University of Calcutta

Semester 4

PHYSICS

Paper: PHS-A-CC-4-10-TH (OLD SYLLABUS)

CURRENT FOR STEP JUNCTION, CURRENT FLOW MECHANISM IN FORWARD AND REVERSE BIASED JUNCTION

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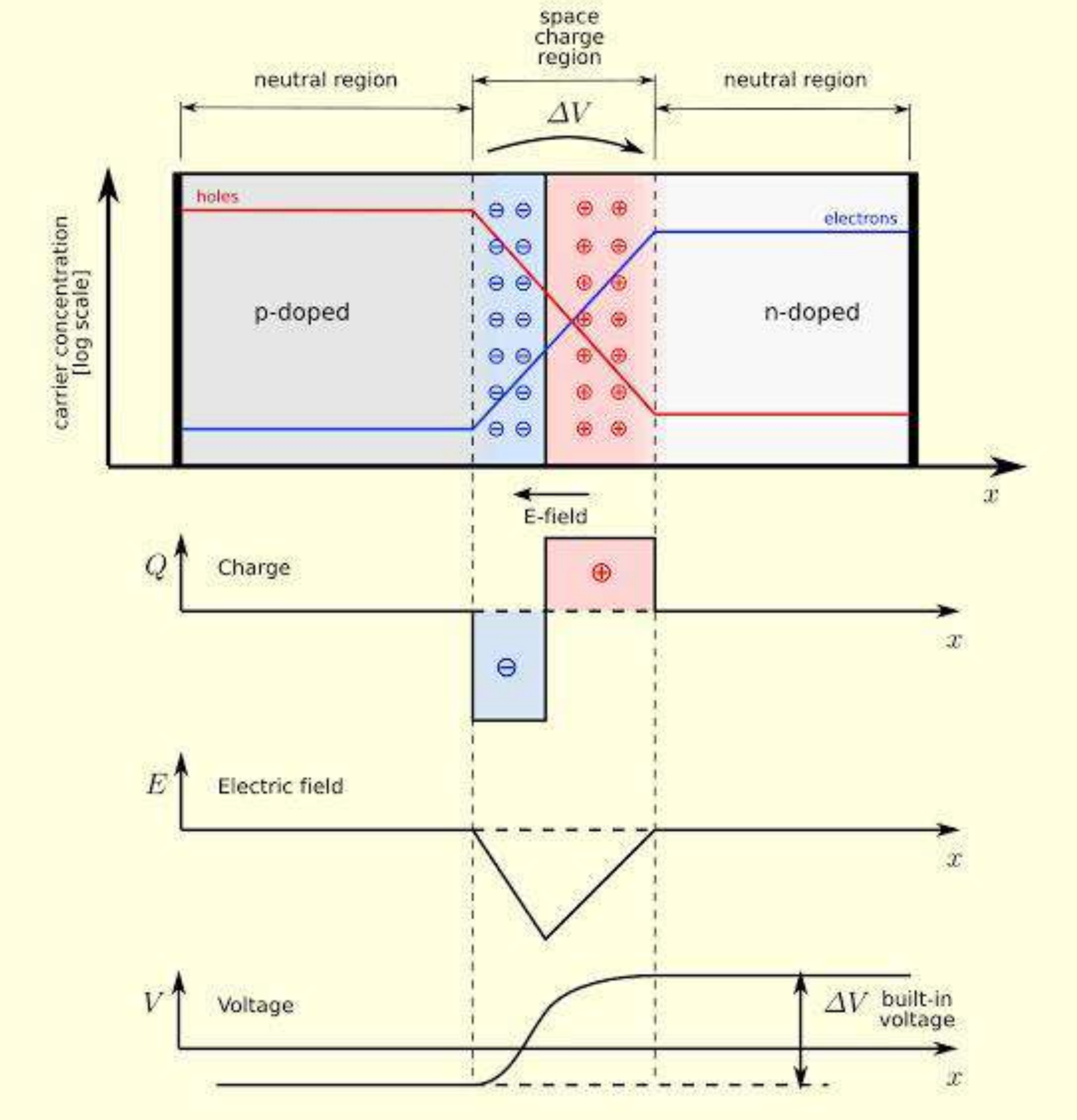
BARRIER POTENTIAL



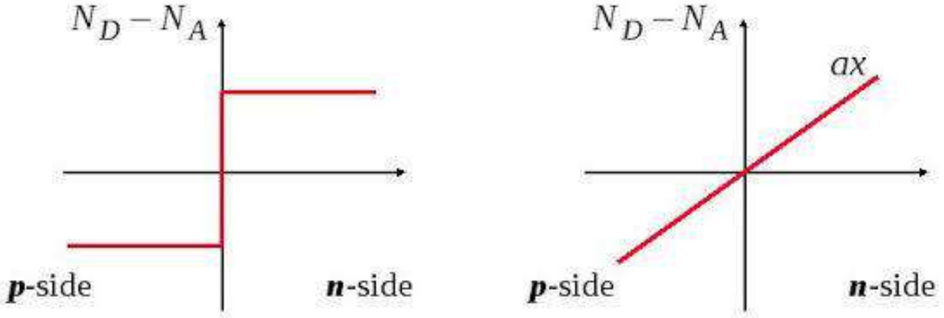
Barrier Potential

In the state of equilibrium, there is no current in a p-n junction. A difference of potential develops across the junction of the two regions due to the loss of electrons by the n-region and the subsequent gain by the p-region. The polarity of the potential opposes the further flow of carriers to maintain the state of equilibrium. This is the Barrier Potential.

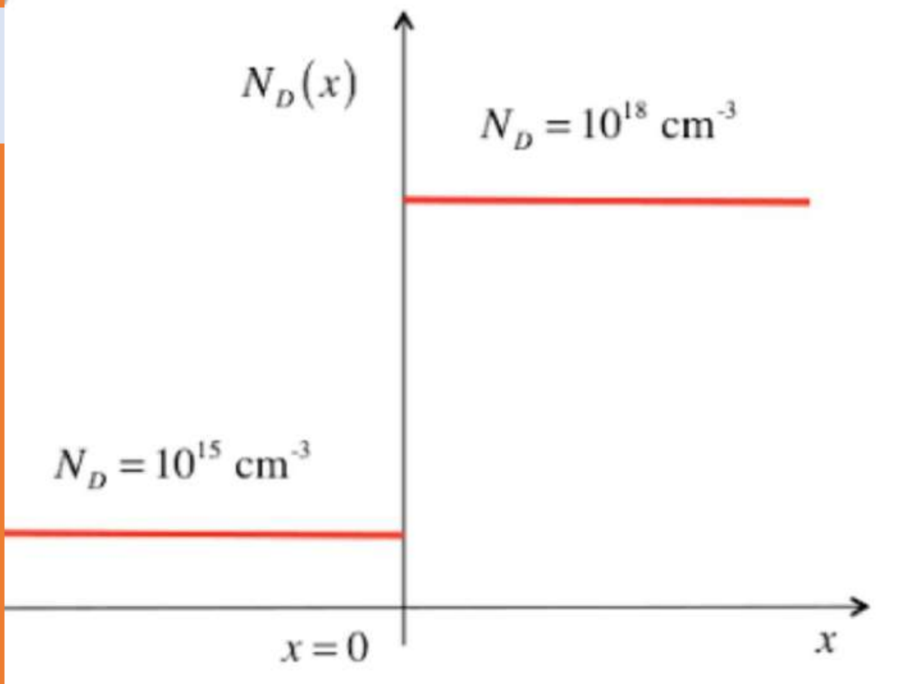
WHAT IS STEP JUNCTION ??

1. PN-junctions - General Consideration:

- PN-junction is a **two terminal** device.
- Based on the **doping profile**, PN-junctions can be separated into two major categories:
  - step junctions
  - linearly-graded junctions

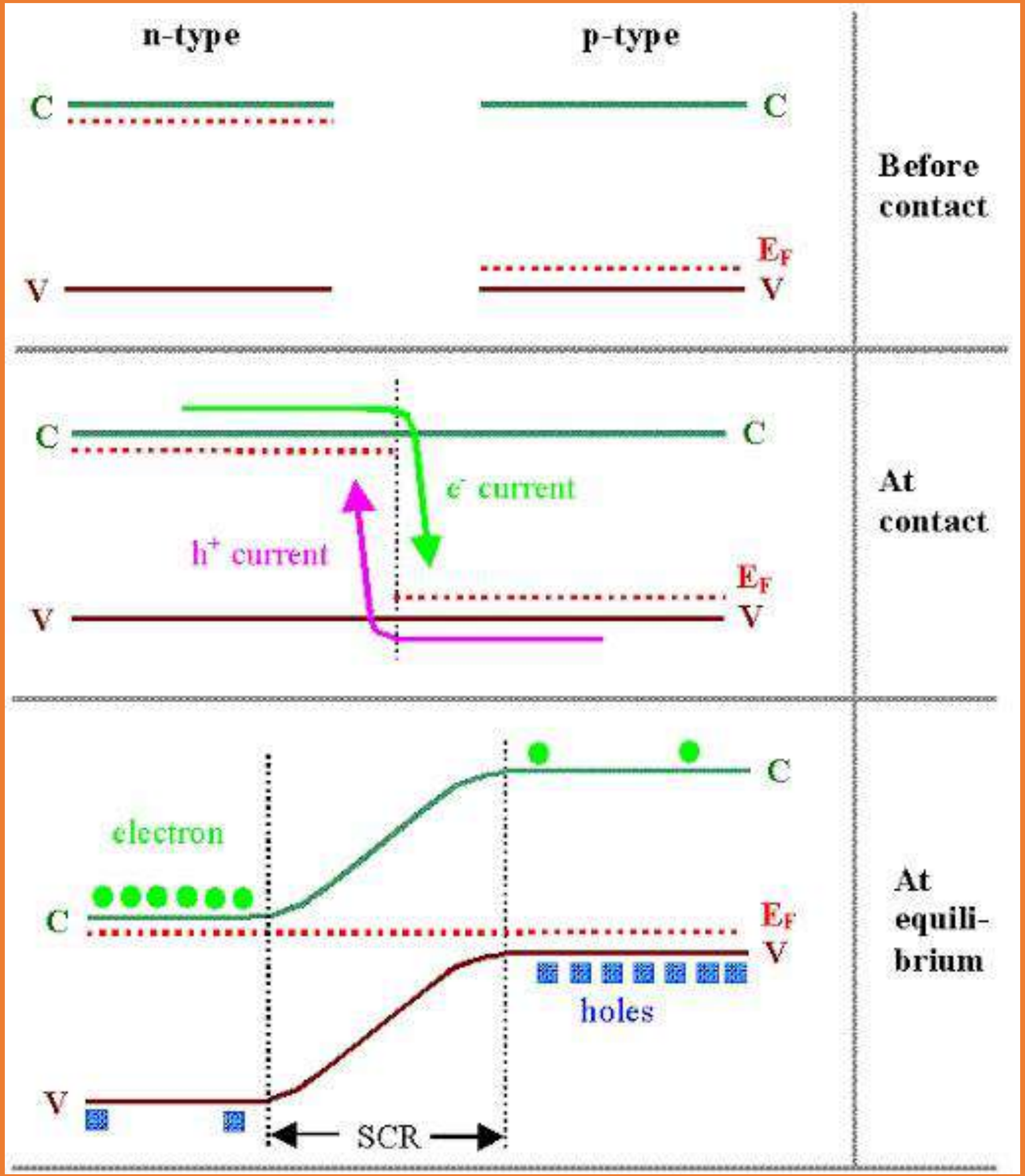


Step junction   Linearly-graded junction



Step junction is a pn **junction** in which the p-type material and n-type material has an abrupt planar boundary and both the n-side and p-side has a uniform doping profile so that if you plot the doping profile, then it looks like a **step** function, hence the name **step junction**.

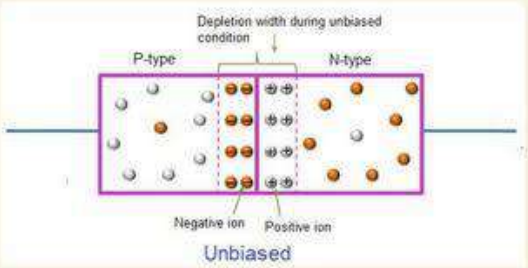
YOUR TASK: EXPLAIN THE DIAGRAMS



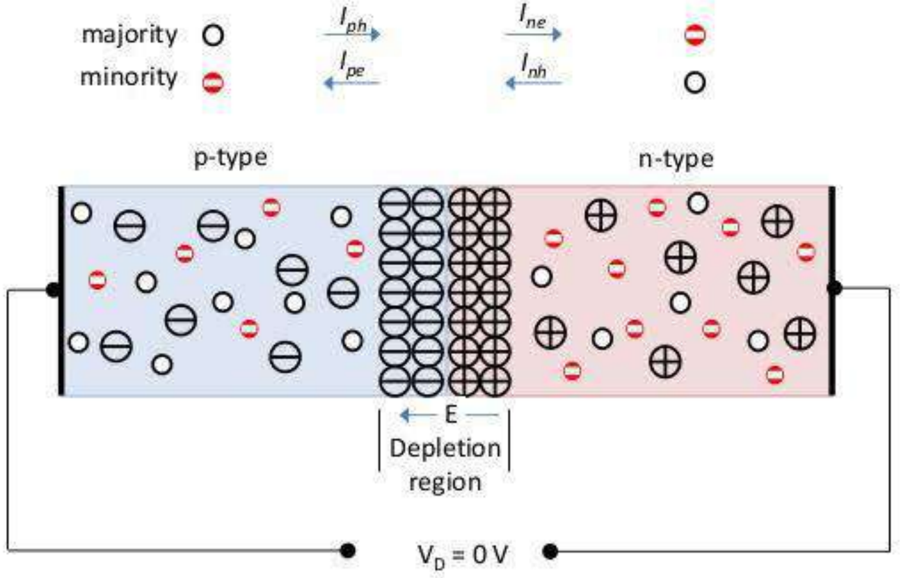
NON-BIAS CONDITION

NO BIAS CONDITION

- ✓ Small minority carriers flow which are near the junction. Closer is the minority carrier to the junction it will experience more attraction from the ions present in opposite material
- ✓ As majority carrier acquires insufficient kinetic energy to overcome the barrier, very small majority flows.
- ✓ The net flow of charge in one direction is zero.



PN Junction diode: No bias



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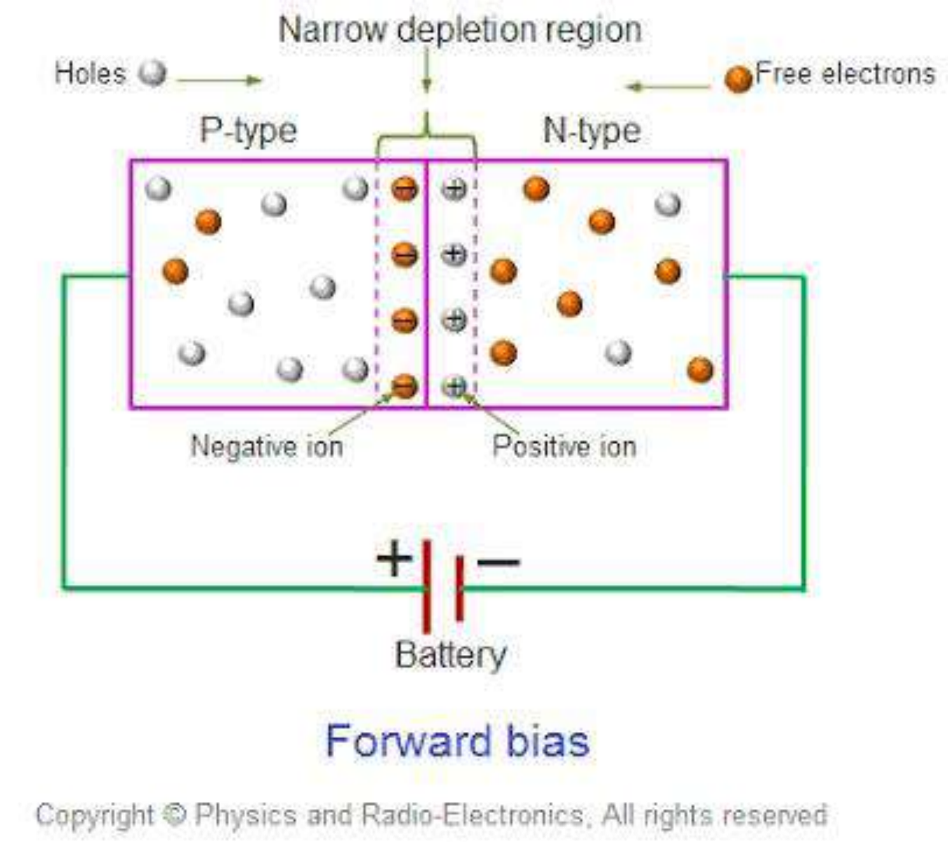
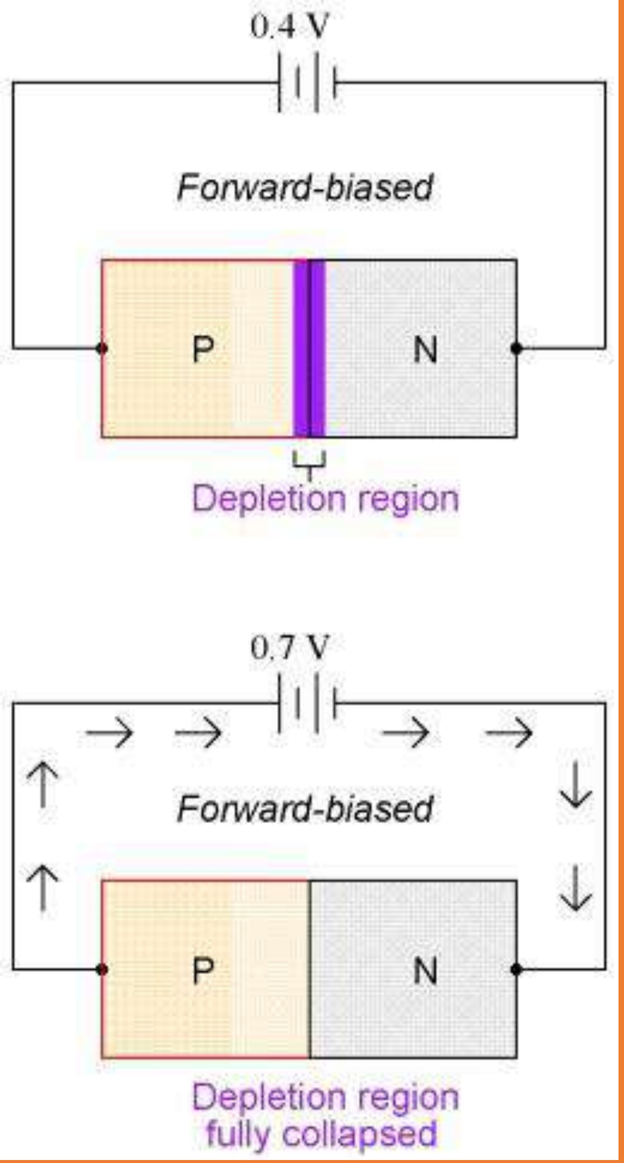
FORWARD BIAS : SCHEMATIC DIAGRAM





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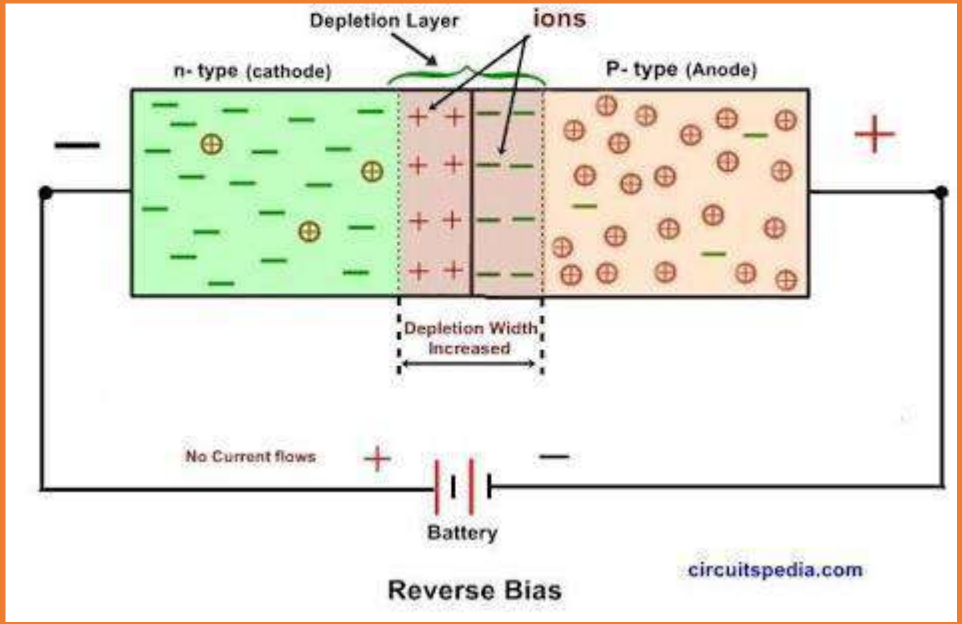
REVERSE BIAS: SHEMATIC DIAGRAM



When a p-n junction is reversed biased, the negative terminal of the battery attracts the free holes in the p-type towards itself whereas the positive terminal attracts the free electrons in n-type towards itself. Hence, the electrons and the holes move away from the junction which results in increasing of the depletion width as well as the potential barrier.

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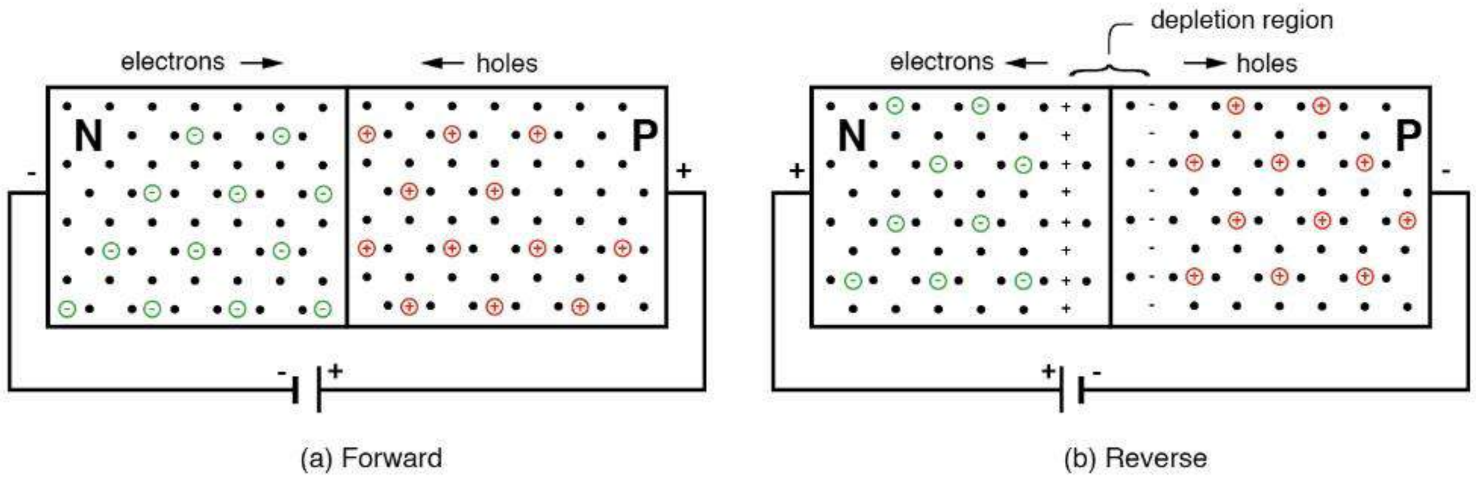
BRIEF DISCUSSION

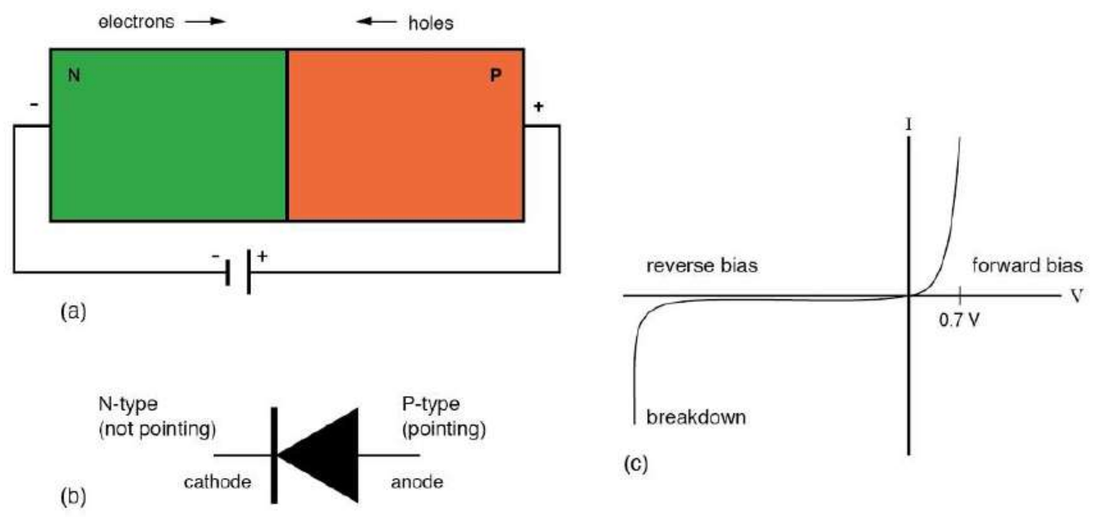


PN Junction Bias

In Figure below(a) the battery is arranged so that the negative terminal supplies electrons to the N-type material. These electrons diffuse toward the junction. The positive terminal removes electrons from the P-type semiconductor, creating holes that diffuse toward the junction. If the battery voltage is great enough to overcome the junction potential (0.6V in Si), the N-type electrons and P-holes combine annihilating each other. This frees up space within the lattice for more carriers to flow toward the junction. Thus, currents of N-type and P-type majority carriers flow toward the junction. The recombination at the junction allows battery current to flow through the PN junction diode. Such a junction is said to be *forward-biased*.

If the battery polarity is reversed as in Figure above(b) majority carriers are attracted away from the junction toward the battery terminals. The positive battery terminal attracts N-type majority carriers, electrons, away from the junction. The negative terminal attracts P-type majority carriers, holes, away from the junction. This increases the thickness of the nonconducting depletion region. There is no recombination of majority carriers; thus, no conduction. This arrangement of battery polarity is called *reverse bias*.

GRAPHICAL PRESENTATION OF FORWARD AND REVERSE BIASED CURRENT



(a) Forward biased PN junction, (b) Corresponding diode schematic symbol (c) Silicon Diode I vs V characteristic curve.

If a diode is forward biased as in Figure above(a), the current will increase slightly as the voltage is increased from 0 V. In the case of a silicon diode a measurable current flows when the voltage approaches 0.6 V in Figure above(c). As the voltage increases past 0.6 V, current increases considerably after the knee. Increasing the voltage well beyond 0.7 V may result in high enough current to destroy the diode. The forward voltage, VF, is a characteristic of the semiconductor: 0.6 to 0.7 V for silicon, 0.2 V for germanium, a few volts for Light Emitting Diodes (LED). The forward current ranges from a few mA for point contact diodes to 100 mA for small signal diodes to tens or thousands of amperes for power diodes.

If the diode is reverse biased, only the leakage current of the intrinsic semiconductor flows. This is plotted to the left of the origin in Figure above(c). This current will only be as high as 1 µA for the most extreme conditions for silicon small signal diodes. This current does not increase appreciably with increasing reverse bias until the diode breaks down. At the breakdown, the current increases so greatly that the diode will be destroyed unless a high series resistance limits current. We normally select a diode with a higher reverse voltage rating than any applied voltage to prevent this. Silicon diodes are typically available with reverse break down ratings of 50, 100, 200, 400, 800 V and higher. It is possible to fabricate diodes with a lower rating of a few volts for use as voltage standards.