the electric potential energy per unit charge.***

$$\Delta V = \Delta U/q_o$$

➢ Unit:

SI Unit of potential difference is **Volt**.

➢ Volt:

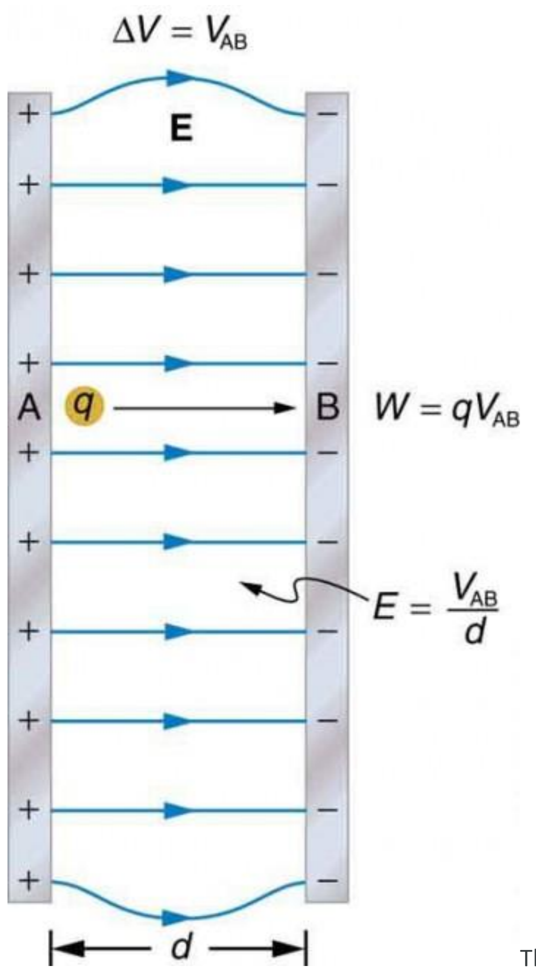
If one joule work is done in carrying a unit positive charge from one point to another keeping electrostatic equilibrium then the potential difference is said to be one volt.

1 volt = 1 joule/ 1 coulomb

➢ Potential difference between any two points in the electric field lines:

A uniform electric field **E** is produced by placing a potential difference (or voltage) ΔV across two parallel metal plates, labeled A and B.

Voltage is needed to produce a certain electric field strength; it will also reveal a more fundamental relationship between electric potential and electric field. From a physicist's point of view, either ΔV or **E** can be used to describe any charge distribution. ΔV is most closely tied to energy, whereas **E** is most closely related to force. ΔV is a *scalar* quantity and has no direction, while **E** is a *vector* quantity, having both magnitude and direction. (Note that the magnitude of the electric field strength, a scalar quantity, is represented by E below.) The relationship between ΔV and **E** is revealed by calculating the work done by the force in moving a charge from point A to point B.



The relationship between V and E for parallel conducting plates is E=Vd$E=Vd$. (Note that $\Delta V = V_{AB}$ in magnitude. For a charge that is moved from plate A at higher potential to plate B at lower potential, a minus sign needs to be included as follows: $-\Delta V = V_A - V_B = V_{AB}$.

The work done by the electric field in Figure 1 to move a positive charge q from A, the positive plate, higher potential, to B, the negative plate, lower potential, is

$$W = -\Delta \mathrm{PE} = -q\Delta V.$$

The potential difference between points A and B is

$$-\Delta V = -(V_B - V_A) = V_A - V_B = V_{AB}.$$

Entering this into the expression for work yields $W = qV_{AB}$.

Work is $W = Fd \cos \vartheta$; here $\cos \vartheta = 1$, since the path is parallel to the field, and so $W = Fd$. Since $F = qE$, we see that $W = qEd$. Substituting this expression for work into the previous equation gives $qEd = qV_{AB}$.

The charge cancels, and so the voltage between points A and B is seen to be

{VAB=Ed

{E=V$_{AB}$/d

(uniform E − field only)

where d is the distance from A to B, or the distance between the plates in Figure 1. Note that the above equation implies the units for electric field are volts per meter. We already know the units for electric field are newtons per coulomb; thus the following relation among units is valid: 1 N/C = 1 V/m.