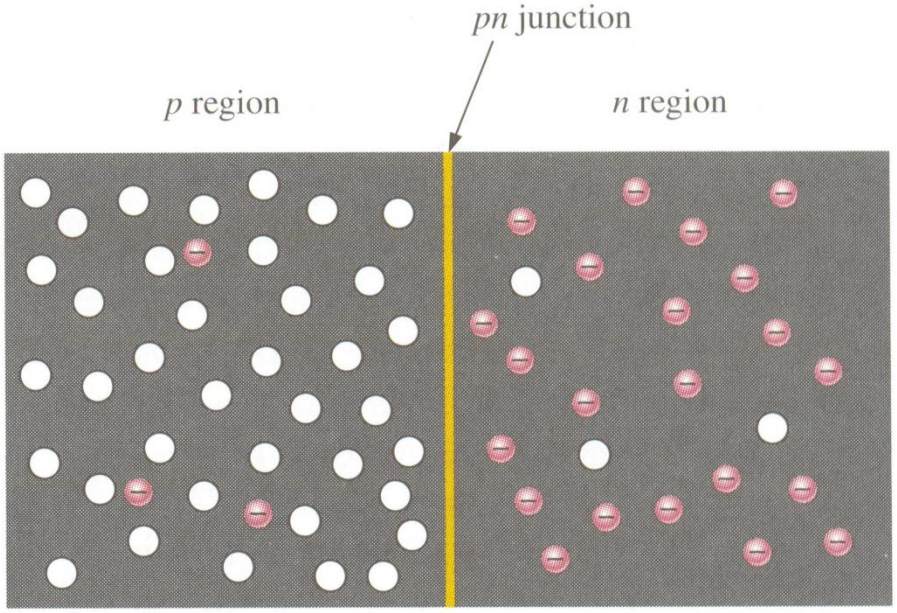
Lecture 7:PN Junction

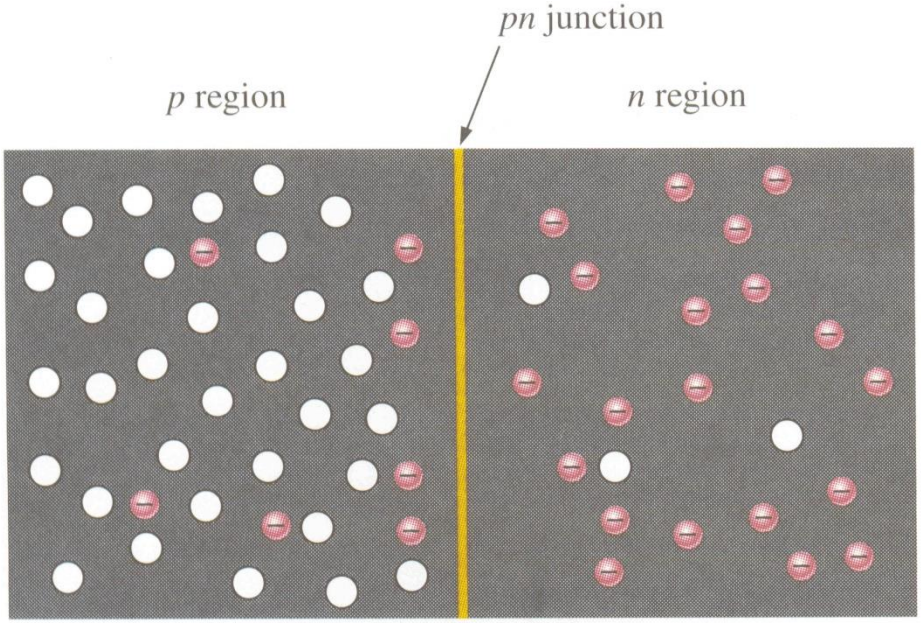
Structure, Depletion region, Different bias Conditions, IV characteristics, Examples

PN Junction

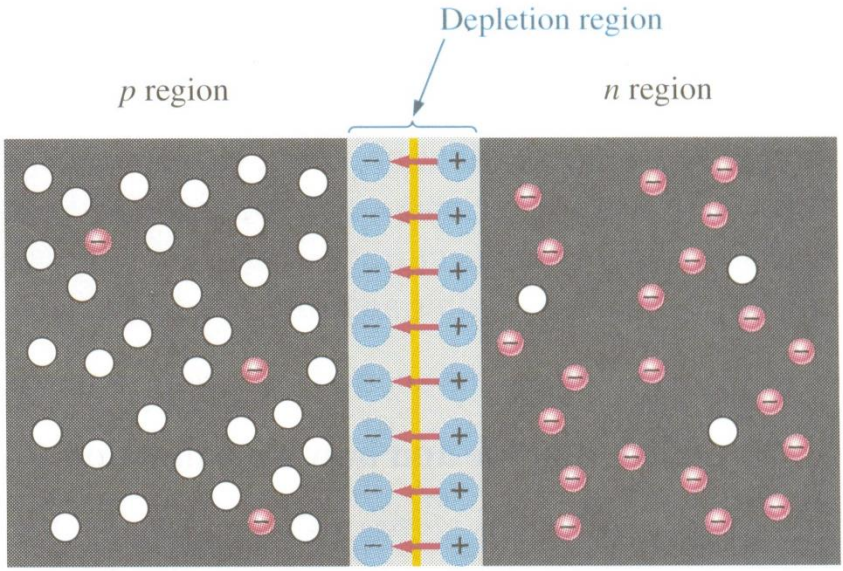


The *diode (pn junction)* is formed by dopping a piece of intrinsic silicon, such that a *p*-type region is adjacent to a *n*-type region.

The free electrons near the junction in the *n*-type diffuse across the junction to combine with holes in the *p*-type near the junction.



Diode (Cont'd)

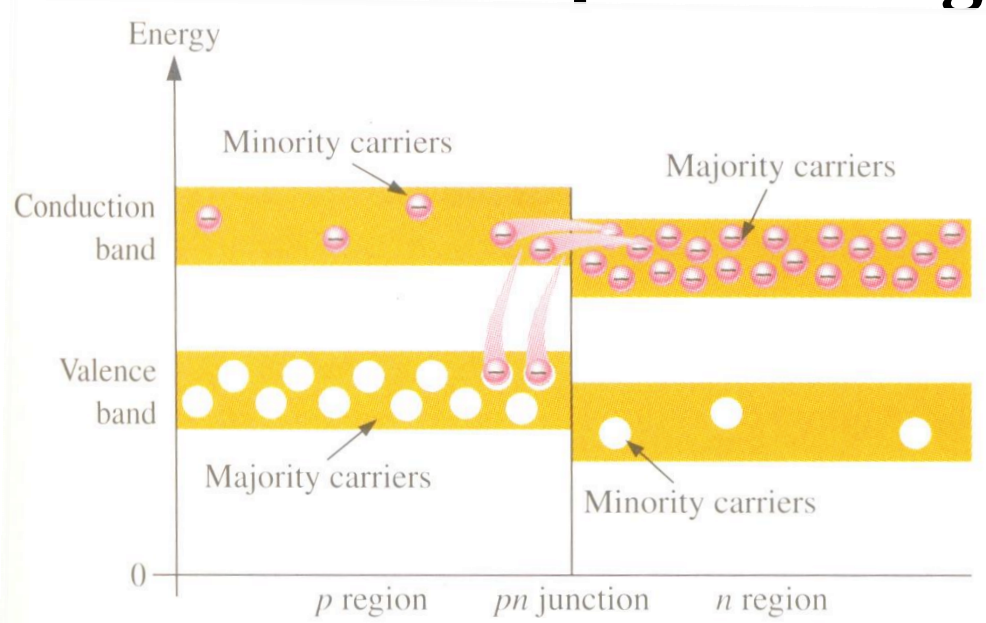


As a result, the region in the *n*-type close to the junction loses its carriers (electrons) and becomes *positively* charged.

Similarly, the region in the *p*-type close to the junction loses its carriers (holes) and becomes *negatively* charges.

Consequently, the region around the junction is depleted from the current carriers. It is referred to as the *depletion region*.

Before Formation of Depletion Region

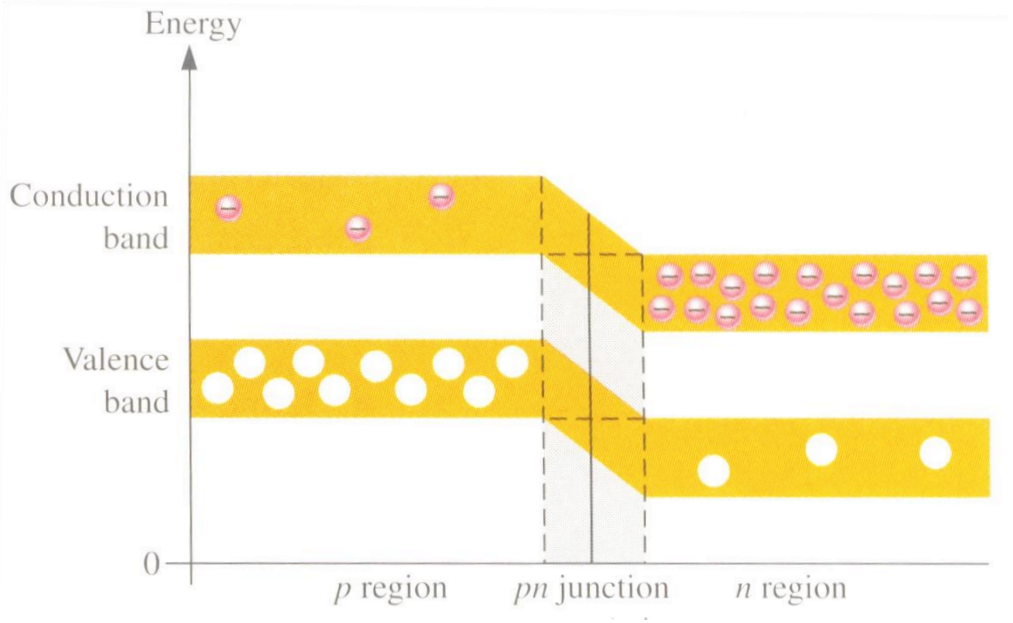


The energy bands of the *n*- and *p*-types are overlapping

Free electrons in the conduction band of the *n*-type diffuse to that of the *p*-type

These electrons recombine with holes in the valence band.

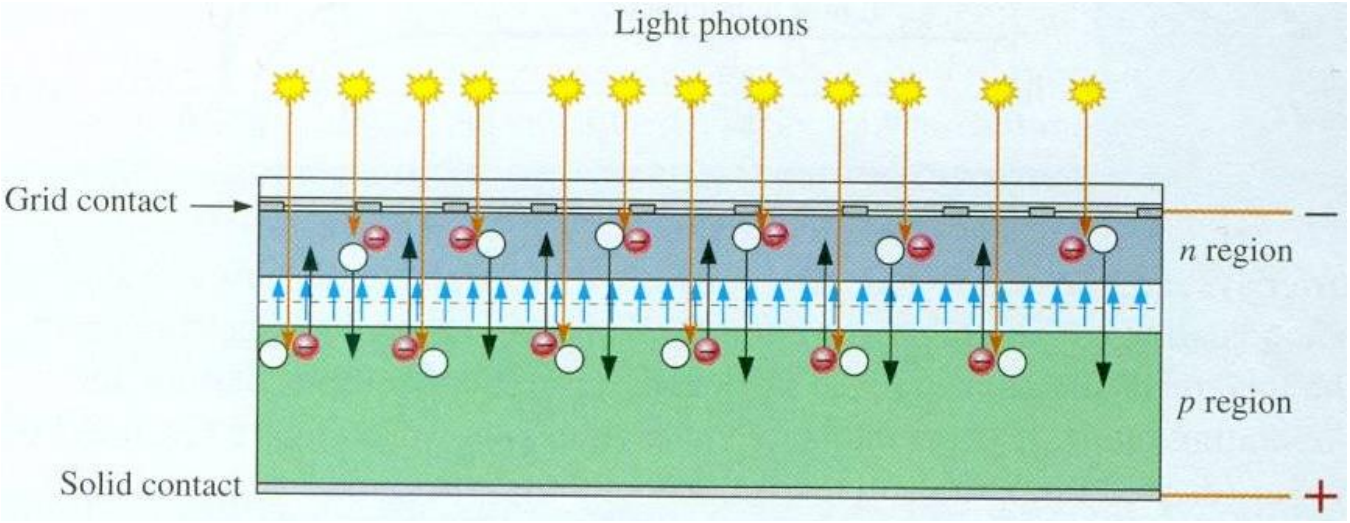
After formation of Depletion Region



Due to this process of energy transfer, the energy bands of the *n*-type are shifted down, and those of the *p*-type are shifted up.

This difference in energy bands, which is proportional to the *barrier potential (0.7V)*, prevents further diffusion of electrons.

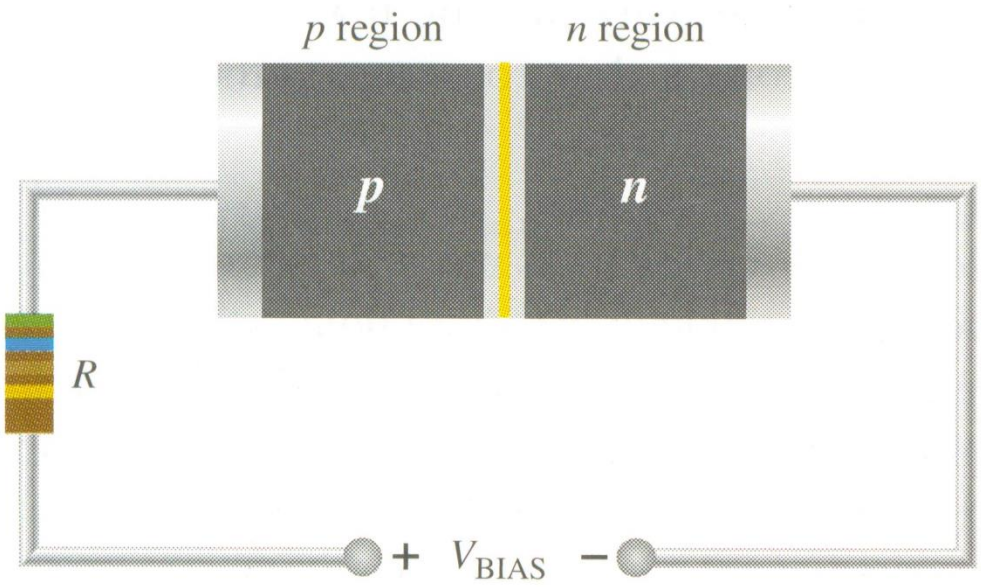
PN Junction as Solar Cell



Incident solar energy is composed of *photons* (energy packets) whose wavelengths fall within *visible light* range (350 nm till 750 nm)

Each photon hits a silicon atom in either regions, can generate an *electron-hole pair*, as its energy is higher than the energy band gap of silicon

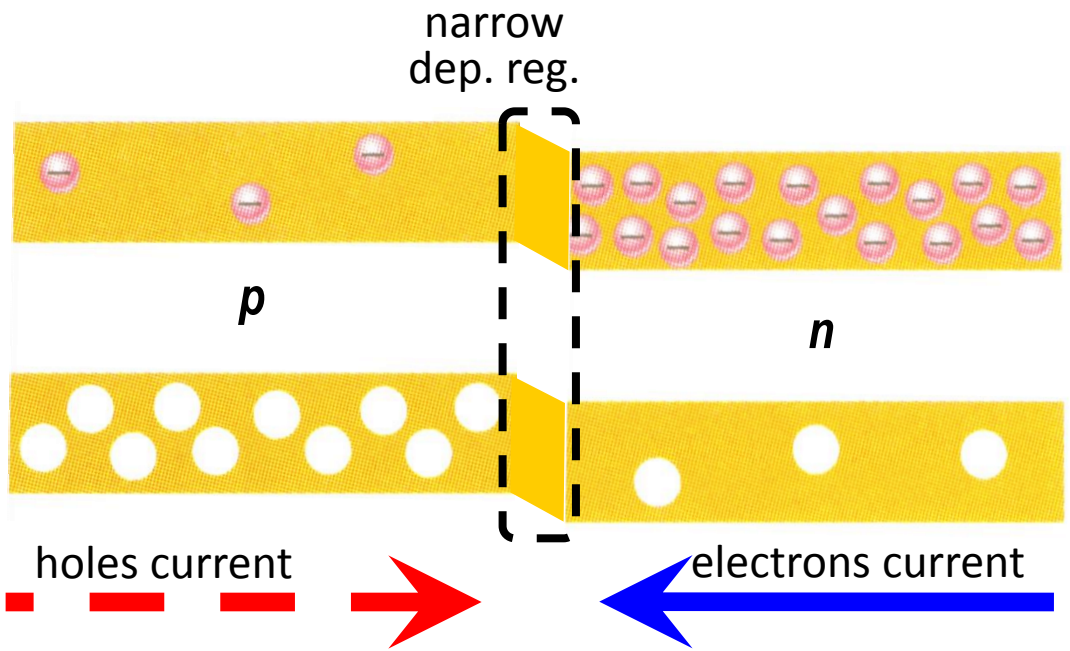
Forward Biasing a Diode



The +ve side of V_{BIAS} is connected to the *p*-type.

The -ve side of V_{BIAS} is connected to the *n*-type.

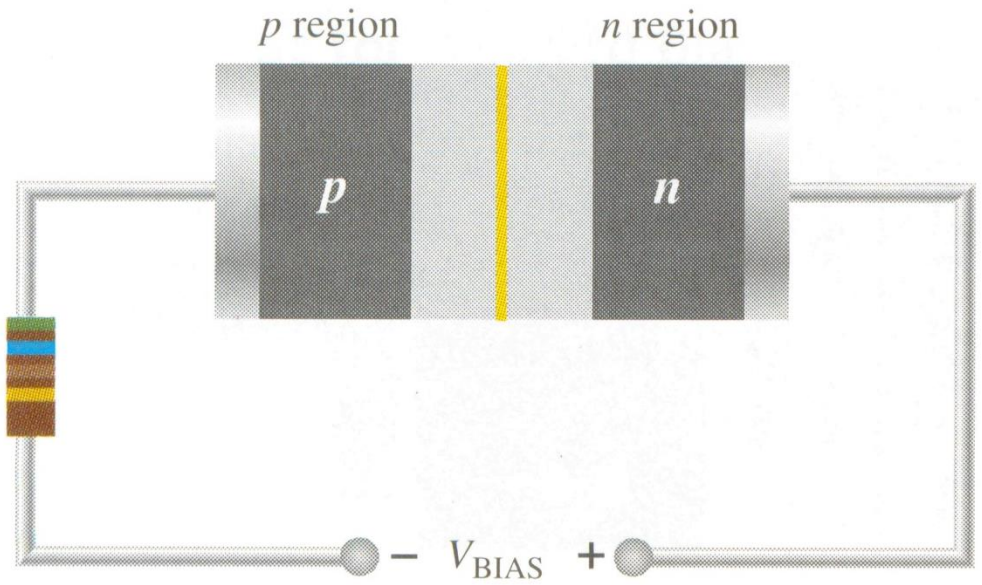
Forward Biasing a Diode (Cont'd)



The <u>*-ve side*</u> of the battery shifts <u>*up*</u> the energy levels of the *n*-type, while the <u>*+ve side*</u> shifts <u>*down*</u> the bands of the *p*-type.

A voltage difference of 0.7V should be maintained across the depletion region, to overcome the barrier potential and to keep the energy bands overlapping.

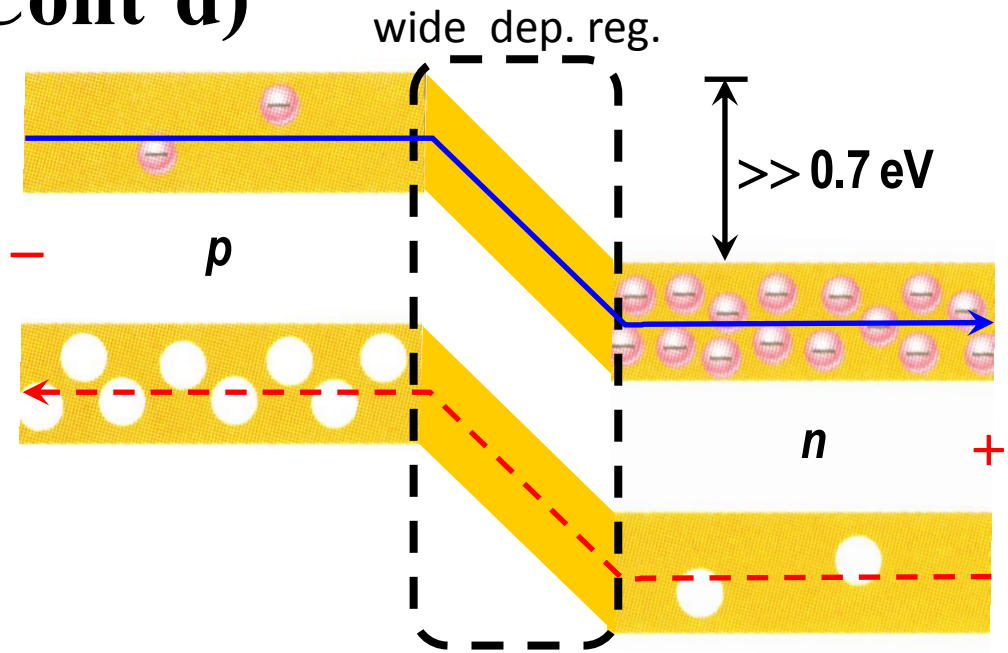
Reverse Biasing a Diode



The +ve side of V_{BIAS} is connected to the *n*-type.

The -ve side of V_{BIAS} is connected to the *p*-type.

Reverse Biasing (Cont'd)



The energy band shifts up in the region connected to the -ve side of the battery and shifts down in the other region connected to the +ve side, which deepen the energy hills.

The electrons (holes) majority carries are unable to roll-up (roll-down) the energy hills in the conduction (valance) bands. Only minority carriers in both regions can cross the junction.

Reverse Biasing (Cont'd)

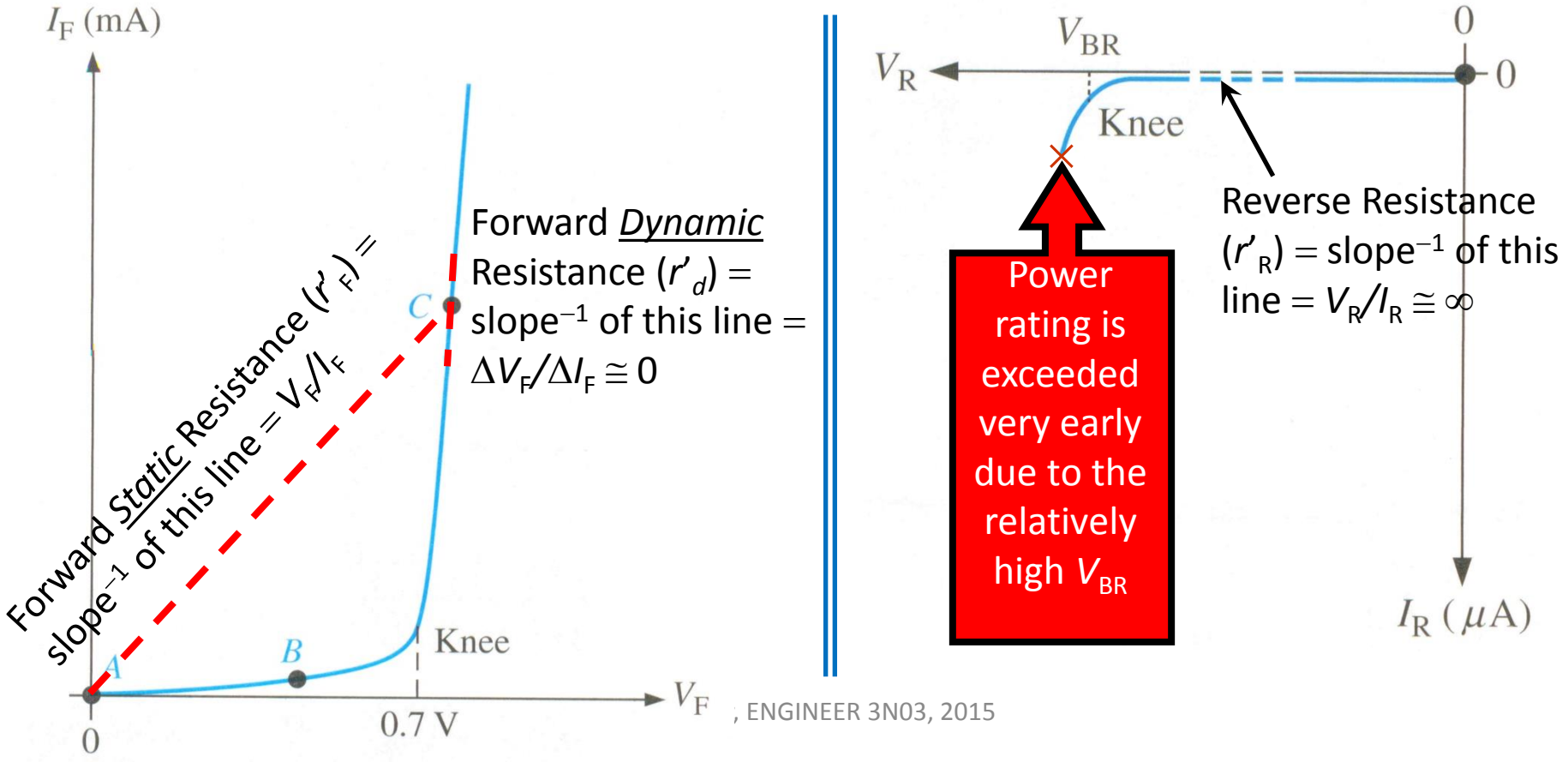
negligible reverse current can flow which is carried by *minority* carriers.

The large difference between the energy bands of both regions *widen the depletion region* across which the entire voltage difference V_{BIAS} can be dropped.

If V_{BIAS} exceeds the *breakdown voltage* (V_{BR}), the depletion region cannot expand any more, and the electric field in it becomes very intensive. Via *Avalanche Breakdown*, this field can release large number of valence electrons from their covalent bonds and the diode *starts to conduct*.

VI-Characteristics of a Diode

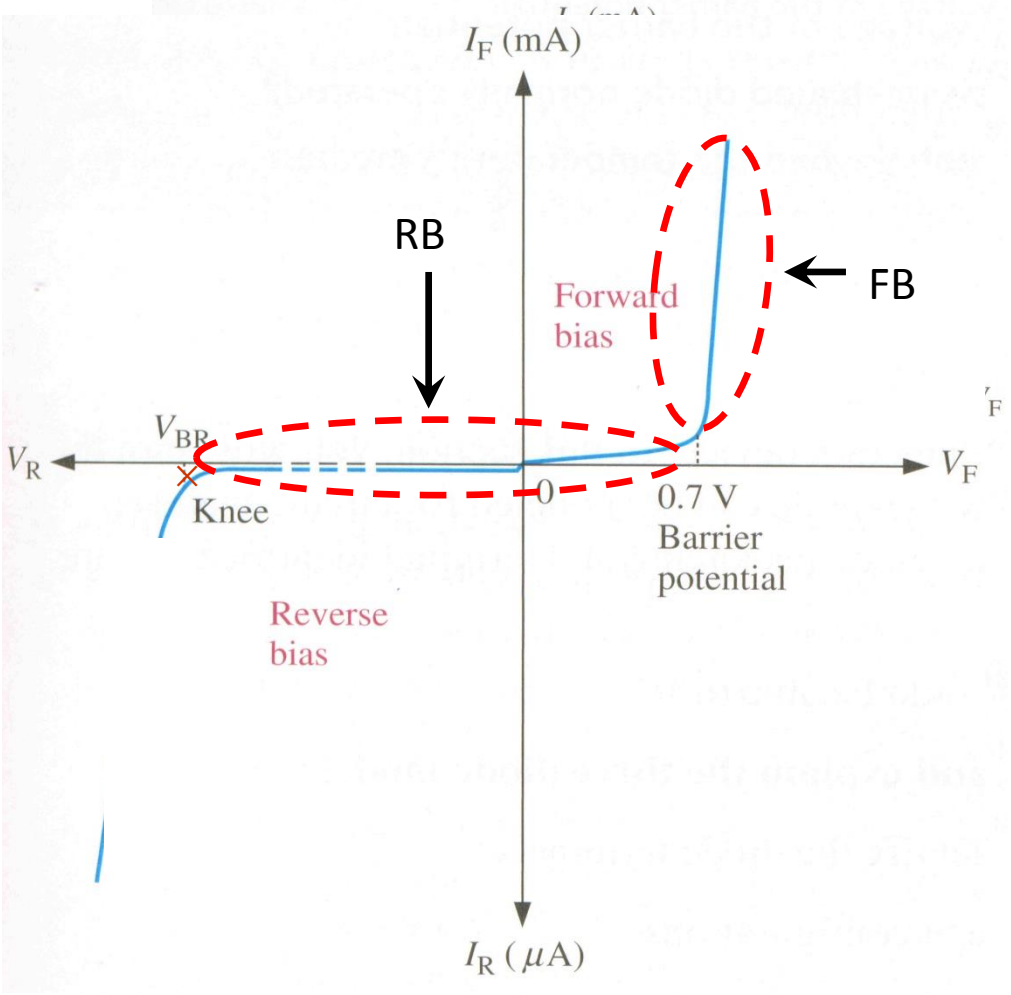
VI-Characteristic of a diode is the relation, based on its physical structure, between the current flowing through it and the voltage applied across it.



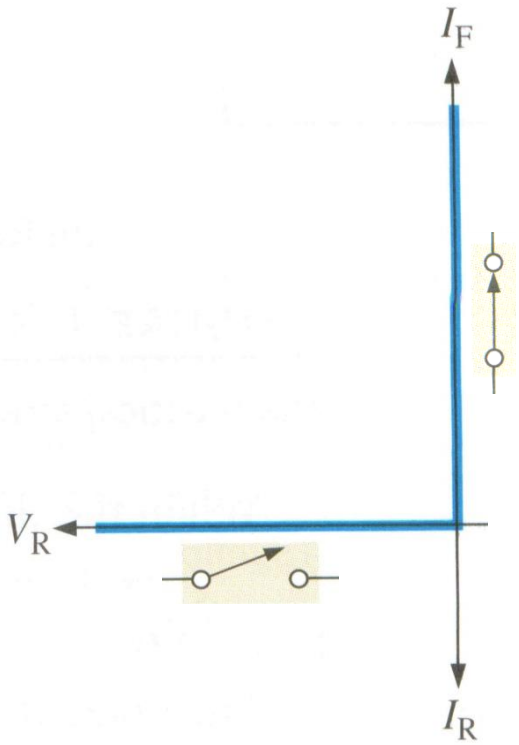
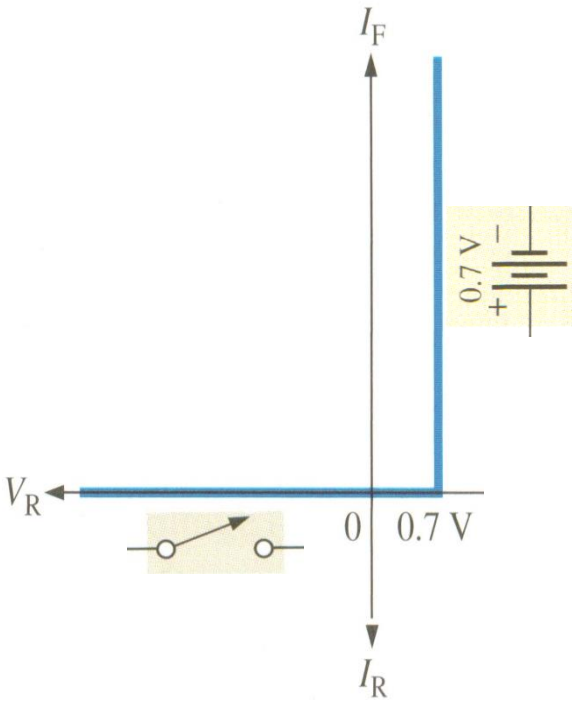
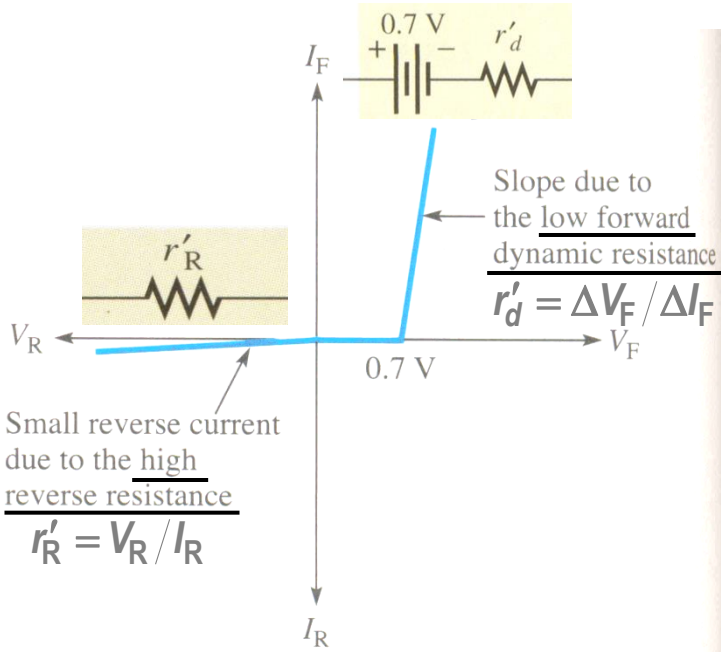
V-I Characteristics (Cont'd)

The complete *V-I* characteristic curve of the diode can be obtained by combining the curves of both forward and reverse bias regions.

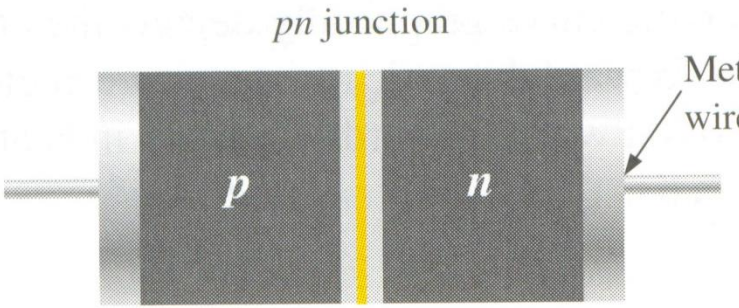
From now on, the forward-bias part below 0.7V will be grouped with the reverse-bias curve of the diode, to define what is called the *effective reverse-bias (RB) region*.



Diode Models

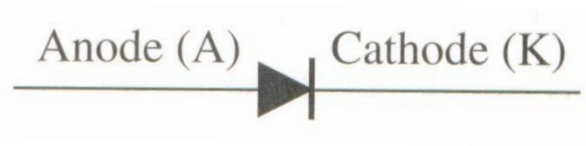
Ideal Model	*Practical Model*	*Complete Model*
		

Diode Symbol



Physical Structure

in circuits

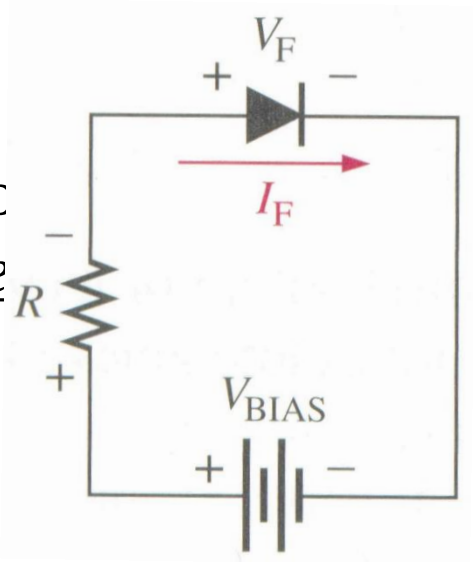


Schematic Symbol

Forward Bias

The forward-biased diode *allows* current to flow in the *same* direction as its *arrow symbol*.

$V_F \cong 0.7$ V



Reverse Bias

The reverse-biased diode *doesn't allow* current to flow in a direction *opposite* to its *arrow symbol*.

$V_R = V_{BIAS}$