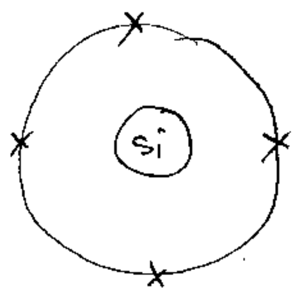
Basic semiconductor theory.

(will cover very shallow).
(more detail in device physics course)

"Intrinsic semiconductors" (1.1.1)

they are pure.

usually column 4 of periodic table.



4 electrons in outer ring.
(valence electrons)

8 is full,

so they share

Form a crystal.

Poor conductor

(not really an insulator, but...)

"Extrinsic semiconductors" (1.1.2)

Add impurities — either column 3 or column 5 elements.

3	5
Boron	Phosphorus
Aluminum	Arsenic.
Gallium	

This is called "doping".

Col. 3 — missing electron — a hole
"acceptor impurity" "P" type

Col. 5 — extra electron
"donor impurities" "N" type

Drift and diffusion currents (1.1.3)

These holes or free electrons move in presence of electric field. ⟹ Drift currents

They also move due to variations in the impurities ⟶ Diffusion currents

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Excess carriers (1.1.4)

When heated, more electrons break loose from their crystal structure.

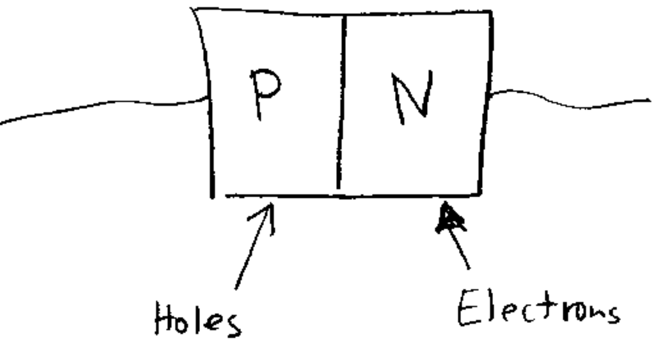
⟶ excess electrons.

They leave a space

⟶ excess holes.

This increases the conductivity

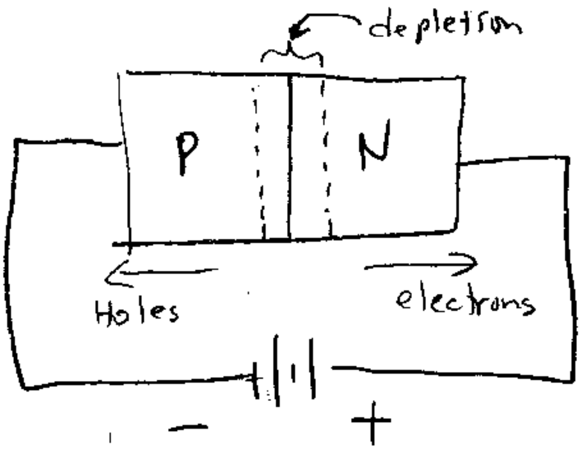
The P-N junction (1.2)



At equilibrium —
(0 volts)
It doesn't conduct at the junction
(will see why later)

Reverse biased (1.2.2)

Apply a voltage:



This causes holes and electrons to move away from the junction.

Forming a <u>depletion region</u>.

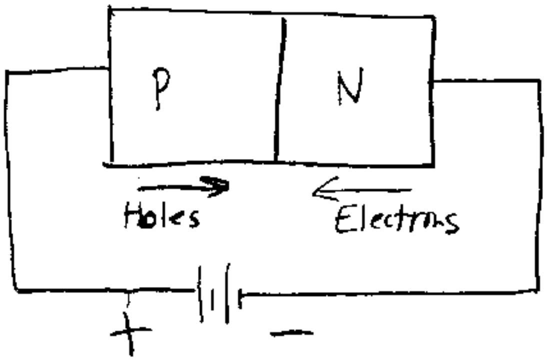
This is a region in which there are no carriers. — Does not conduct.

Increase the negative bias — increases thickness of depletion region.

→ It acts like a capacitor. that varies with voltage.

(Actually ... it does conduct a little -- $\approx 10^{-15}$ A "reverse saturation current")

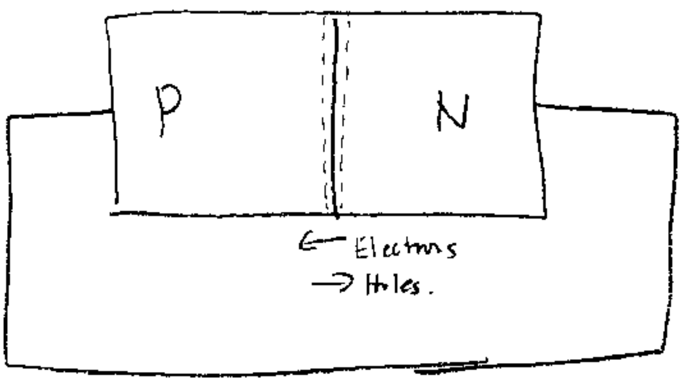
Forward biased (1,2,3)



Holes and electrons both move toward the junction.

Lots of carriers near the junction causes it to <u>conduct</u>.

At equrlibrium (1,2,1)



(zero volts).

Diffusion current causes some migration —

Electrons move into P region, filling holes.

→ This too makes a depletion region —

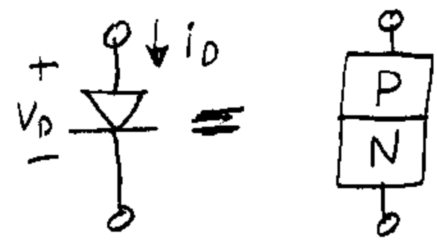
Does not conduct.

The book shows some math - so you can calculate how much.

You should be able to make the calculations, but they may not appear to be useful.

Ideal current-voltage relationships (1,2,4).

$$i_D = I_S \left[e^{\frac{V_D}{nV_T}} - 1 \right]$$



I_S = "reverse saturation current"

Typical value -- 10^{-15} to 10^{-13} amps.

Depends on — doping concentration

area.

V_T = "thermal voltage" $\approx .026$ at room temperature

Actually — $V_T = \frac{KT}{Q}$

K = Boltzmann's Constant
1.38×10^{-23}

Q = Charge of an electron
1.6×10^{-19} coulombs

T = Temperature Kelvin.

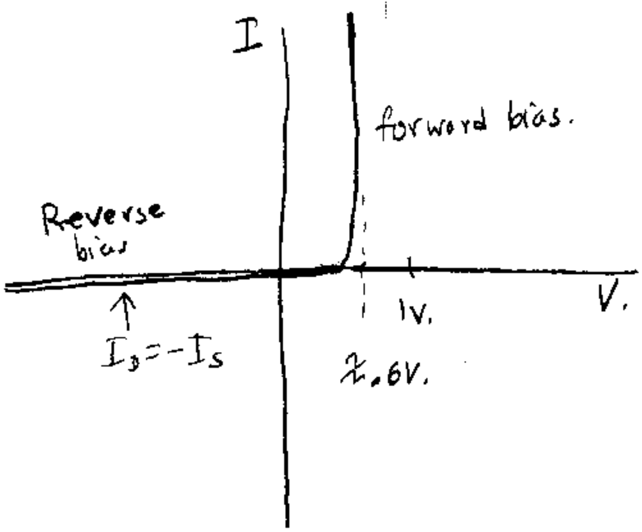
n = "emission coefficient" — Typical 1 to 2
"ideality factor"

Adjusts for recombination in depletion (space charge) region.

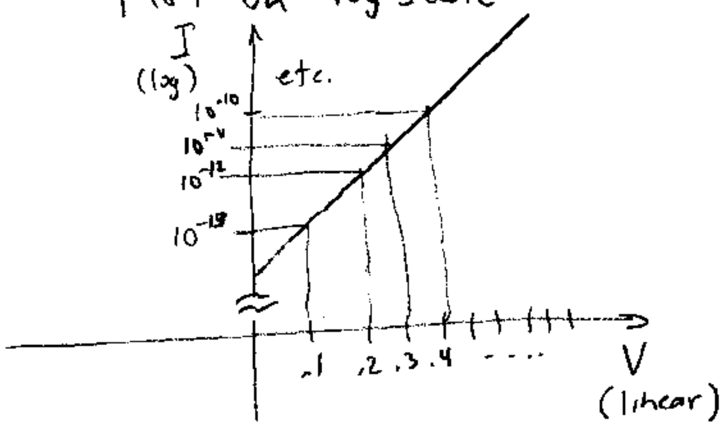
Depends on current —
usually — assume $= 1$.

Diode characteristics (1,2,5)

Plot that formula --
Looks like this:



Plot on log scale



Other effects

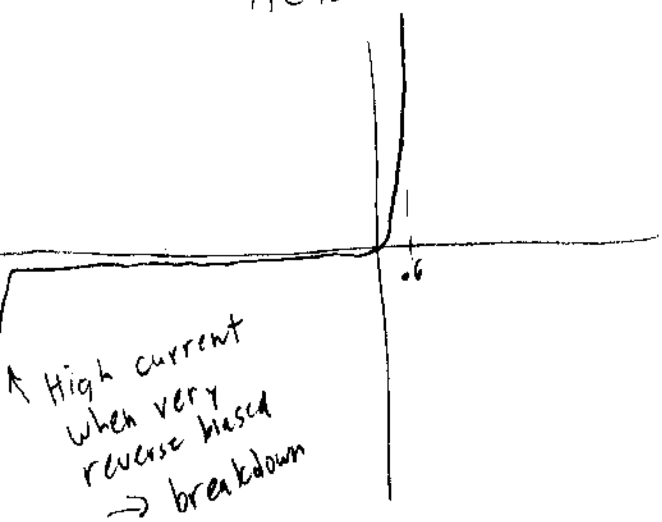
Temperature - V_T is a function of temperature

$$\frac{\Delta V_T}{\Delta T} \approx 2 \frac{mV}{°C}$$

I_S — function of intrinsic carrier concentration.
Doubles for 5°C rise in temp.

Breakdown

Actual I/V:



Breakdown voltage --
most diodes - 50 to 1000 V.
("PIV" rating peak inverse voltage)
"Zener" diodes — 3 to ____ Volts
designed to operate in breakdown.

→ Non-destructive —

Exercises – (not to hand in) (answers in text)

Page	exercise	
p. 7	1, 2	You should be able to apply the formula, but don't worry too much about it. Don't memorize the formula – You can look it up.
9	3	
12	4, 5, 6	
14	7, 8	
16	9	← This one might be useful – You can still look it up. You should understand why it works. You should also be able to calculate the capacitance with a non-zero bias.
18	10, 11	← This formula is critical. Also do 10 (a) for: $V_D = .1$ V, 1 V, 10 V, 100 V, 1000 V. What is the significance? Also do 11 for: "resulting current" = 1 A, 10 A, 100 A, 1000 A. What is the significance?
23	12	

Harder problems –

Page	exercise
43	1.17
44	1.23