- Depletion region ✓
- Breakdown ✓
- effect of temp
- diode models

Diode recap

pn Junction Diode Basic

majority: holes

majority: electrons

Min: e⁻

min: hole

minority charge carriers depend only on temp, cuz electrons gain thermal energy and break covalent bonds

not on V applied

- The above p-type material is positive?
  Do you agree?

  No, the atoms are neutral

- The above n-type material is negative?
  Do you agree?

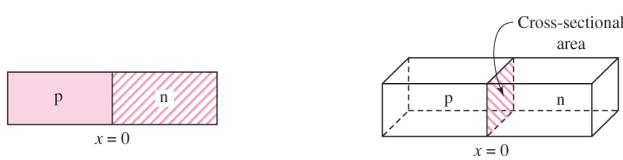
  NO, p-type and n-type are neutral.

- Overall the pn-junction diode is charged and not neutral.
  Do you agree?

  when put in a junction it is still electrically neutral

1

pn Junction Diode Basic (continued ...)



- Assume that a diode is virgin, which means it has never been connected to a power source after it was manufactured.

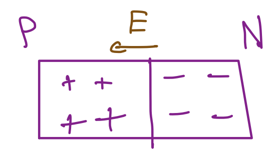
  The above diagram represents such virgin diodes. Note that there is no depletion region.

  Do you agree?

  No, there is a depletion region regardless of wether a bias is applied or not. Bias only affects size of depletion region

2

* Diffusion current due to majority charge carriers



there is a conc gradient. -ve charges will diffuse to P side.

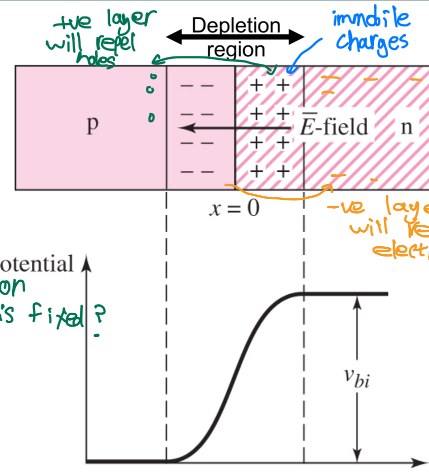
An electric field is set up.

Conc gradient fights with electric field, they oppose each other

Diffusion
- holes from p-side combines with electrons from n-side.
- As recombination takes place immobile ions will surface out (uncovering)

- Depletion region: no mobile charges but only uncovered immobile ion (depleted of mobile charges)

Depletion Region



How does the depletion region form?

why the width of depletion region is fixed?

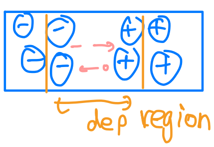
How does the diffusion process stop?

electric field opposes

width of depletion region should be width of diode, but it doesn't happen. Electric field stops movement of charge carriers

* Depletion region acts as barrier for further movement of carriers (Barrier potential)

3



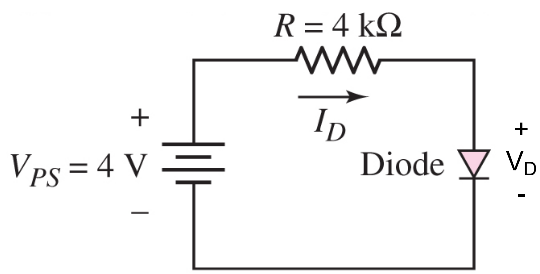
- movement of minority carries makes drift current
- electrons drift to +ve layer

- drift current opposes diffusion current

drift: due to minority
diffusion: due to maj

**under steady state: **
diffusion = drift
net current = 0

Here is a Quiz For You!

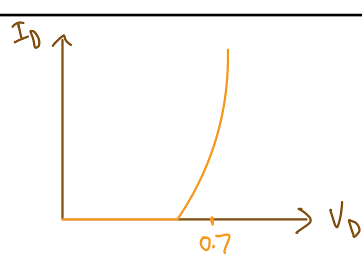


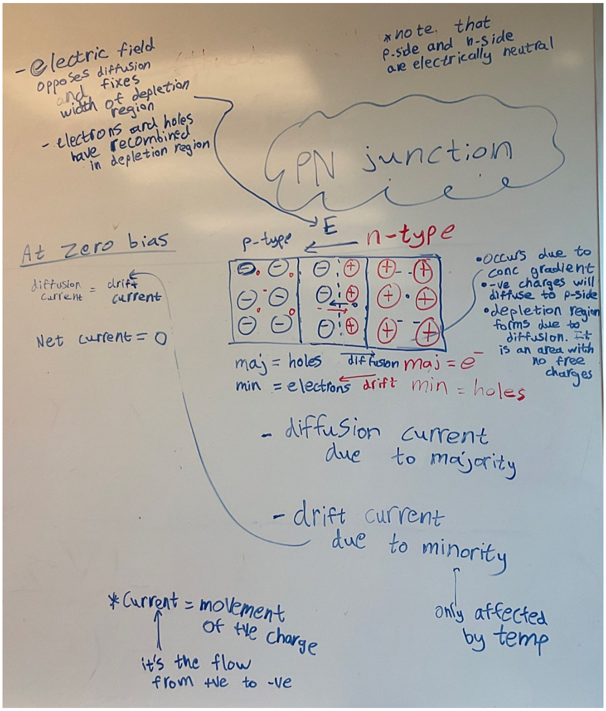
Which of the followings is an easier way to make V_D = 1.2 V?

a) By increasing V_{PS} when R remains unchanged
b) By decreasing R when V_{PS} remains unchanged
c) By making suitable changes to both R and V_{PS}
d) None of the above

There is no way to change voltage across diode

4

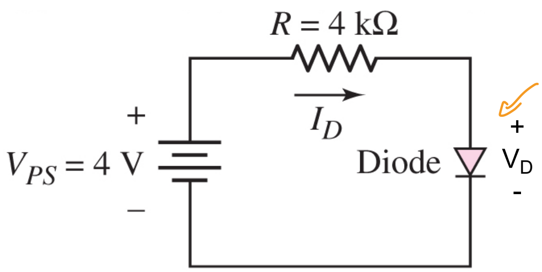




BJT can be considered as a device with 2 diodes.

- one diode is biased by current of other diode

The Simplest Diode Circuit



sort of works as V source in opposite direction

Determine I_D

VR=4 -0.6=3.4V

ID = 3.4/4 =0.85 mA

depletion region reduces + barrier potential reduces

↑ becomes = $V_f - V_D$

Forward Biased pn Junction Diode

- V_D forces majority free charge carriers to recombine and reduce width of depletion region

* holes combine with -ve ions

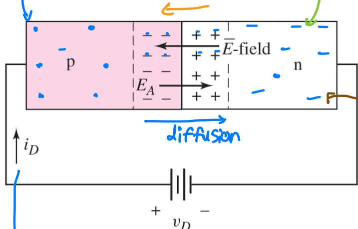
* electrons combine with +ve ions

↳ depletion region has no mobile carriers, only immobile ions.

holes on p-side will be repelled since they are positively charged

drift

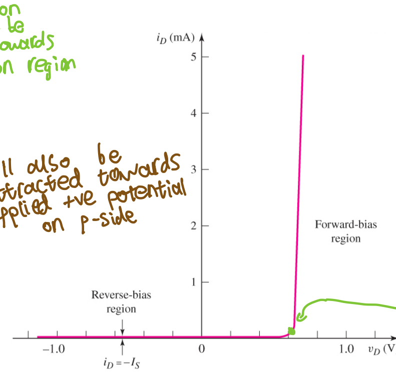
electrons on n-side will be repelled, towards depletion region



diffusion

will also be attracted towards applied +ve potential on p-side

$\boxed{i_D = \text{diffusion current} - \text{drift current}}$



$V_f = 0.7$

As V_D reaches 0.7 barrier potential = 0

∴ Flood of electrons can now pass thru junction, resulting in exponential rise in i_D

If the diode was made of a different material than Si, the cut-off voltage would still remain the same.

Do you agree?

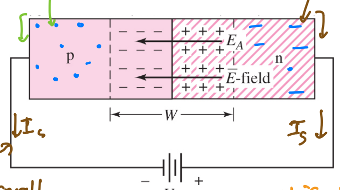
- cut in voltage depends on material, so it will change

Reverse Biased pn Junction Diode

- results in uncovering of mobile ions and width of depletion region to increase

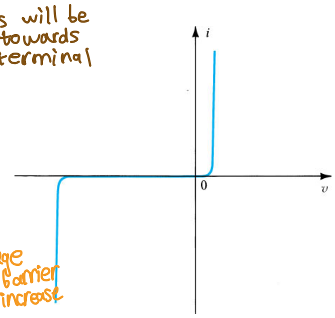
holes will be drawn towards -ve terminal

electrons will be drawn towards +ve terminal



very small since it only depends on minority

as this voltage increases, the barrier potential will increase



-now majority charge carriers can't cross junction

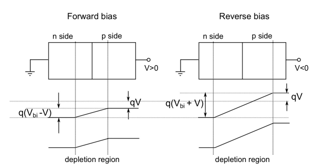
Maj carrier flow = 0

difusion current reduces while drift current stays the same

only affected by minority

Which of the following statements is correct for the depletion region width W for a given pn junction diode.

a) $W_{(\text{Reverse bias})} > W_{(\text{forward bias})}$
b) $W_{(\text{Reverse bias})} < W_{(\text{forward bias})}$
c) $W_{(\text{Reverse bias})} = W_{(\text{forward bias})}$
d) None of the above



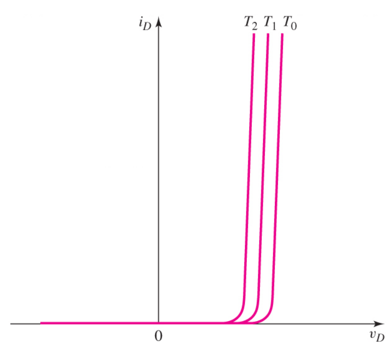
built in barrier reduced, easier for current to flow

7

depletion width: reverse bias > no bias > fwd bias

barrier potential: reverse bias > no bias > fwd bias

Temperature Effect



Temp ↑
min carriers ↑

Which of the following statements is correct for the above characteristic curve of a forward biased diode?

a) $T_0 > T_1 > T_2$
b) $T_0 < T_1 < T_2$

-heat gives it more free carriers, equal No. of holes and electrons are broken in the system

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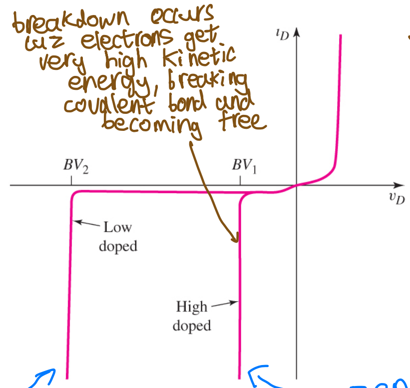
Effect of Doping on Depletion Region

- For normal diode, it can't withstand high power being dissipated and it will break

breakdown occurs b/z electrons get very high kinetic energy, breaking covalent bond and becoming free

will also collide with other electrons in a chain reaction



avalanche (normal)

zener

Does it make sense to you?

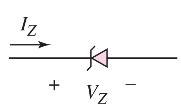
9

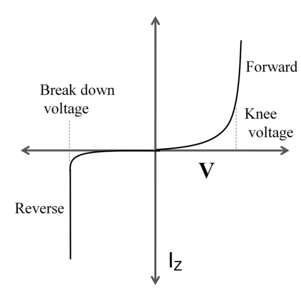
low doped

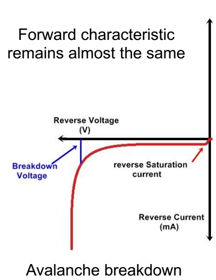
highly doped

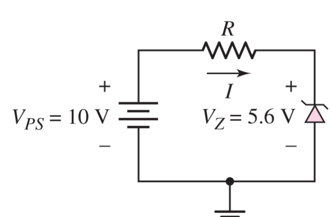
Avalanche Breakdown and Zener Breakdown

* Do I need to know more on zener diodes??

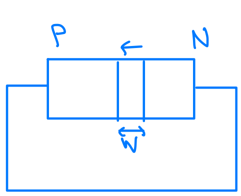








10



$W = 10\ \mu m$

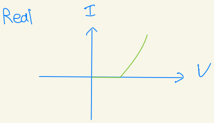
$V_{(Break)} = 10\,V$

electric field only present within depletion region

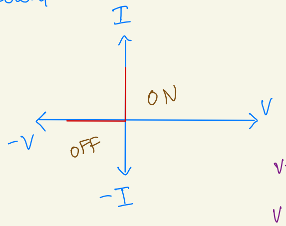
$E = \frac{V}{d} = \frac{10\times10^6}{10}$

$= 1\ MV/m = 1\ kV/mm$

Real



Ideal

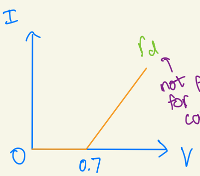


- acts like a perfect switch

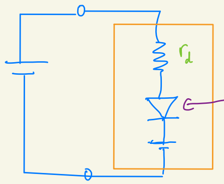
$V = 0_+$, $I = \infty$

$V = 0_-$, $I = 0$

what we can model



not pleasant for simple calculations



ideal diode

*go over models again

another accepted model