Semiconductor diode, I-V characteristics in forward and reverse bias,

CLASS-XII

SUBJECT : PHYSICS
CHAPTER NUMBER: 14
CHAPTER NAME : Semi conductor electronics: Materials, devices and simple circuits

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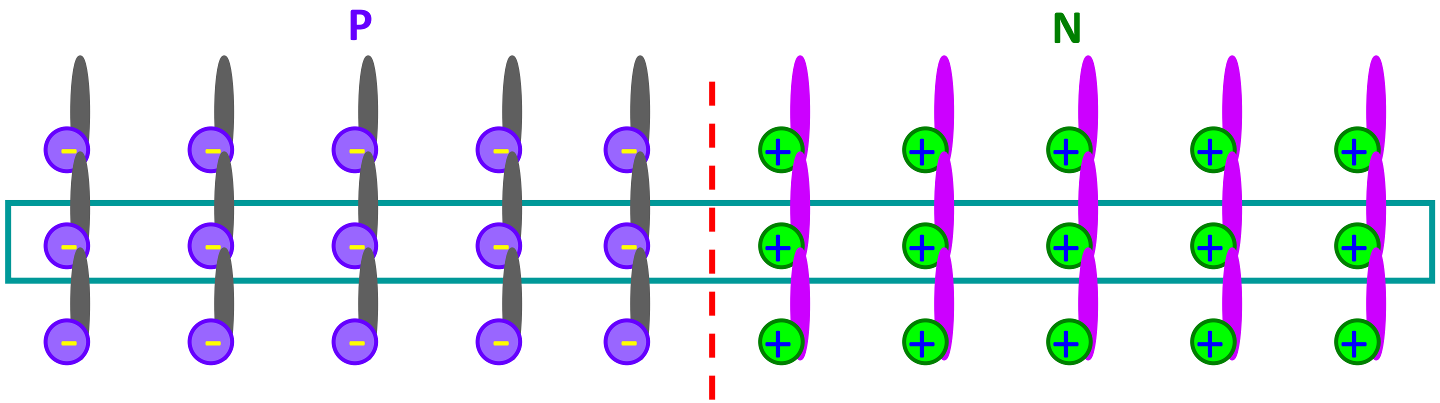
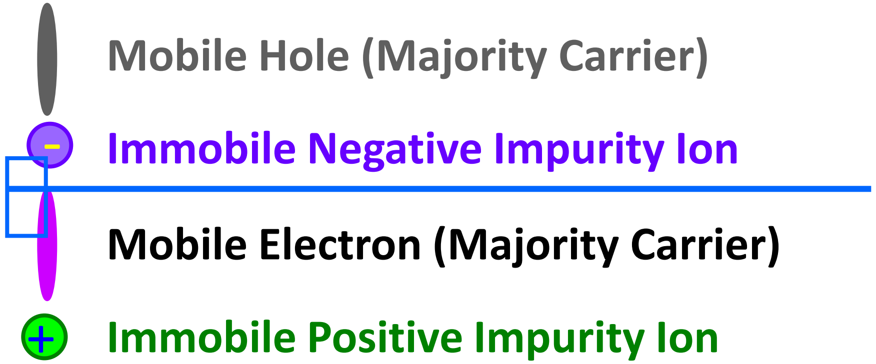
PN Junction Diode:

When a P-type semiconductor is joined to a N-type semiconductor such that the crystal structure remains continuous at the boundary, the resulting arrangement is called a PN junction diode or a semiconductor diode or a crystal diode.



When a PN junction is formed, the P region has mobile holes (+) and immobile negatively charged ions.

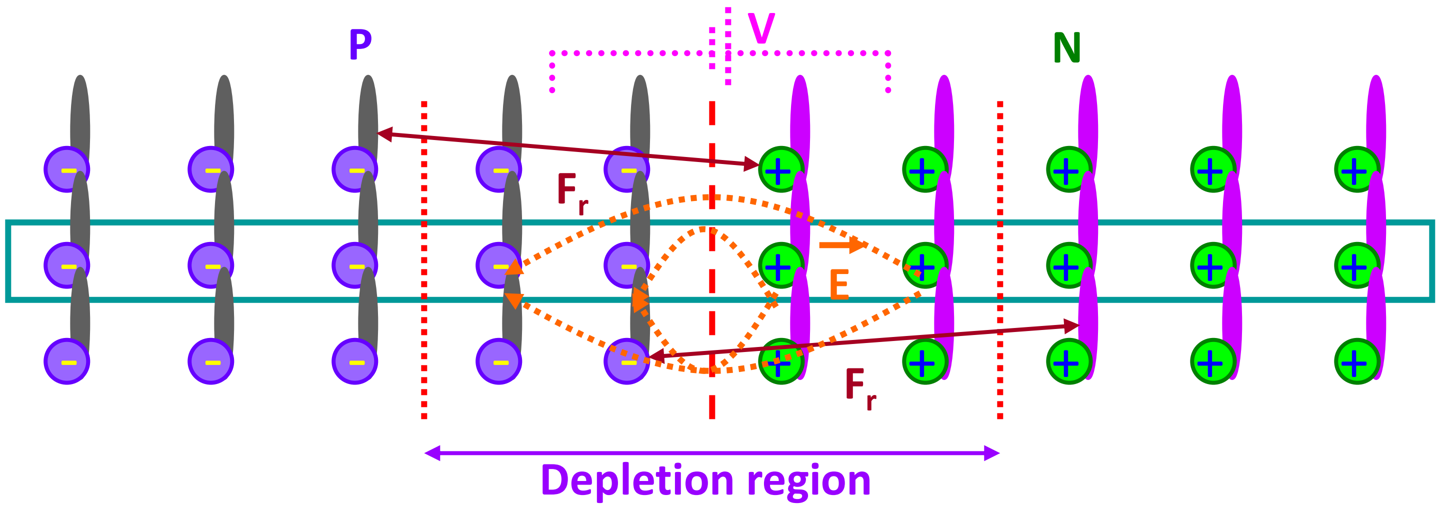
N region has mobile electrons (-) and immobile positively charged ions.



The whole arrangement is electrically neutral.

For simplicity, the minority charge carriers are not shown in the figure.

PN Junction Diode immediately after it is formed :



After the PN junction diode is formed –

i) Holes from P region diffuse into N region due to difference in concentration.

ii) Free electrons from N region diffuse into P region due to the same reason.

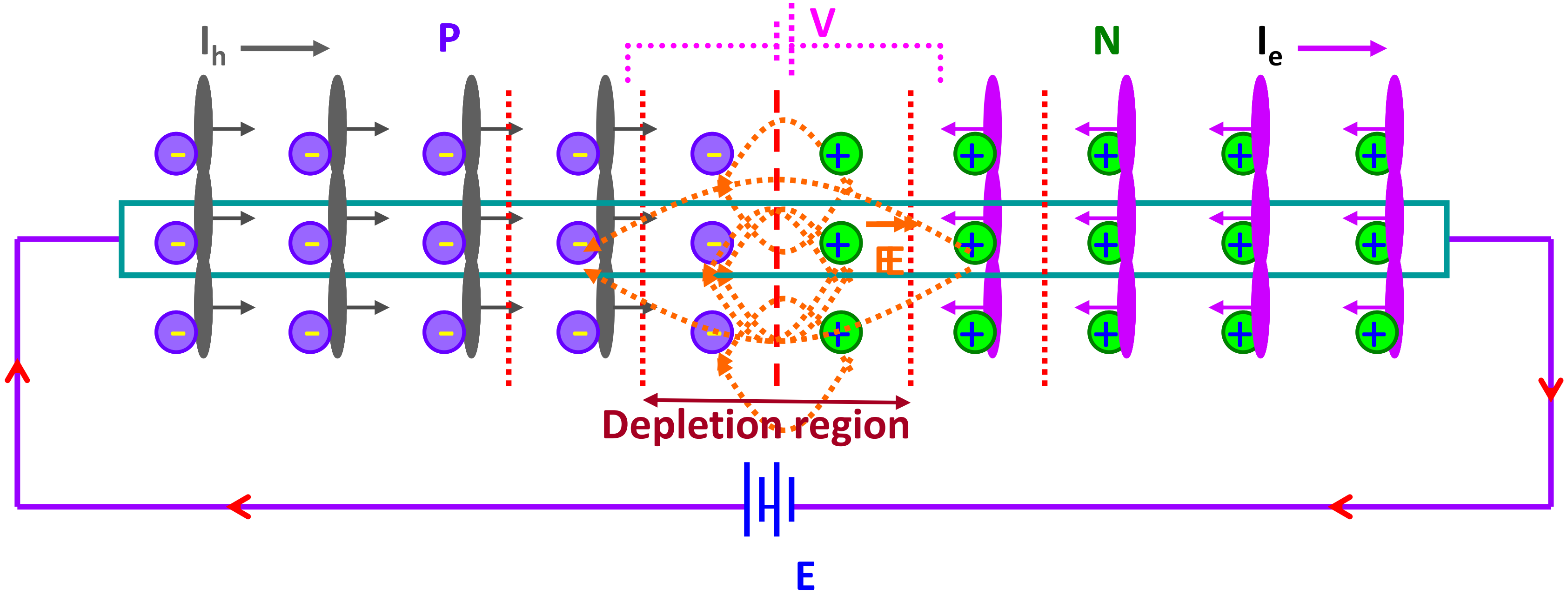
iii) Holes and free electrons combine near the junction.

iv) Each recombination eliminates an electron and a hole.

v) The uncompensated negative immobile ions in the P region do not allow any more free electrons to diffuse from N region.

vi) The uncompensated positive immobile ions in the N region do not allow any more holes to diffuse from P region.

Forward Bias:



When the positive terminal of the battery is connected to P-region and negative terminal is connected to N-region, then the PN junction diode is said to be forward-biased.

i) Holes in P-region are repelled by +ve terminal of the battery and the free electrons are repelled by –ve terminal of the battery.

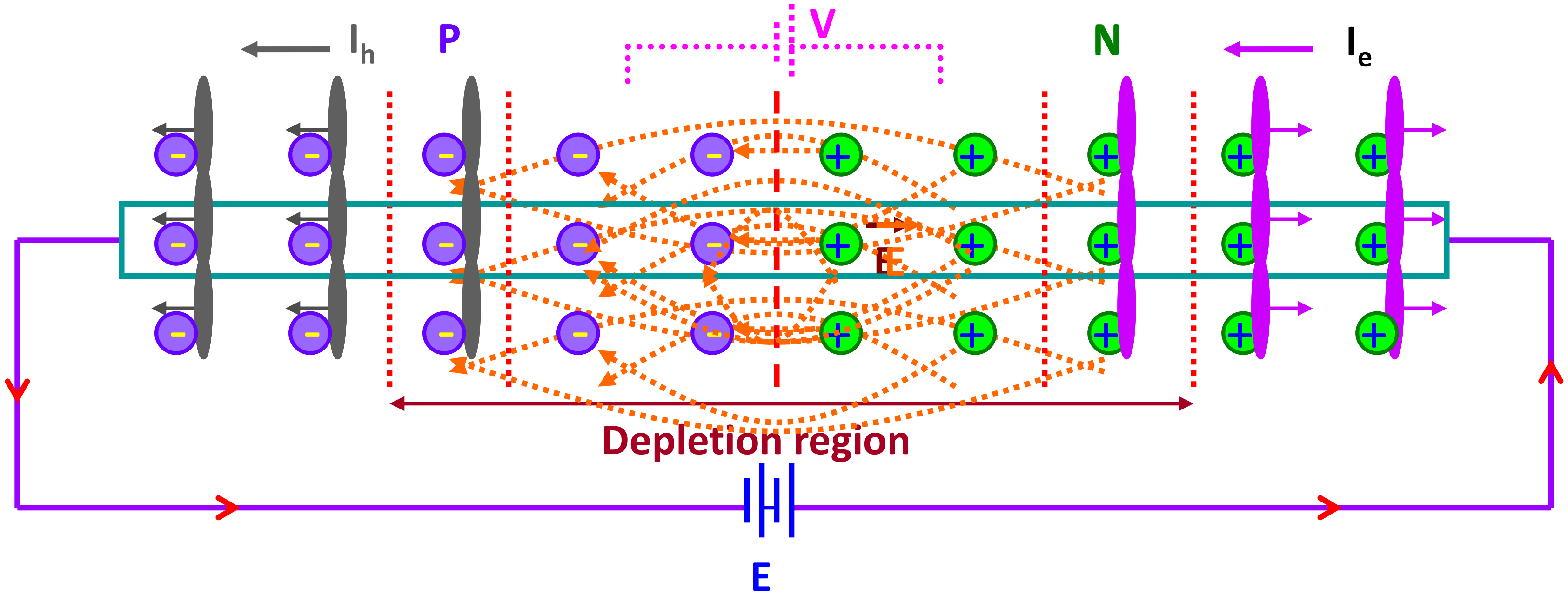
ii) So, some holes and free electrons enter into the depletion region.

iii) The potential barrier and the width of the depletion region decrease.

iv) Therefore, a large number of majority carriers diffuse across the junction.

v) Hole current and electronic current are in the same direction and add up.

Reverse Bias:



When the negative terminal of the battery is connected to P-region and positive terminal is connected to N-region, then the PN junction diode is said to be reverse-biased.

i) Holes in P-region are attracted by -ve terminal of the battery and the free electrons are attracted by +ve terminal of the battery.

ii) Thus, the majority carriers are pulled away from the junction.

iii) The potential barrier and the width of the depletion region increase.

iv) Therefore, it becomes more difficult for majority carriers diffuse across the junction.

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v) But the potential barrier helps the movement of the minority carriers. As soon as the minority carriers are generated, they are swept away by the potential barrier.

vi) At a given temperature, the rate of generation of minority carriers is constant.

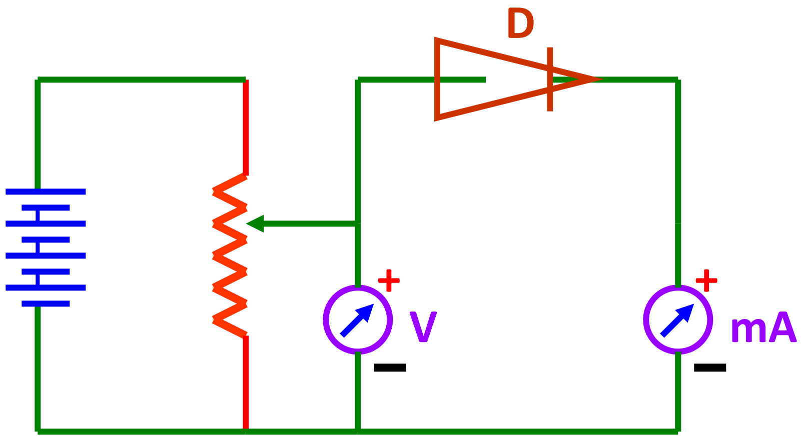
vii) So, the resulting current is constant irrespective of the applied voltage. For this reason, this current is called 'reverse saturation current'.

viii) Since the number of minority carriers is small, therefore, this current is small and is in the order of 10^{-9} A in silicon diode and 10^{-6} A in germanium diode.

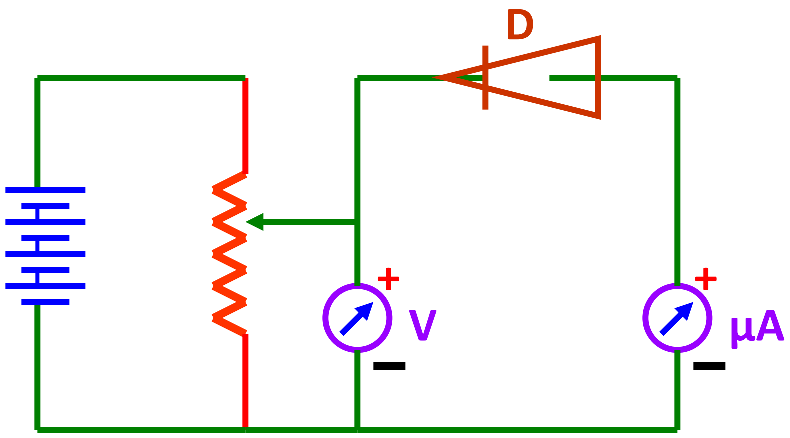
ix) The reverse – biased PN junction diode has an effective capacitance called 'transition or depletion capacitance'. P and N regions act as the plates of the capacitor and the depletion region acts as a dielectric medium.

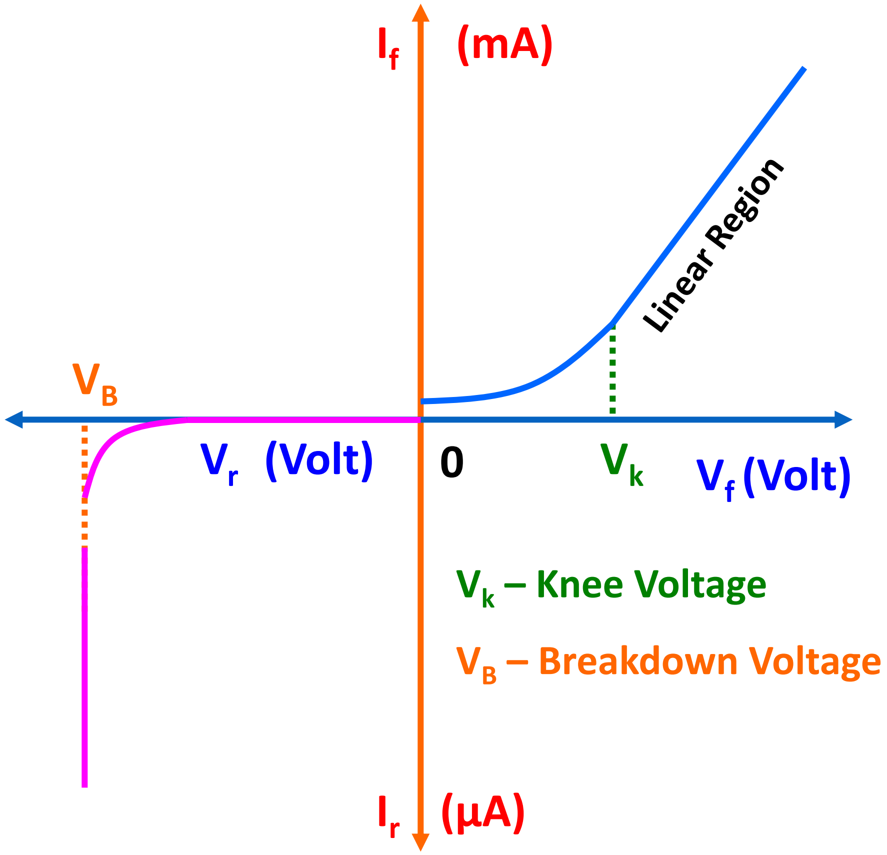
Diode Characteristics:

Forward Bias:



Reverse Bias:





Resistance of a Diode:

i) Static or DC Resistance $R_{d.c} = V / I$

ii) Dynamic or AC Resistance

$$\boxed{R_{a.c} = \Delta V / \Delta I}$$

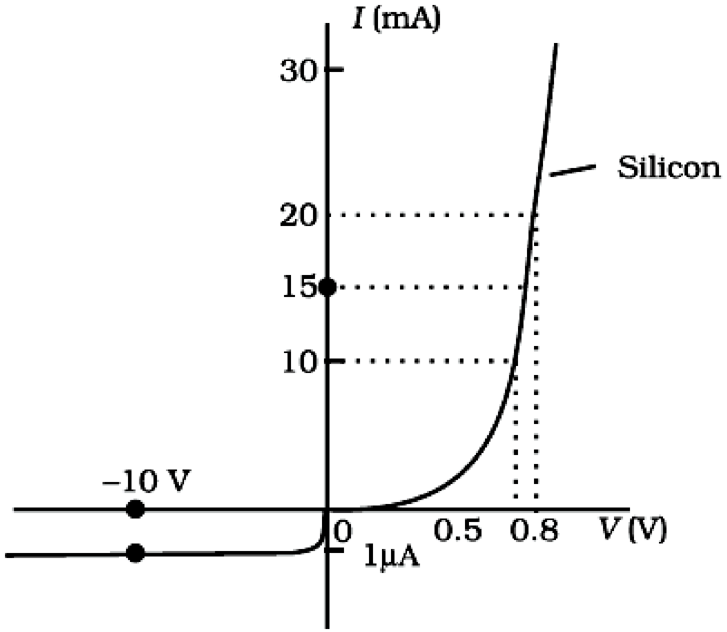
NUMERICAL:

Can we take one slab of p-type semiconductor and physically join it to another n-type semiconductor to get a p-n junction?

NUMERICAL:

The V-I characteristic of a silicon diode is shown in the following figure. Calculate the dynamic resistance at

(a) $I_D = 15A$ (b) $V_D = -10V$.



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