

## Study Material

Program Code: All Program

Semester: First

Course Name: Basic Science (Physics)

Course Code: 22102

Topic Name: Electricity, Magnetism & Semiconductors

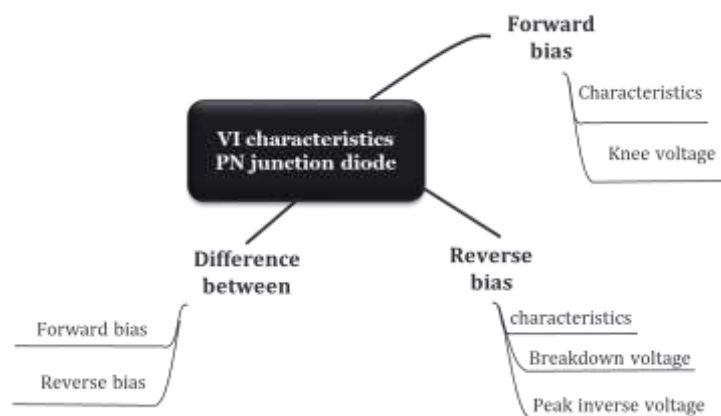
UO2f: Explain the I-V characteristics and applications of the given p-n junction diodes.

LO11: Student will be able to explain the I-V characteristics p-n junction diode.

Course Expert: S. K. Rawat

Date: 03/09/2020

Concept Map:



**Key words:** p-n junction diode, VI characteristic, forward bias, knee voltage, reverse bias, breakdown voltage, PIV

**Key Questions:**

1. What are forward bias characteristics of PN junction diode?
2. What are reverse bias characteristics of PN junction diode?
3. What is knee voltage, breakdown voltage and peak inverse voltage?

**Key Definition:**

1. V-I characteristics of a diode is the variation of current as a function of applied voltage across the diode.
2. The forward voltage at which the current through the junction starts to increase rapidly is called knee voltage or threshold voltage or cut-off voltage.
3. The reverse voltage at which p-n junction breaks down with sudden rise in reverse current is called breakdown voltage.
4. The maximum reverse voltage that can be applied to the p-n junction without damage to the junction of diode is called peak inverse voltage.

**Notes**

**V-I characteristics of p-n junction diode**

The circuit arrangement for studying the V-I characteristics of a diode, (i.e., the variation of current as a function of applied voltage) are shown in Fig. 1. The battery is connected to the diode through a potentiometer (or rheostats) so that the applied voltage to the diode can be changed. For different values of voltages, the value of the current is noted. A graph between V and I is obtained as in Fig. 1 (c). In forward bias measurement, milliammeter is used since the expected current is large (as explained in the earlier section), while microammeter is used to measure the current in reverse bias.

## Forward bias characteristics (VI characteristics)

With forward bias condition, the potential barrier is reduced. At some forward voltage (0.7V for Si or 0.3V for Ge diode), the potential barrier is completely reduced and current starts flowing in the circuit. From forward bias characteristics as seen in Fig. 1 (c), it is observed that at the starting (region OA), the current increases very slowly, almost negligibly, till the voltage across the diode crosses a certain value.

After the characteristic voltage, the diode current increases significantly (exponentially), even for a very small increase in the diode bias voltage. Thus the curve is non-linear (region AB), as the external applied voltage is used to overcome the potential barrier and the p-n junction diode conducts.

This voltage is called the knee voltage or threshold voltage or cut-in voltage ( $\sim 0.2\text{V}$  for germanium diode and  $\sim 0.7\text{V}$  for silicon diode).

**Knee voltage:** The forward voltage at which the current through the junction starts to increase rapidly is called knee voltage or threshold voltage or cut-off voltage.

## Reverse bias characteristics (VI characteristics)

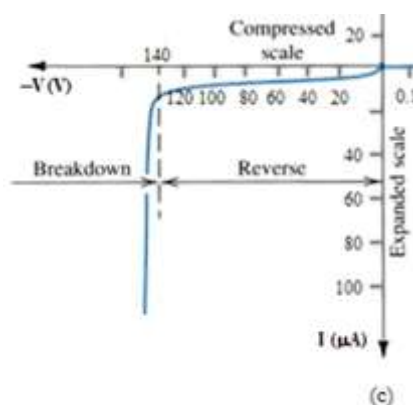
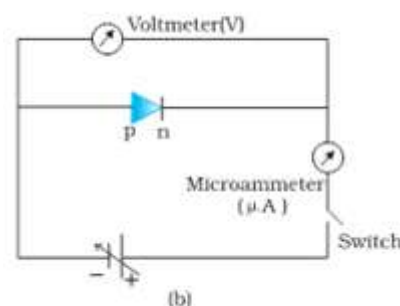
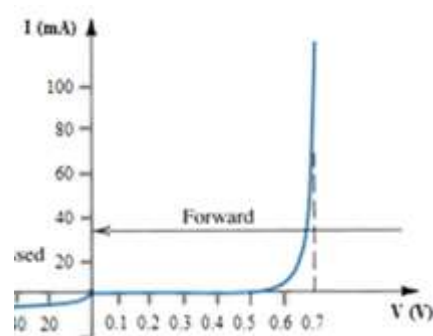
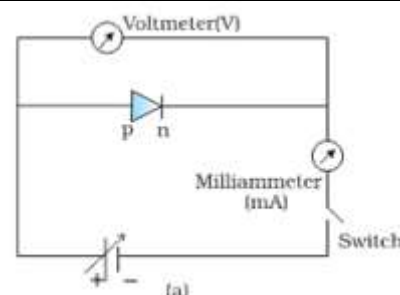
For the p-n junction diode in reverse bias, barrier potential at the junction is increased. Therefore, the junction resistance becomes very high and practically no current flows through the circuit. However in practice a very small current ( $\sim$  flows in the circuit and almost remains constant with change in bias. As the flow of current is due to minority carriers, it is called reverse saturation current. However, for special cases, at very high reverse bias (breakdown voltage), the current suddenly increases as seen in Fig. 1 (c).

If reverse voltage is increased continuously at one stage breakdown of the junction occurs. It is mainly because of sudden rise of reverse current and a sudden fall of the resistance of potential barrier. This may destroy the junction permanently due to excessive heat.

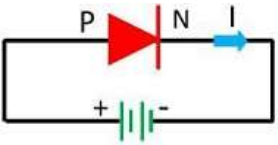
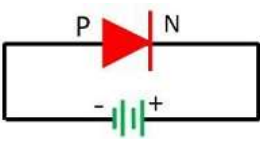
**Breakdown voltage:** The reverse voltage at which p-n junction breaks down with sudden rise in reverse current is called breakdown voltage.

**Peak inverse voltage (PIV):** The maximum reverse voltage that can be applied to the p-n junction without damage to the junction of diode is called peak inverse voltage.

The above discussion shows that the p-n junction diode primarily allows the flow of current only in one direction (forward bias).



## Difference: Forward Bias and Reverse Bias

Points	Forward Biasing	Reverse Biasing
Definition	The external voltage which is applied across the PN-diode for reducing the potential barrier to constitute the easy flow of current through it is called forward bias.	The external voltage which is applied to the PN junction for strengthening the potential barrier and prevents the flow of current through it is called reverse bias.
Symbol		
Connection	The positive terminal of the battery is connected to the P-type semiconductor of the device and the negative terminal is connected to N-type semiconductor	The negative terminal of the battery is connected to the P-region and the positive terminal of the battery is connected to N-type semiconductor.
Barrier Potential	Reduces	Strengthen
Voltage	The voltage of an anode is greater than cathode.	The voltage of cathode is greater than an anode.
Forward Current	Large	Small
Depletion layer	Thin	Thick
Resistance	Low	High
Current Flow	Allows	Prevents
Current Magnitude	Depends on forward voltage.	Zero
Operate	Conductor	Insulator

### Link to YouTube/ OER/ video/e-book:

- <http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html>
- [https://www.electronics-tutorials.ws/diode/diode\\_1.html](https://www.electronics-tutorials.ws/diode/diode_1.html)
- [https://www.electronics-notes.com/articles/basic\\_concepts/conductors-semiconductors-insulators/what-is-a-semiconductor.php](https://www.electronics-notes.com/articles/basic_concepts/conductors-semiconductors-insulators/what-is-a-semiconductor.php)
- <https://circuitglobe.com/difference-between-forward-and-reverse-biasing.html#:~:text=The%20Forward%20bias%20decreases%20the,current%20to%20flow%20through%20it.>

### Key Take away:

- P-N junction diode in forward bias.
- P-N junction diode in reverse bias.

## Formative Assessments

<22102> : <All Program> : < All Program >: <Electricity, Magnetism & Semiconductors>: <UO2f> :  
<LO11> : <Assessments> : <Formative>

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### Assessment Type: Formative Assessments: Embedded questions in video/ PPT

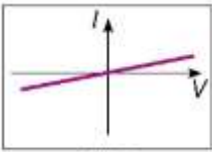
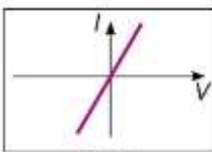
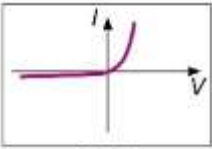
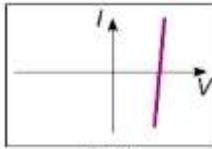
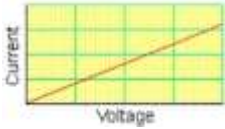
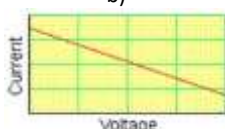
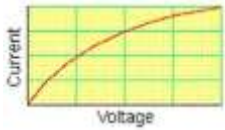
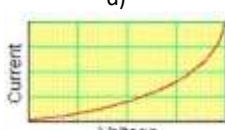
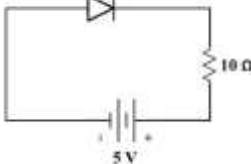
Set 1		
Question No 1	Question No 2	Question No 3
The leakage current in a PN junction diode is of the order of _____	The barrier voltage at a PN junction diode for germanium is about _____	The forward voltage at which the current through the PN junction starts to increase rapidly is called _____
Remembering	Remembering	Understanding
a) A	a) 2V	a) knee voltage
b) mA	b) 3V	b) breakdown voltage
c) nA	c) 5V	c) peak inverse voltage
d) $\mu$ A	d) 7V	d) reverse voltage
Ans: < $\mu$ A >	Ans: < 3V >	Ans: < knee voltage >

Set 2		
Question No 1	Question No 2	Question No 3
In reverse bias condition, the junction of P-N Junction diode may get destroyed completely due to	The maximum reverse voltage that can be applied to the p-n junction without damage to the junction of diode is called _____	There is a small amount of current across the barrier of a reverse-biased diode. This current is called _____
Understanding	Understanding	Understanding
a) knee voltage	a) knee voltage	a) forward-bias current
b) fall in forward current	b) breakdown voltage	b) reverse breakdown current
c) rise in reverse current	c) peak inverse voltage	c) conventional current
d) fall in reverse current	d) reverse voltage	d) reverse leakage current
Ans: < rise in reverse current >	Ans: < peak inverse voltage >	Ans: < reverse breakdown current >

## Practice Worksheets

<22102> : <All Program> : < All Program >: <Electricity, Magnetism & Semiconductors>: <UO2f> :  
<LO11> : <Assessments> : <Summative>

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A. Which of the following represents the forward characteristics of p-n junction diode?		<div>a)</div>  <div>Fig (a)</div>	<div>b)</div>  <div>Fig (b)</div>	A
		<div>c)</div>  <div>Fig (c)</div>	<div>d)</div>  <div>Fig (d)</div>	
B. Which graph displays the I-V graph for an Ohmic conductor?		<div>a)</div>  <div>Current</div> <div>Voltage</div>	<div>b)</div>  <div>Current</div> <div>Voltage</div>	B
		<div>c)</div>  <div>Current</div> <div>Voltage</div>	<div>d)</div>  <div>Current</div> <div>Voltage</div>	
C. In the circuit diagram shown, the current flowing through the resistor is a) 0A b) 0.05A c) 20A d) 0.7A	<div>Si diode</div>  <div>10 <math>\Omega</math></div> <div>5 V</div>		D. In a PN junction the potential barrier is due to the charges on either side of the junction, these charges are a) Majority carriers b) Minority carriers c) Both (a) and (b) d) Fixed donor and acceptor ions	
C		D		
E. When PN junction is in forward bias, by increasing the battery voltage a) Circuit resistance increases b) Current through P-N junction increases c) Current through P-N junction decreases d) None of the above happens		F. When a PN junction is reverse-biased a) Holes and electrons tend to concentrate towards the junction b) The barrier tends to break down c) Holes and electrons tend to move away from the junction d) None of the above		
E		F		