Semiconductors

1/11/2021

① Conductor → e⁻ loosely bound with their own nucleii. e⁻ can jump from one atom to another. But cannot come out of surface.

Materials which have large number of free electrons which can move freely inside the boundary of material in presence of external applied electric field, are called conductors.

Temp↑ Res↑

$\rho \sim 10^{-8} \rightarrow 10^{-2}\ \Omega m.$

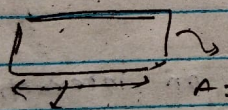
$\sigma \sim 10^{2} \rightarrow 10^{8}\ S m^{-1}$

$R = \frac{10^{-6} \times 0.1}{10^{-4}} = 0.01\ \Omega.$

② Insulators →

Materials having very large resistance to the flow of electric current or outermost electrons of any atom are not free to move, are called insulator.

$\rho = 10^{11} - 10^{15}\ \Omega\text{-m}.$



$R = \frac{10^{15} \times 0.1}{0.01} = 10^{16}\ \Omega.$

③ Semiconductors

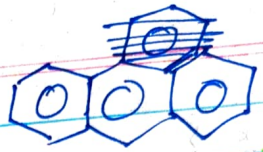
These materials conduct electricity when external field is applied, but the conductivity of no. of conduction electron are very less as compared to conductors at Room Temp.

Temp↑ Res↓.

$\rho \approx 10^{-5}$ to $10^{6}\ \Omega m.$

These are materials used to design devices which control flow of charge inside materials.

Semiconductors →



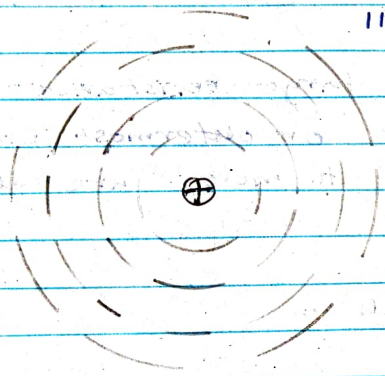
• Silicon	• Anthracene
• Germanium	• Pentacene, Phthalocyanines.

• CdS	Polymers →
• Ga_2As	polypyrole, polyaniline.
• CdSe	Polythiophene.
• InP	

Valence Band & Conduction Band.

Na = 11 ← There are 11 diff. energy electron.

For Na:
$1s^2\ 2s^2\ 2p^6\ 3s^1$



$E = K + U$

U → due to interaction b/w the charges.

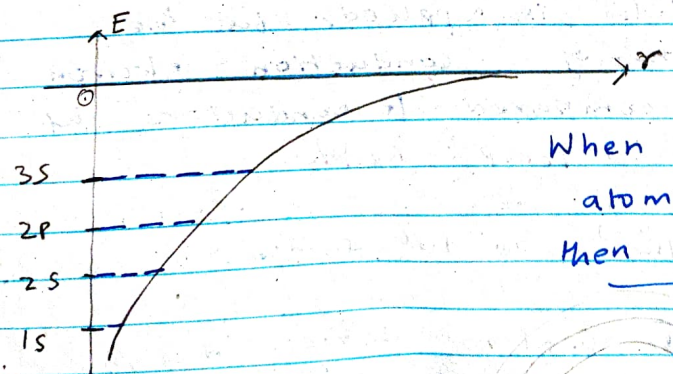
So, total E → depend on interaction with charges.

So total E → -ve

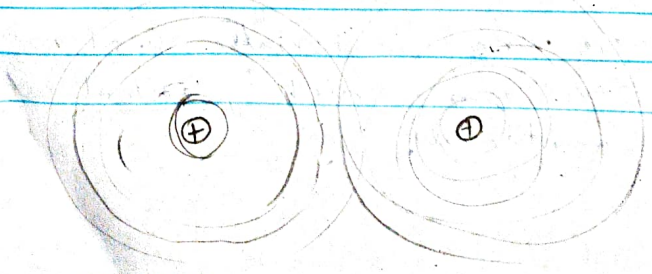
Energy is reqd. to make E = 0

For an isolated atom. (Na).

in C, e^- are strongly bound → so, less free e^- at R.T, compared to Si & Ge.



When more than one atom are there (in lattice) then → (PTO)



Lattice Constants.

It is the physical dimension of unit cells within a crystal lattice, it is side length of the cube.

If ↓ L.C of semiconductor is ↓, means e^- are more ~~loose~~ tightly bound.

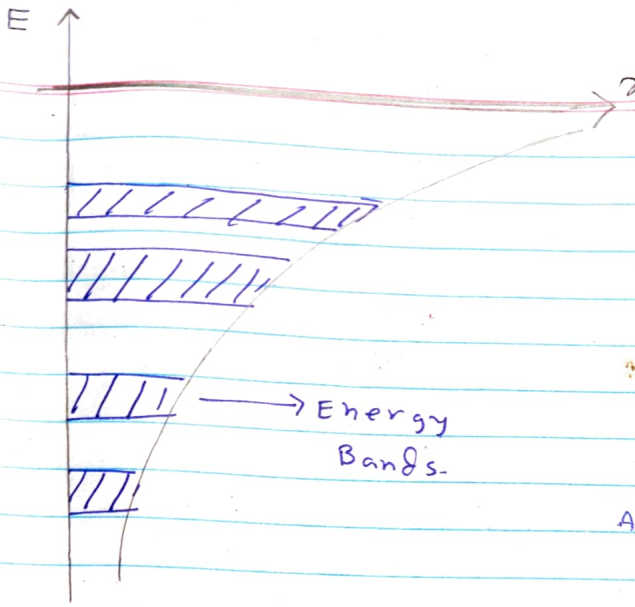
If L.C of " is ↑, e^- are loosely bound.

If L.C is ↓, e^- need more energy to be excited.

ie, width of energy bands of both Valence (E_v) and conduction (E_c) decreases.

~~Where~~ Thus, Band gap E_g increases.

Energy levels splits in crystals.



if 'n' atoms,

So, Total $e^- = n \times 11$

Now, each e^- will have diff. energy.

value → change

All will have interaction.

highest

- Valence Band:— The energy levels which are completely filled at 0K., are called valence band.

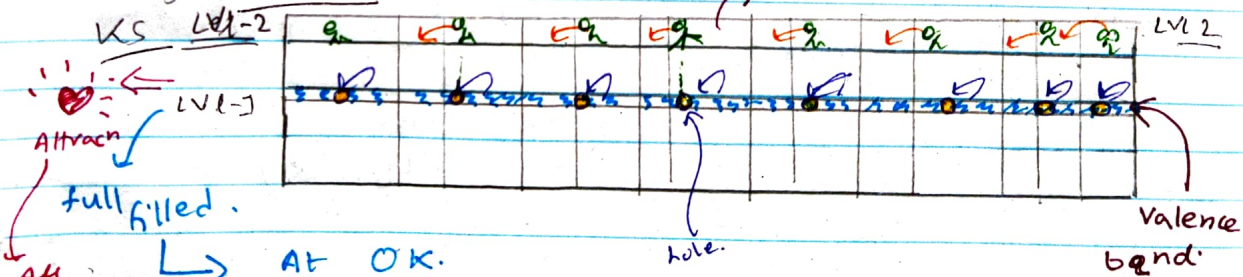
or partially filled.

- Conduction Band:— The next empty, higher energy band to valence band is called conduction band.

L260

Evave — JEE main 2021

KS



All people will rush to it.

Lvl 1, Lvl 2 → Roof tops of each band.

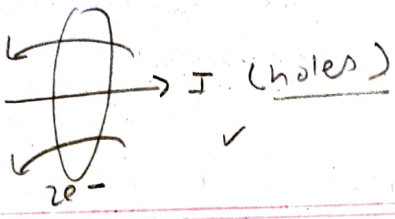
(If) As Temp ↑, ~~each people~~ energy ↑, of each people, to avoid congestion, one-one people climb up to → conduction band, leaving a vacancy ⊖.

At Lvl 2- roop, vacant place, so, all rush towards (⊖), ∴

hole movement ∝ e^- movement

↳ in valence band.

(opp. to movement of e^-).



Jumping
Jampags
Y at same level.

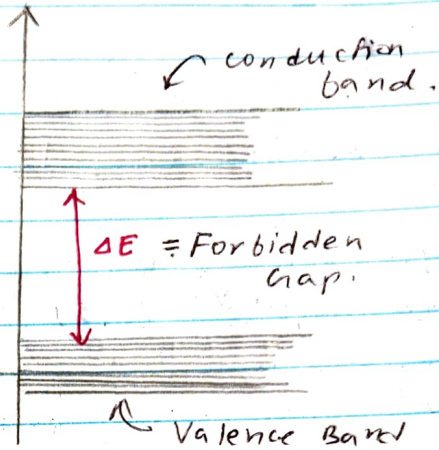
For semiconductors,

$\Delta E \simeq K_B \cdot T_{room} + \sim$ other factors.

$\simeq 0.01 eV$

K_B = Boltzmann's constant

T_{room} = Room Temp.



For Silicon,

$\Delta E = 1.1 eV$.

For Germanium,

$\Delta E = 0.68 eV$.

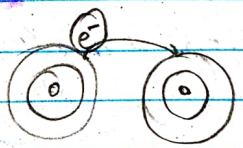
$K_B = 1.38 \times 10^{-23}$ $m^2 kg/s^2 - K$

This Energy is achieved by few e⁻, which jumps.

For insulators,

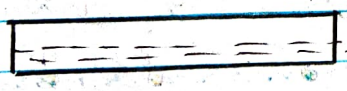
$\Delta E_{ins} > 3 eV$.

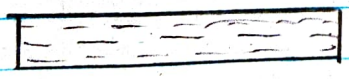
$\Rightarrow$ Conductors.



Eg- e⁻.

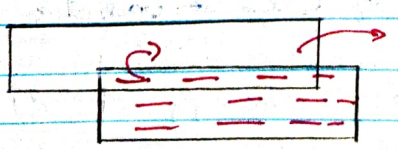
C-1)





Some e⁻ is already in their C.B.
So, easily they can jump.
(Na)

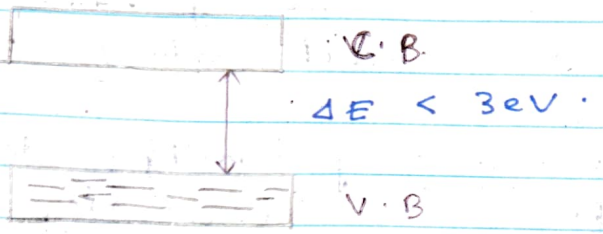
C-2)



However, in Zn, Valence, B, completely filled, C.B empty.
But C.B overlaps with V.B.

⇒ Semiconductors.

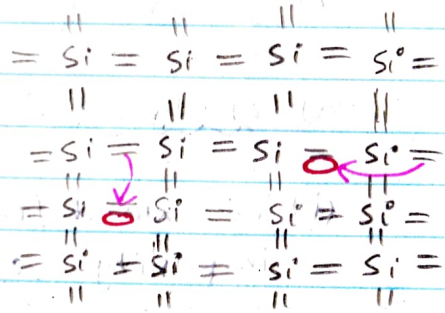
At room Temp, some e⁻ manage to jump from C.B from V.B.



*

1) Intrinsic Semiconductors (Pure Semiconductors).

Eg → Pure Si crystal



Z = 14

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

G.S 14 | 1 | 1 | | OK.

E.S 1 | 1 | 1 | 1 | R-T

When valence electron is shifted to conduction band, a hole is created in valence band.

→ 1 conduction e⁻ + 1 hole ⊕

In intrinsic semiconductor, | Here $n_{e^-} = n_H$

no. of holes = no. of conduction e⁻

⇒ However, the no. of e⁻ & hole pair is very small. in pure.

To increase conductivity → Extrinsic.

T↑ n↑ . v↓ .

2) Extrinsic Semiconductor

Pure Si have only a small fraction of conduction electrons or, very small fraction of Valence band electrons are able to reach conduction band.

- By diffusing small amount of impurities (doping) it's conductivity can be drastically changed.

- This procen of diffusing impurity is called DOPING.

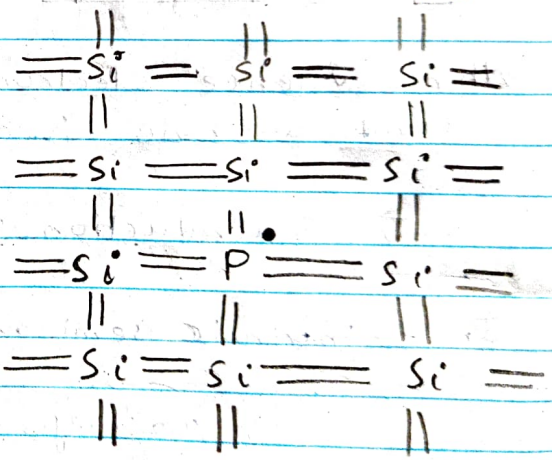
They are of 2 types.

(a) N-type Semiconductor.

(i) If we diffuse a small amount of pentavalent impurity such as Phosphorus (P) into Si crystal.

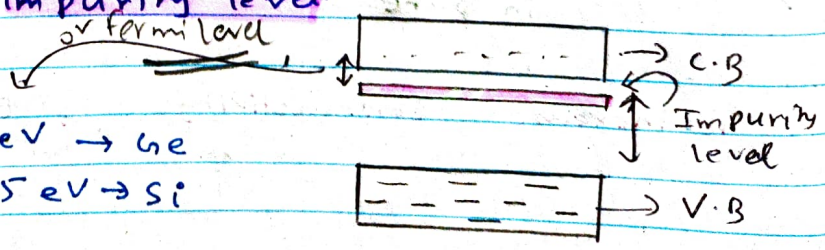
- Some P atoms replace Si atoms and occupy their place.

P has 1 extra e^- remain.



- This e^- (extra) of P, has much higher energy than the valence electron energy level.

- This energy level of this extra e^- is known as impurity level.



0.01 eV → Ge

0.05 eV → Si

- The no. of conduction e^- increases due to diffusion of 'P' atoms in Si crystal.

⇒ Impurities which donate e^- are called donor impurity.

No hole pair...

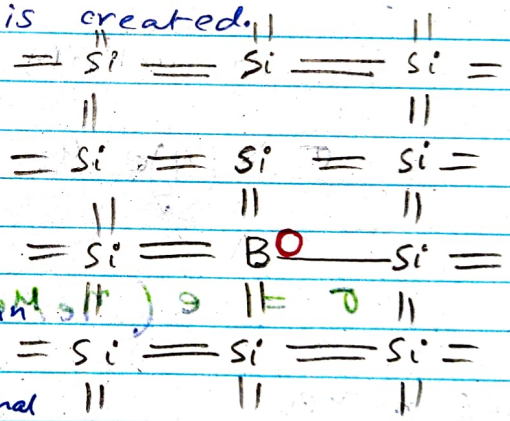
Hence

$n_{e^-} > n_h$ ⇒ so, 'n' type semiconductor

↑ Majority charge carrier. ↑ Minority charge carrier.

(b) p-type semiconductor.

If we diffuse small amount of trivalent impurities such as Al, B, In, etc then these atoms can replace atoms of Si or Ge in its cryptal and a hole is created.



Here.

$n_H > n_{e^-}$

↑ Majority ↑ Minority

Note:

Cryptal maintains an overall charge neutrality as the charge of additional charge carriers is just equal and opp. to that of the ionised cores in lattice.

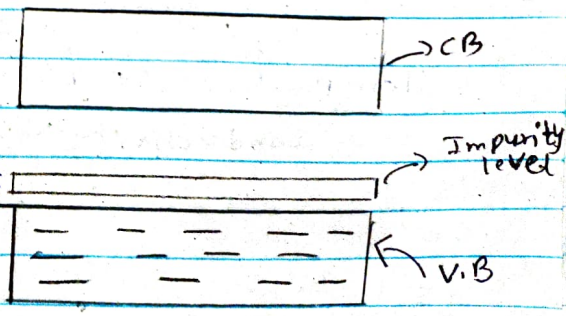
in thermal eqlbm.

$n_e \cdot n_H = n_i^2$

(n_i = Intrinsic for Semicond.

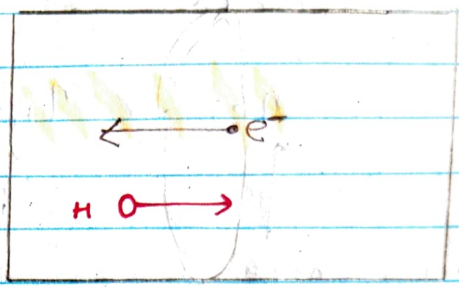
$n_i = n_{e,i} = n_{h,i}$) Si → 0.057 e^-

For Extrinsic. $n_e \uparrow$ $n_h \downarrow$.



* Conductivity of Semiconductors.

Here,
current



$I = (n_e) A e v_{d,e-} + (n_h) A e v_{d,h}$.

So, $E = \rho J$ And, $\sigma = \frac{1}{\rho} = \frac{J}{E}$

$\therefore n_e \cdot e \left(\frac{v_{d,e}}{E}\right) + n_h e \left(\frac{v_{d,h}}{E}\right)$

$v_d = \mu \cdot E$ $\mu \rightarrow$ mobility $= \frac{e\tau}{m}$

So, conductivity, σ

$\sigma = (n_e) e \mu_e + (n_h) e \mu_h$

$$\sigma = e(n_e \mu_e + n_h \cdot \mu_h)$$

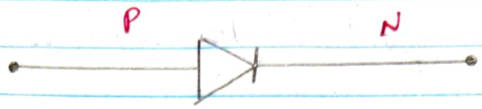
If n-type

$n_e >> n_h$. | $\mu_h << \mu_e$.

$\sigma_{,n} \cong (n_e) e \cdot (\mu_e)$.

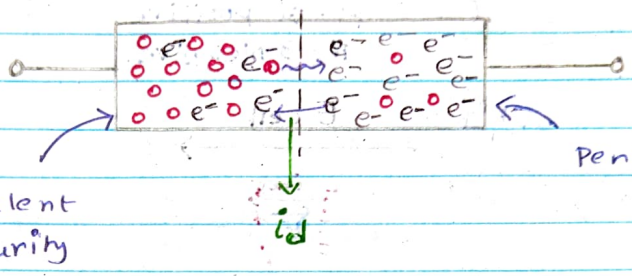
Temp ↑ n_e ↑, n_h ↑ So σ ↑
conductivity ↑.

P-N Junction Diode



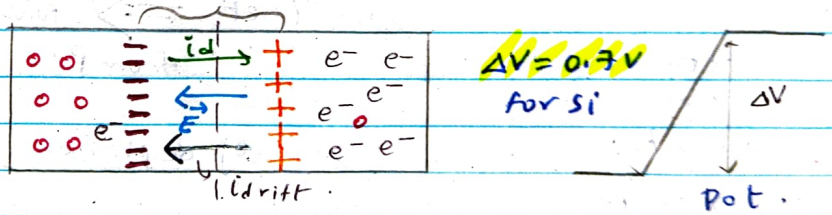
Diffusion Current (i_d)

↳ Flowing due to conc. difference, due to majority charge carrier



- Initially at t=0, both side of boundary, neutral.
- Then e^- & holes start flowing.
- After some time, one side becomes (-ve)ly charge, and other side (+)ve Charge

Depletion Layer.



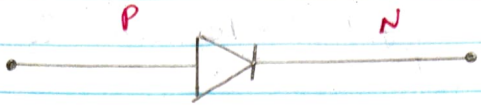
- Diffusion current gradually decreases, and Barrier Hill, eqlbm.
- If some minority carriers remain on either side, upon entering the layer, the $\vec{E}$ pushes it to the opp. side, hence creating another type of current, mistakenly.

This is called Drift current, caused by minority charge carriers., or due to formation of e⁻hole pair in depletion layer.

At equilibrium,

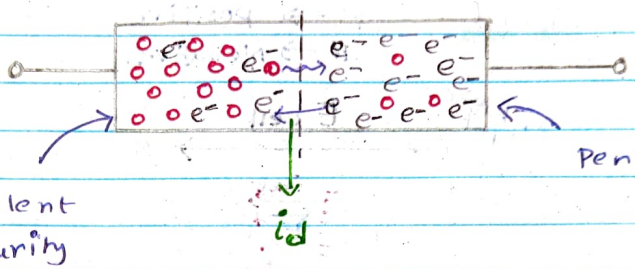
$$i_{drift} = i_{diffusion}$$

P-N Junction Diode



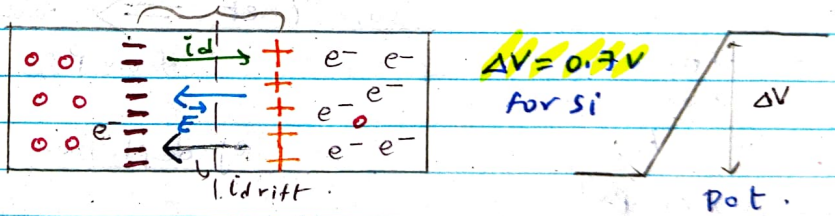
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At equilibrium;

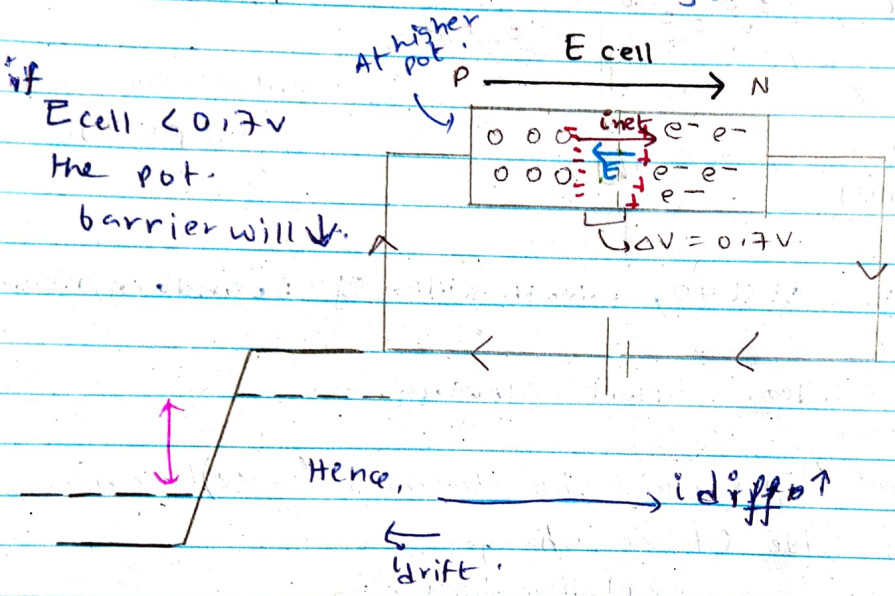
$i_{drift} = i_{diffusion}$

Biasing of ~~PN~~ PN Junction Diode →

Study of behaviour of diode when a pot. diff is applied across it.

(i) Unbiased → No pot. difference applied.

(ii) Forward Biased : P → Positive
N → Negative



if $E_{cell} < 0.7V$ the pot. barrier will ↓.

So, i_{net} ⟹ towards N. from P.

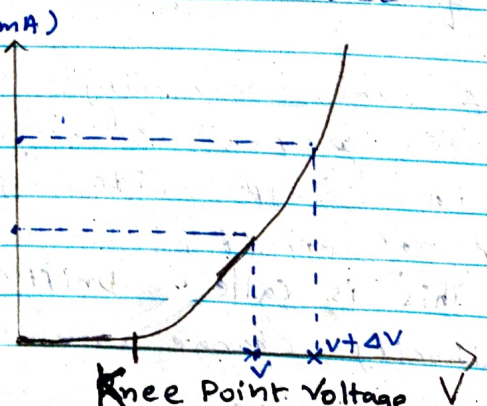
e⁻ flows from lower to higher pot.

with ~~of~~ depletion layer decreases ~~decreases~~.

Why? Explain.

Characteristics.

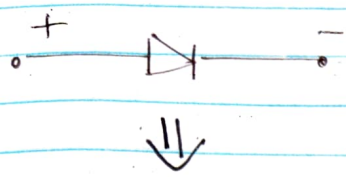
So, we study the variation of current with a with variation of pot. diff in forward biased.



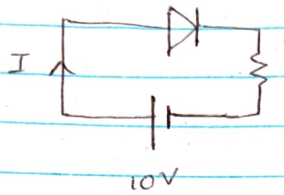
It has non-ohmic resistance.

$R_{dynamic}$ (Resistance) = $\frac{\Delta V}{\Delta I}$.

Forward Biased

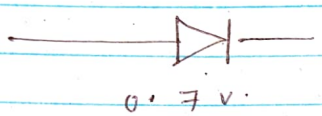


In forward biased, we replace diode with connecting wire.

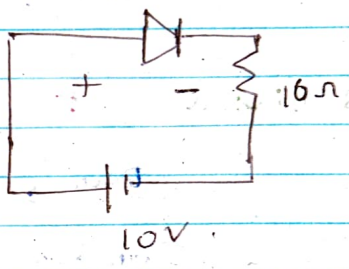
(i) 

$I = \frac{10}{10} = 1\ A$ Ans.

If no voltage given.

(ii) 

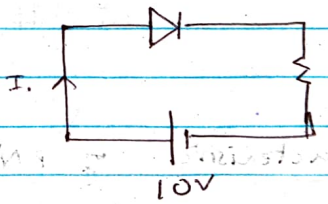
0.7V drop.



If given

$I = \frac{10 - 0.7}{10} = 0.93\ V$.

(iii) Forward resistance of diode is given $= 5\Omega$.

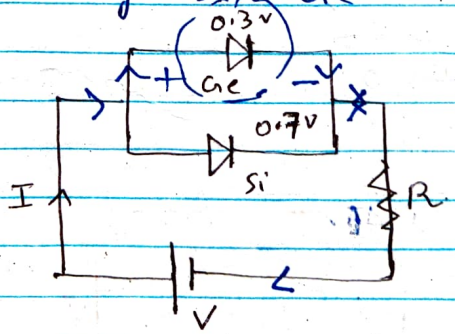


then

$I = \frac{10}{5+10} = \frac{2}{3}$

(iv) Connecting Si & Ge diode in parallel.

Q) $I = ?$



$I = \frac{V - 0.3}{R}$

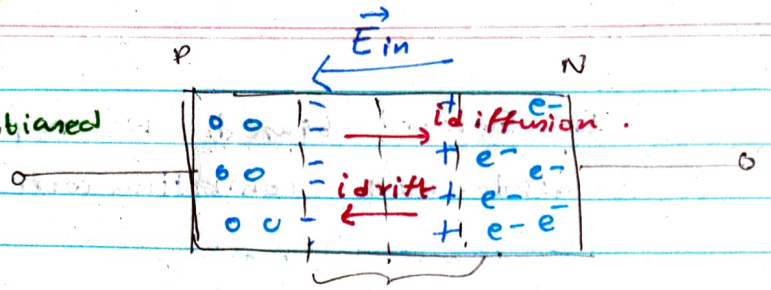
if 0.3V is attached the 0.7V is already short.

যদি pot. এর Accross 0.3V এর বেশি অথবা কম্পনিত অবস্থা না।



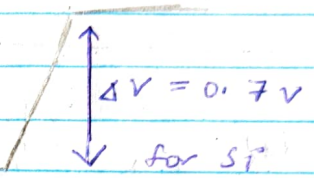
Rev

(1) Unbiased

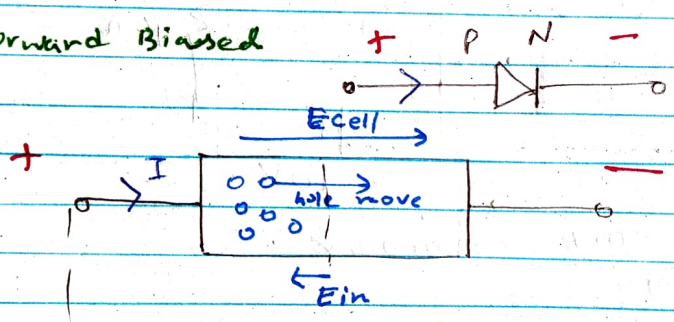


(i) Unbiased ⇒ $I_{diff} = I_{drift}$ (due to conc. diff. / due to minority charge carrier)

↑ order of (μA)



(2) Forward Biased



P → positive

n → negative

so, I_{diff} ↑.

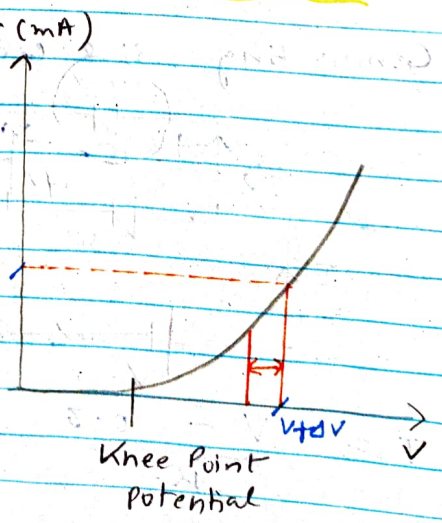
$I_{diff} > I_{drift}$

↓ (mA)

Forward Characteristic of PN junction diode.

When $\Delta V < 0.7$ V then, $I_f \to 0$.

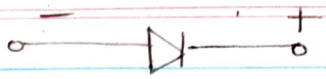
$R_{dynamic} = \frac{\Delta V}{\Delta I}$.



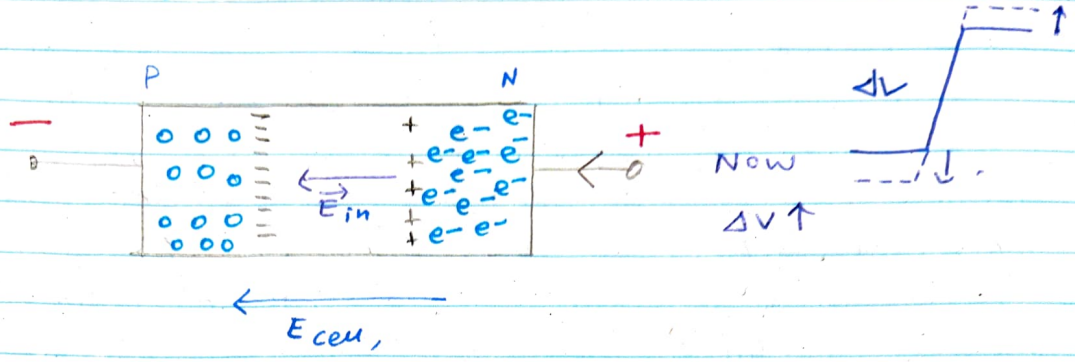
p ⟶ negative

n ⟶ positive.

Reverse-Biased

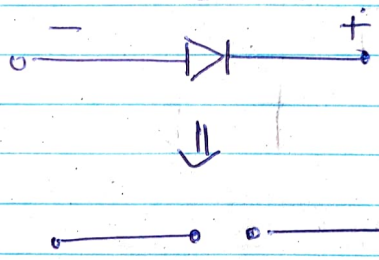


- Depletion layer increase.



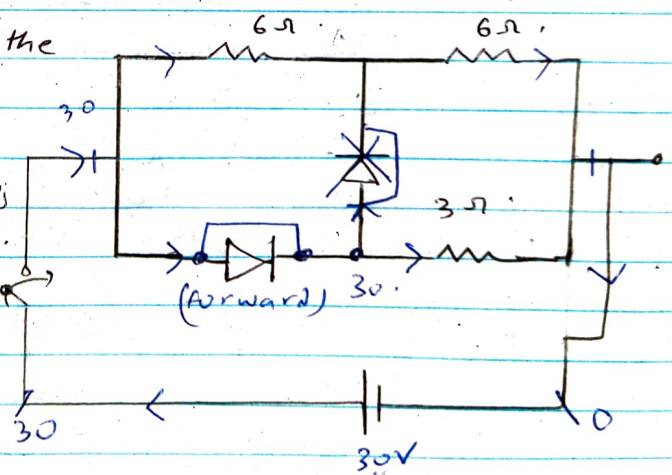
- I drift will be flowing only (μA).
- I diffusion stops (which provided major current),

It will give '∞' Resistance



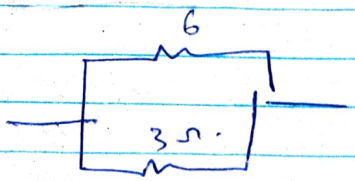
~~Short~~ Open Circuit.

Q1) Find current through the battery ?
Repeat the question if polarity of battery is reversed.



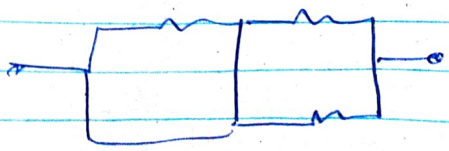
Sol $I = \frac{30}{Req.}$

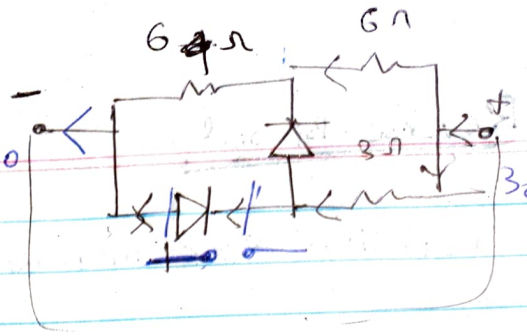
Now



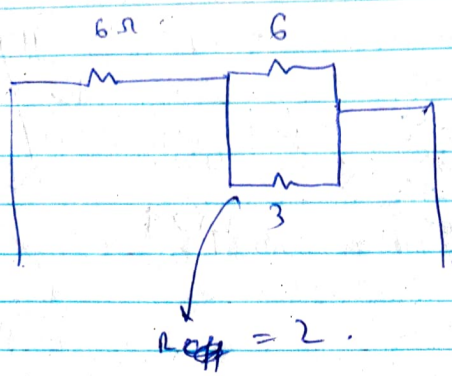
$R_{eff} = \frac{6 \times 3}{9} = 2\Omega$ ①

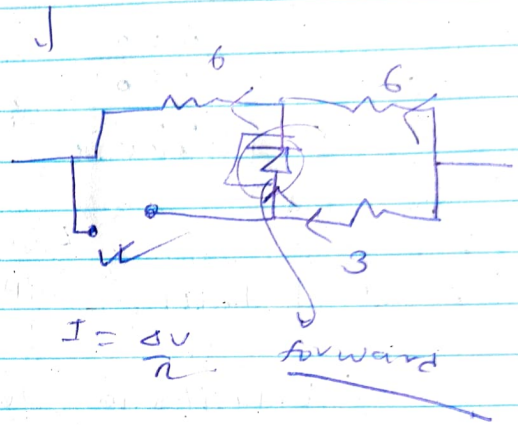
$I_1 = 15\ A$





(ii)

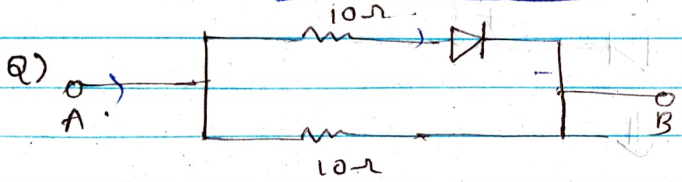




Reff = 8.

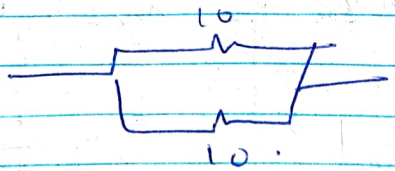
$$I = \frac{15}{4} = \frac{15}{4}\ A$$

Q)



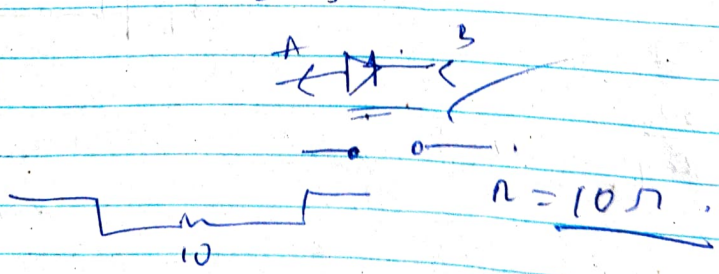
i) Find Req if
(i) A is at higher pot.
(ii) If B is at higher potential

A (i)



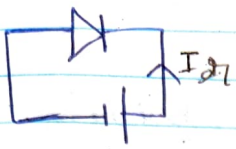
R = 5Ω.

(ii)



R = 10Ω.

Reverse-Biased Characteristic of p-n-junction Diode.



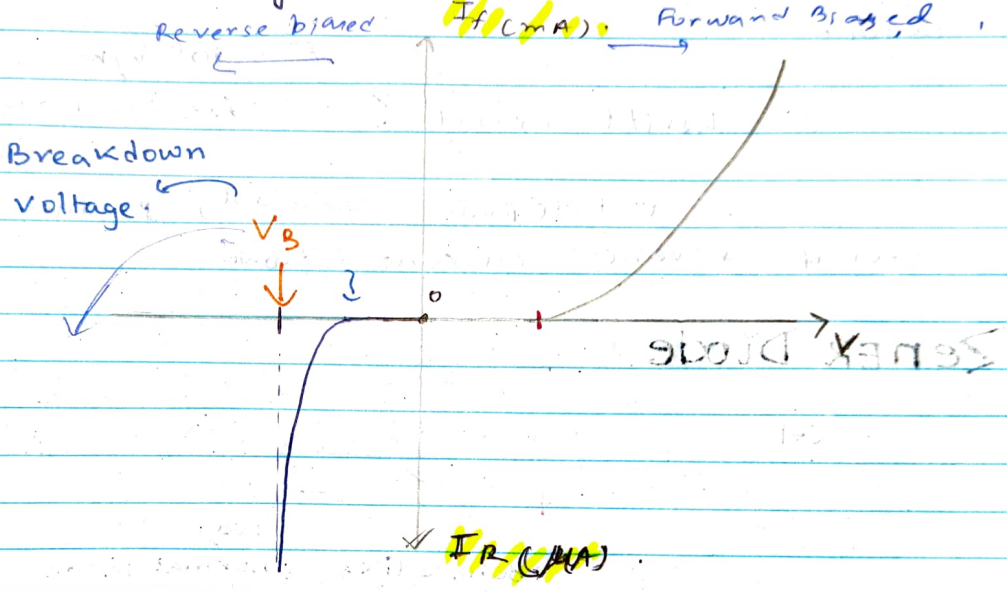
I_R → I_n → $I_{reverse}$ → order of μA.

Plot (-ve Y Axis)

or

As $I_n = -I_f$.

Combining:



However current is increased, V_B ← constant.

Breakdown of PN Junction Diode in reversed biasing.

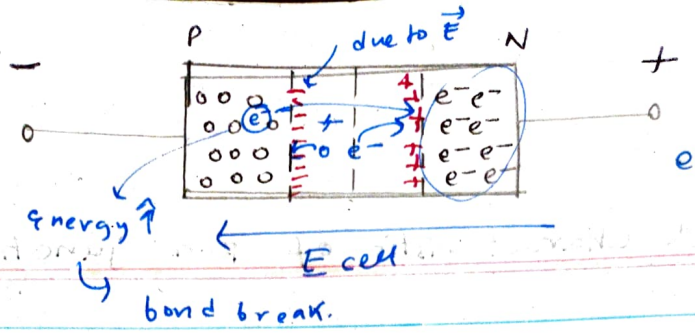
- Avalanche Breakdown.
- Zener Diode.

⇒ PN sides of diodes are moderately doped, and depletion layer is thick.

⇒ Electrons from P sides (minority) will be accelerated across the depletion region due to reverse biasing, these e^- can break other covalent bonds in depletion layer and will generated new e^--hole pair, which will increase drift current.

$e^- \rightarrow$ ← E_{net}.

⇒ It occurs when semiconductor is heavily doped and depletion layer is very small.



Hence i_{drift} increases.

Zener-Breakdown

- This breakdown occurs due to breaking of covalent bond due to high electric field in depletion layer.

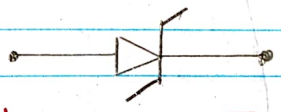
$\vec{E} \simeq 10^6$ V/m for breakdown.

So, i_{drift} current ⇑

e⁻ hole pair continuosly produces, even if reverse current is flown

Zener Diode

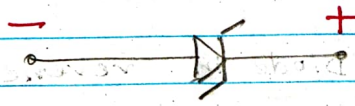
C-1



(fwd)

Behave like a normal Diode

But in reverse biased.



C-2 if $V < V_B$

⇓

open circuit.

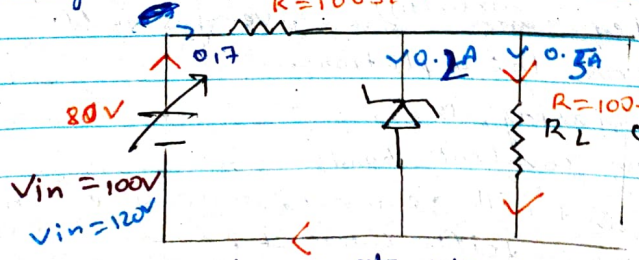
C-3 if $V > V_B$ (tried)

⇓

then δV can never be greater than $V_{Breakdown}$.

$V \equiv V_B$ always (No matter how I ↑)

Thus Zener diode act as, Voltage stabilizer.



We ~~want~~ want ΔV across Load (L)

Case-1 Let $V_B = 50\ V$.

Let Resistance → $R = 100\ \Omega$.

(i) $V_{in} = 80V$.

If Zener Diode was not there,

Then $R_{eq} = 200\ \Omega$.

$\therefore I = \frac{80}{200}\ A$.

$V_R = \frac{80}{200} \times 100 = 40V$.

& $V_L = 40V$,

So we see ΔV_{out} is $= 40\ V$ which is $< V_B$ (50V).

No Breakdown occurs.

Diode → open.

C-2.

Then, if $V_{in} = 100V$

then, $V_L = 40$,

$\therefore \Delta V$ across Zener diode $= 50\ V$

Hence,

exactly Breakdown occurs.

But I through Diode $= 0$.

$I_Z = I_R - I_L$

C-2 $V_{in} = 120V$

then,

I

Drop across

$V_R = 120 - 50 = 70\ V$.

$I_R = \frac{70}{100} = 0.7A$

But now, ΔV_{out} has to be kept 50 V across R_L

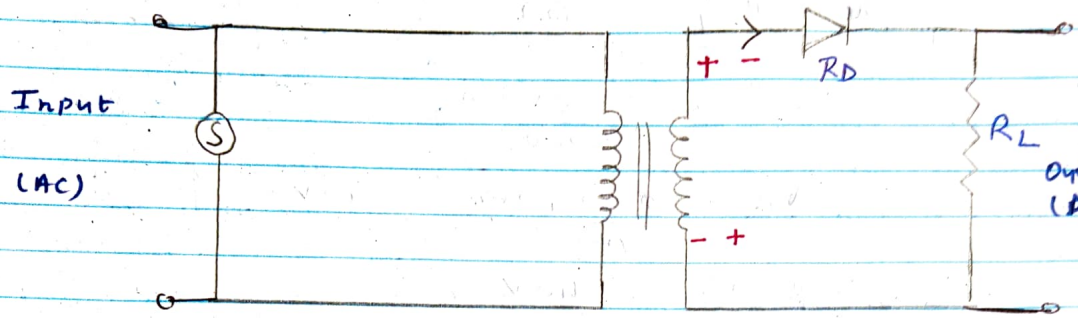
$\therefore 50 = I \cdot 100$. $I_{load} = 0.5\ A$.

& I through diode = 0.2A A

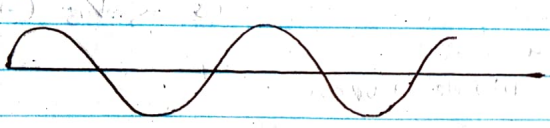
Efficiency, $\eta_{HW} = 40 \times \left(\frac{R_L}{R_d + R_L}\right)$ %.

P-N junction as Half Wave Rectifier

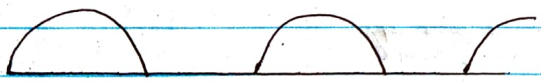
Rectifier → A device which convert an A.C current into a D.C current.



Input



Output

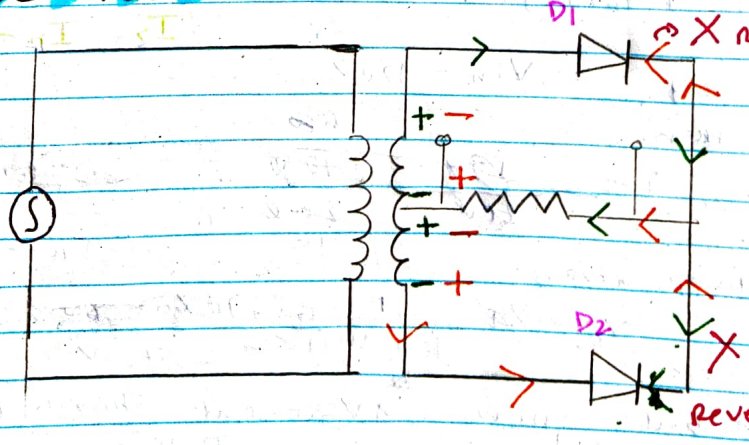


(when current comes diode → Reverse biased → Circuit breaks).

Efficiency of half wave Rectifier

$\eta = 40\%$.

Full-Wave Rectifier → (Common center Tap Rectifier)



Input



output



Efficiency = 81%.

current flow



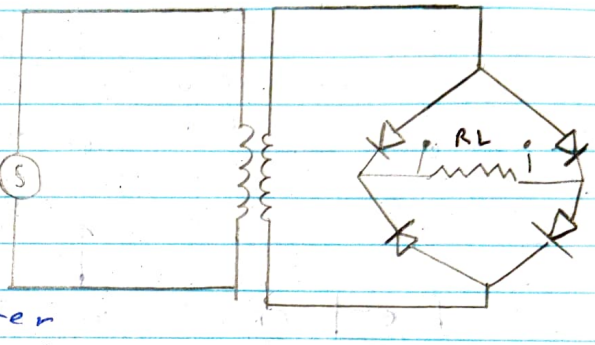
a) If a full wave rectifier circuit is operating from 50Hz mains, fundamental freq. in the ripple?



So frequency twice.
≡ 100Hz.

$$\eta_{\text{Full wave}} = \frac{0.8 \ln 2}{\left(1 + \frac{r_d}{R_L}\right)}$$

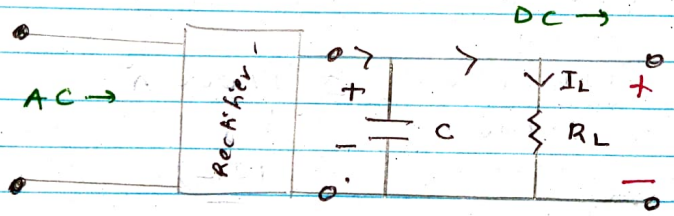
Bridge Rectifier.

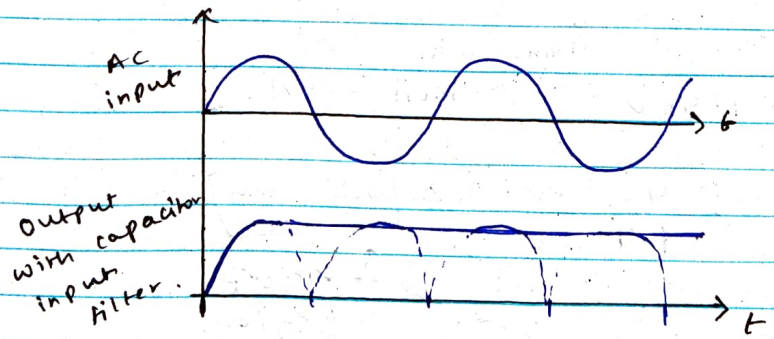


η → more.
90%.

Since these additional circuits appear to filter out the ac ripple and give a pure DC voltage, so they are called filters.

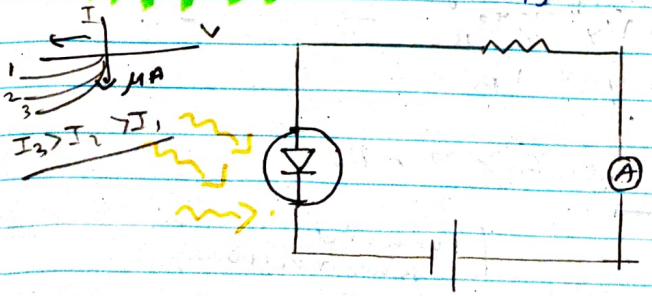
Use of capacitor as a filter.

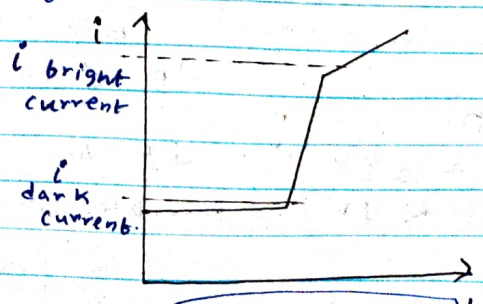




$\eta \uparrow$ with small ~~as band~~ ~~gap diode~~ increase in band gap. but $\eta \downarrow$ for large increase in band gap.
↑ More close to 1.5eV More η ≡

Photo Diode → Light sensing Diode.



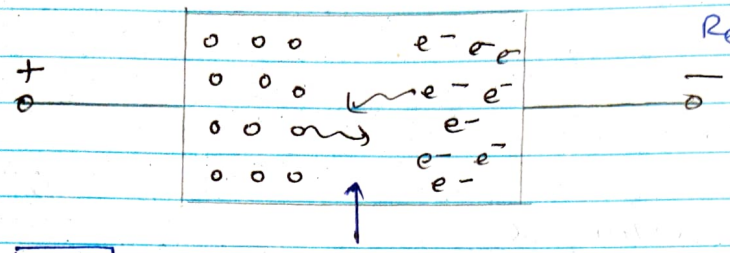


Light incident, e-hole pair form ↑ diff.

operated in reverse voltage.

Light Emitting Diode (LED)

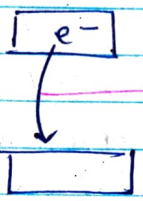
operate only in ~~reverse~~ forward biased mode.



Heavily doped

Reverse breakdown ~ 5V

recombination of e⁻ and hole pairs.



For silicon, $E_p = 1.1\,eV$

$E_{photon} \leq E_{gap}$

$\therefore \frac{hc}{\lambda} = 1.1\,eV$

ΔE ↑ band gap.

$\lambda = \frac{12400\,eV}{1.1\,eV} \simeq 11000\,\text{Å}$ (IR)

But semiconductors like.

GaAsP

↳ $\Delta E = 1.9\,eV$

Band width ~ 100Å − 500Å

$\lambda = \frac{12400\,eV}{1.9} \simeq 650\,nm$

↑ visible Region.

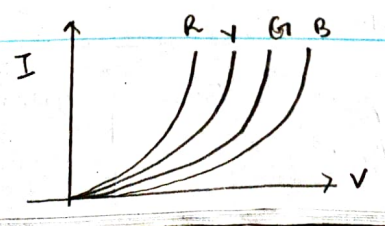
Plot of I-V characteristic of an LED.

we know; $V_B > V_G > V_Y > V_R$

$\therefore \lambda_B < \lambda_G < \lambda_Y < \lambda_R$.

$E = e\Delta V$ ↳ ΔE for B > G > Y > R

$E \propto \Delta V$ ∴ Possible Graph →



Forward Biased always ∴ I → +ve

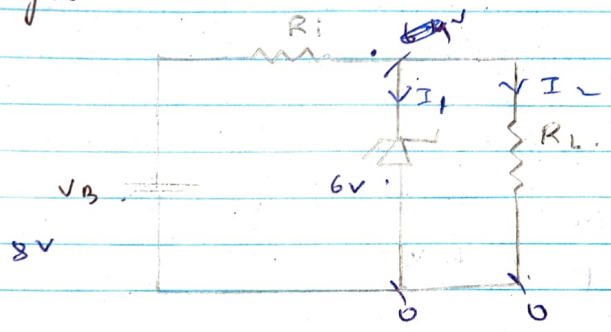
Main 2015.

Q) The fig → voltage Regulator circuit using zener Diode.
The breakdown V_B of diode = 6V.

R_L = 4 kΩ. R_i = 1 kΩ.

If V_B varies from 8V to 16V.

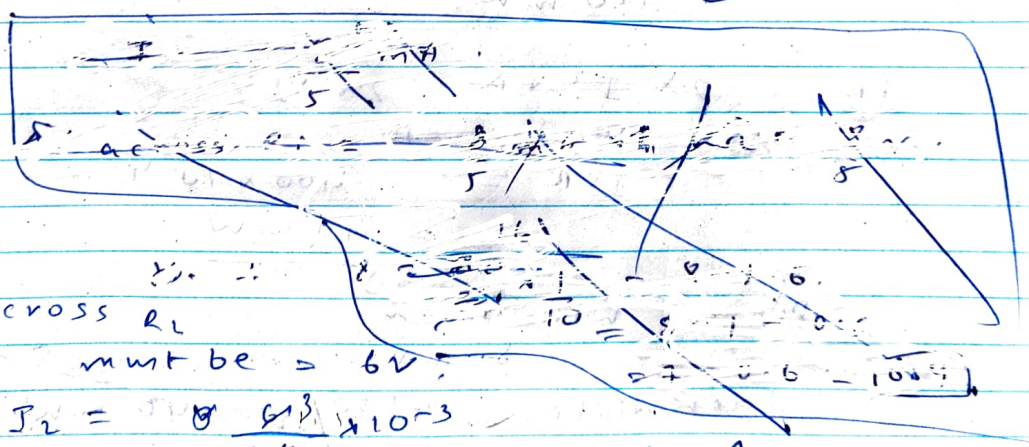
What are minm & maxm values of current through diode.



When $V_B = 8V$.

$R = R_i + R_L$

$= 1 + 4 = 5\ k\Omega$.



ΔV across R_L must be = 6V.

$\therefore I_2 = \frac{6}{4} \times 10^{-3}$

$= 1.5\ mA$.

Now, $i_R = \frac{\Delta V}{R_i} = \frac{8-6}{1 \times 10^3}$

Minm current, $i_z = i_R - i_L$ = 2 mA.

$= 2 - 1.5 = 0.5\ mA$.

When, $V_B = 16V$

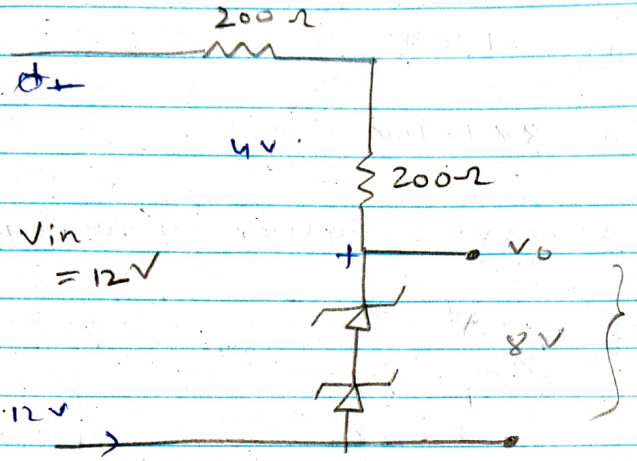
$i_R = \frac{16-6}{10^3} = 10 \times 10^{-3} = 10\ mA$.

$\therefore i_2 = 10 - 1.5 = 8.5\ mA$.

Q). circuit → 8V DC regulated voltage source.

V_{in} = 12 V.

power dissipated (in mW) =?
in each diode.



Across load
drop → 4V.

$\therefore I = \frac{40}{4000} = 10\,mA$
$= 10^{-2} A$

$\therefore P_B = 10 \times 10^{-3} \times 12 \quad (VI)$
$= 120\ mW$

$P_R = 2 \times I^2 \times R \quad 2 \times VI$

$2 \times 4 \times 10\,mA$

$I^2R = 400 \times 10^{-4}$

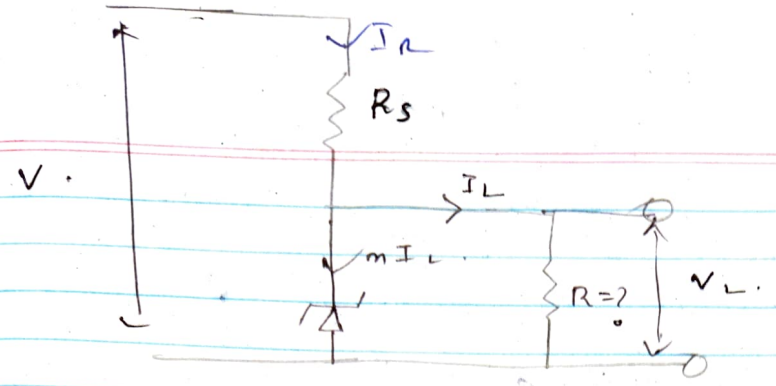
$= 40\ mW$

$\therefore$ Diodes will consum
$= 80\ mV$

each diode → $80/2 = 40\ mW$

A

Q) Value of Resistor R_s, needed in DC voltage)



We know

I_z = ~~$I_L + I$~~

$I_R \rightarrow I_L$

$I_z = nI_L$.

$\therefore I_R = (n+1) I_L$.

Now, $I_L = \frac{V_L}{R}$ $R_s = ?$

& $I_R = \frac{V - V_L}{R_s}$.

$\therefore \left(\frac{V - V_L}{R_s}\right) = (n+1)\left(\frac{V_L}{R}\right)$ $K I_L$.

$\Rightarrow R_s = \frac{(V - V_L)}{I_L(n+1)}$. A

ADV

Q) The current voltage relation of diode,

$$I = \left(e^{\frac{1000V}{T}} - 1\right) mA$$

where V → volts, T → Temperature (K)

If error in measuring $V_\sigma = \pm 0.01$ while, $I = 5mA$ at 300 K. What will be the error in value of current in mA?

Given

$$I = e^{1000V/T} - 1$$

$$dI = \frac{1000}{T} e^{\frac{1000V}{T}} \cdot dV.$$

Now

$$5 \times 10^{-3} = e^{1000V/T} - (1 \times 10^{-3})$$

6 mA ~~$5 \times 10^{-3} + 1 = e^{\frac{1000V}{T}}$~~ $\quad -(1)$

From eq (1)

$$dI = \frac{1000}{300} \times 6 \times 10^{-3} \times \frac{1}{100}$$

$$= \frac{1000}{200} \times 6 \times 10^{-3} \times \frac{1}{100}$$

$$= 0.2 \text{ mA}$$

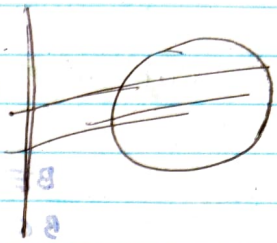
28/11/2021.

TRANSISTORS

Transistors are solid state devices used for Amplifying, controlling and generating electrical signals.

⇒ p-n-p transistor.

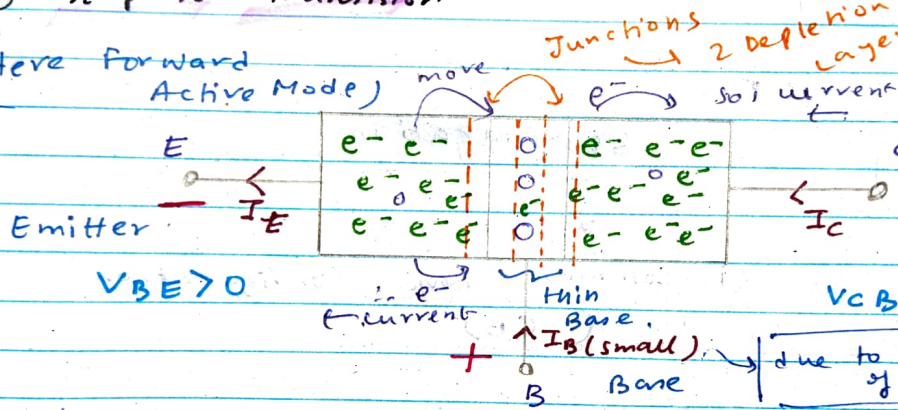
⇒ n-p-n transistor.



- 3 terminal devices (Triode),
  → current inside due to movement of e^-.

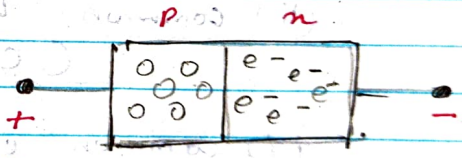
① n-p-n transistor

(Here Forward Active Mode)



Any junction is forward then

p → +ve, n → -ve



∴ There are 4 operating Modes in a transistor

$I_E = I_B + I_C$

(i) Forward Active Mode.
(Amplifier).

B, E → Forward Biased
& B C → Reverse Biased.

(ii) Reverse Active Mode.

BE → Reverse Biased
BC → Forward Biased

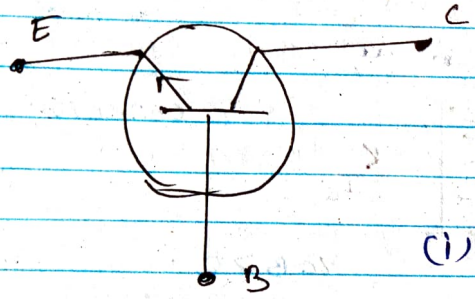
(iii) Saturation Mode.

BE } Forward Biased
BC }

(iv) Cut-off Mode (Switch)

BE } Reverse Biased
BC }

For n-p-n transistor.



Configuration

(i) Common Base Configuration (CB)

(ii) Common Emitter Config. (CE).

(iii) Common collector config (CC).

Common → Means the terminal which we ground.

I_C → always Output side / Current (Ampere)

NOTE

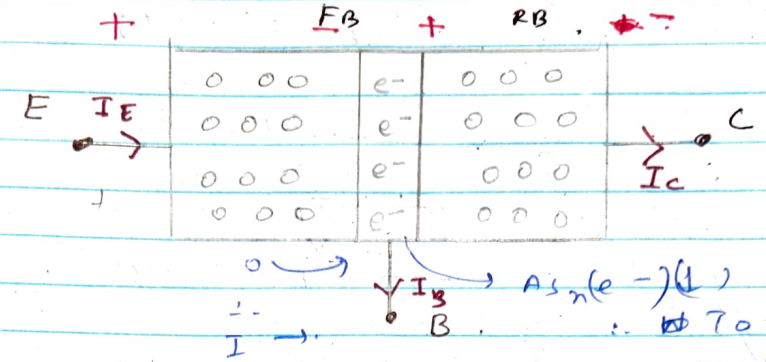
IIT

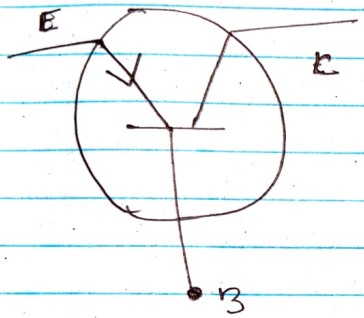
In a common emitter amplifier circuit using an n-p-n transistor, the phase diff b/w the input and output voltage will be 180°, (π).

However in npn, both flow of current inside transistor & circuit → due to e⁻.

↳ current flow due to holes (internal circuit)
But in circuit → e⁻

p-n-P Transistor.

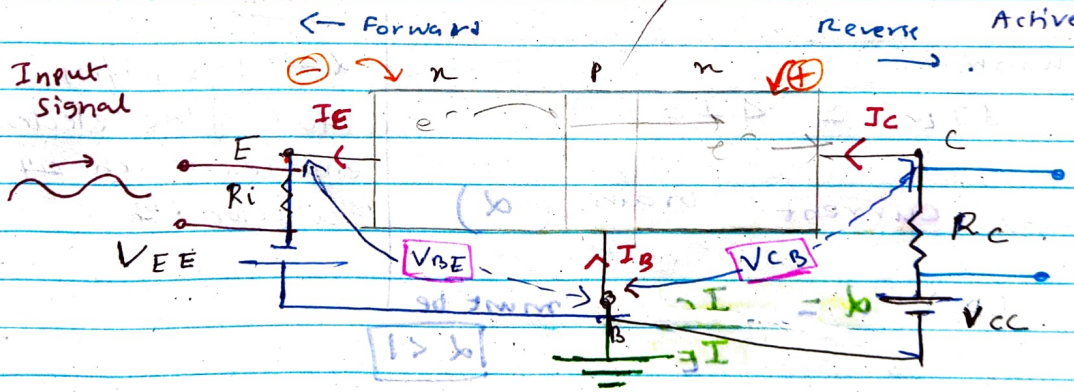




$I_E = I_B + I_C$.

① COMMON BASE CONFG.

By default → Forward Active Mode.

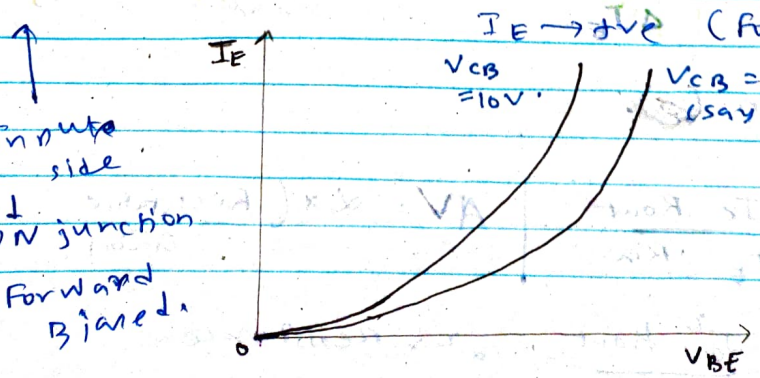


$I_E = I_B + I_C$

Input Characteristics

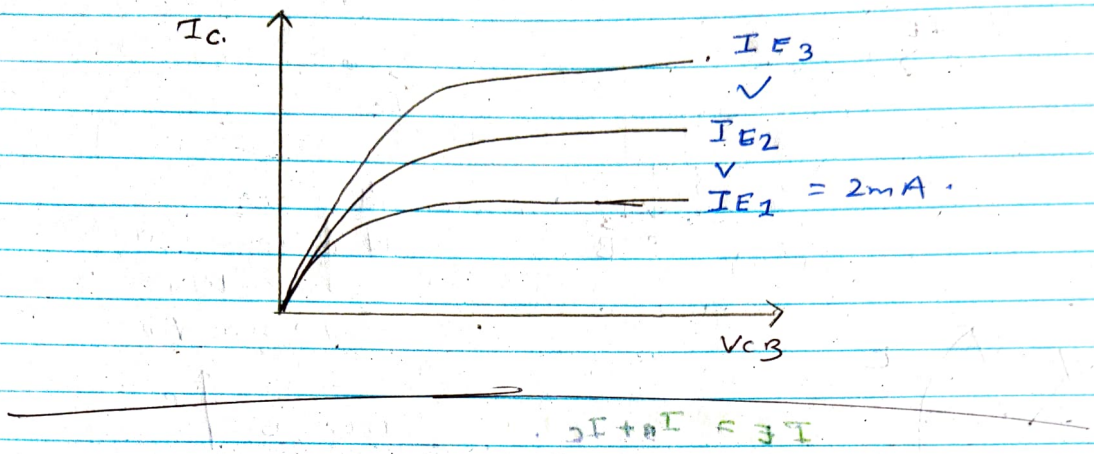
Output : V_{CB} → constant

I_E → +ve (Forward



OUTPUT Characteristics

Varying V_{CB} & I_C.
I_E constant.



Now $I_E = I_B + I_C$.

If we input a variable signal

Both I_B & I_C both change.

We know

$\Delta I_E \simeq \Delta I_C$

⇒ Current Gain (α)

(DC) $\alpha = \frac{I_C}{I_E}$ must be $\alpha < 1$

NOTE

$\alpha = 0.4$ signifies 40% of the electron emitted reach collector.

And if fluctuating Input:

(AC) $\alpha = \frac{\Delta I_C}{\Delta I_E}$

current gain is in CB config is small.

⇒ Voltage Gain

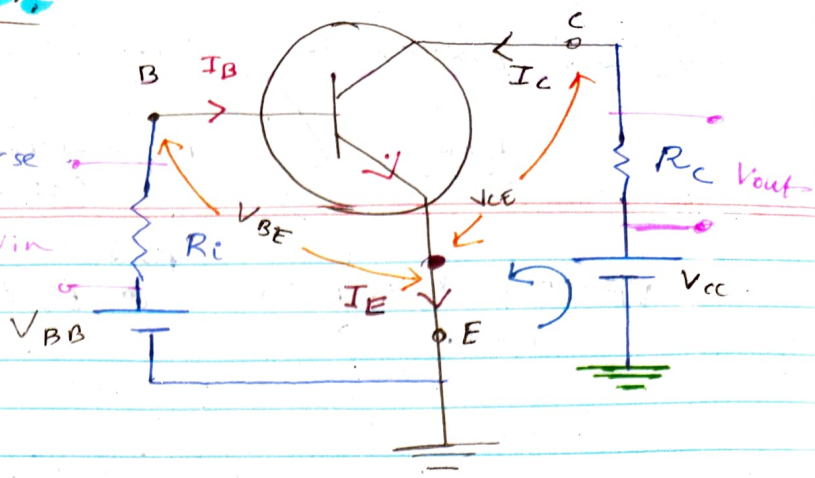
$= \frac{V_{out}}{V_{in}} = \frac{I_C R_{out}}{I_E \cdot R_{in}}$

$A_V = \alpha \times$ (Resistance Gain).

⇒ Power Gain $= \frac{I_C^2 R_{out}}{I_E^2 R_{in}} = \alpha^2 \times$ Resistance.

Common Emitter.

It is npn.



We input voltage Vin

So,

I_B → change.

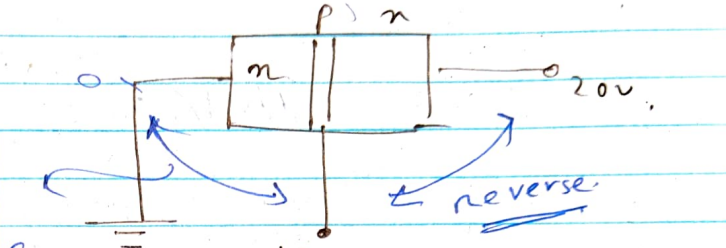
let for eg:-

$I_E = 10mA$.

then

$I_B \rightleftharpoons 10\mu A$

$I_C = 10mA - 10\mu A$



p → +ve

n → -ve. (lower).

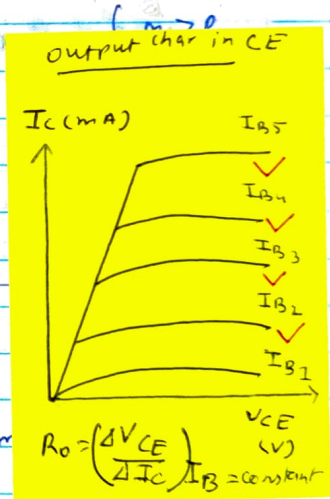
(As n → +ve, p → -ve)

Now let

$I_E = 20mA$.

$I_B \cong 20\mu A$

$I_C \rightleftharpoons 20\,mA$



We see

$\Delta I_B \cong 10\mu A$

$\Delta I_C \cong 10mA$

Current Gain = $\frac{I_C}{I_B}$ ⇒ large

(Same large change in I_C)

Amplifier

DC $\beta = \frac{I_C}{I_B}$ | AC $\beta = \frac{\Delta I_C}{\Delta I_B}$.

A.V Voltage Gain = $\beta \times$ (Resistance Gain).

Power Gain = $\beta^2 \cdot$ (Resistance Gain).

~~$\alpha = \frac{I_C}{I_E}$ & $\frac{I_C}{\Delta I_B}$~~ β.

⇒ Common Emitter in Saturation Mode.

then :

Base → Forward (higher than other)

And

$V_{EC} \simeq 0$ & $V_{CE} \simeq 0$ must.

E, C, lower.

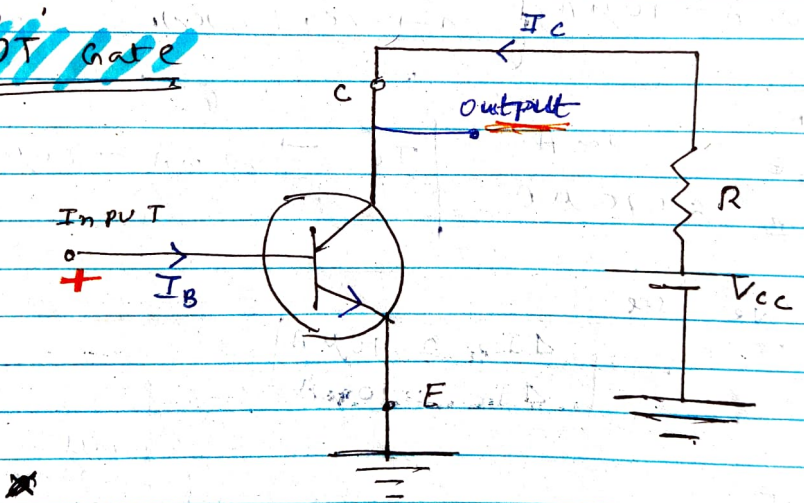
⇒ common Emitter in Cut off. Mode.

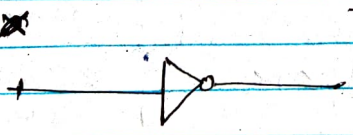
⇒ used as NOT Gate.

All Reverse Biased

used to generate signals

NOT Gate





X	$\bar{X}$
1	0
0	1

At cut off

$I_C = 0$ So,

pot. Across R = V_{cc}

Now, it is a Reversible operation

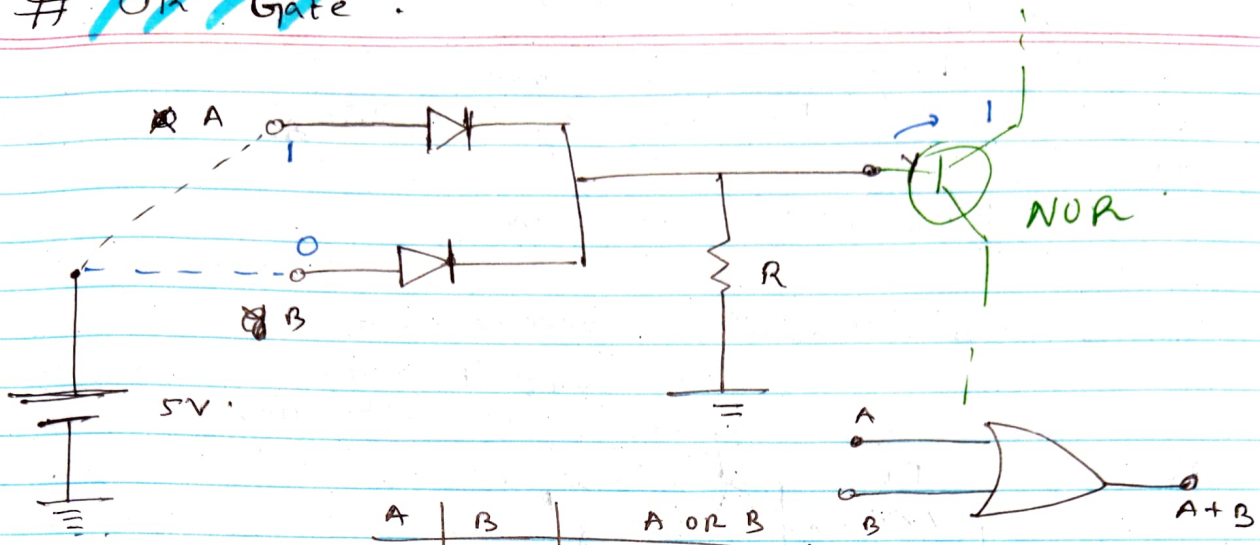
as

$X \rightarrow \bar{X}$

& $\bar{X} \rightarrow \bar{\bar{X}}$

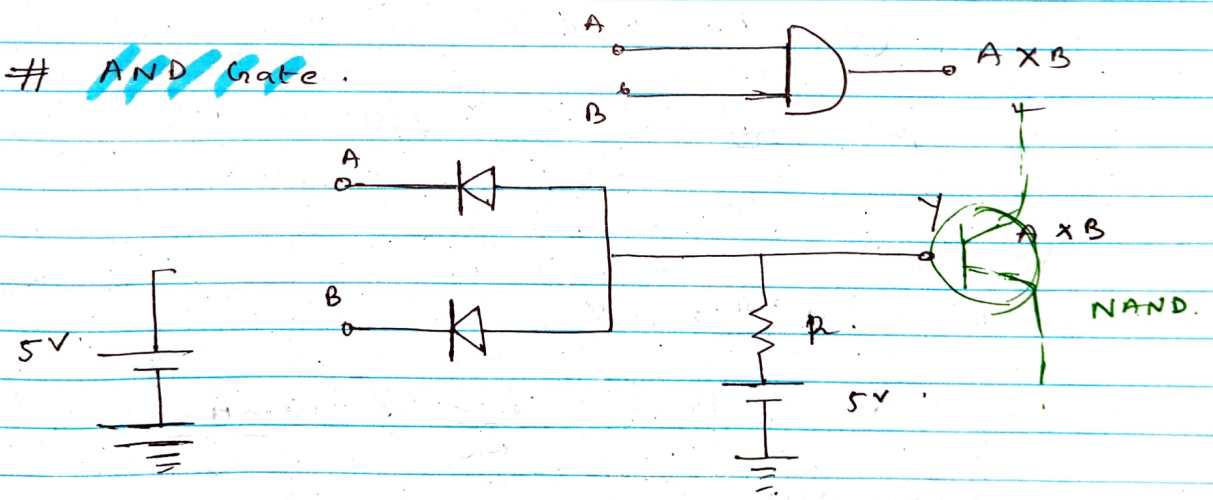
$= X$

OR Gate.



A	B	A OR B
1	0	1
0	1	1
1	1	1
0	0	0

AND Gate.



High → 1
Low → 0

A	B	A × B
0	0	0
1	0	0
0	1	0
1	1	1

If A ← high
then Reverse, Circuit Break.
Again zero.

(Q) A common emitter amplifier circuit, built using an "n-p-n" transistor, is shown.

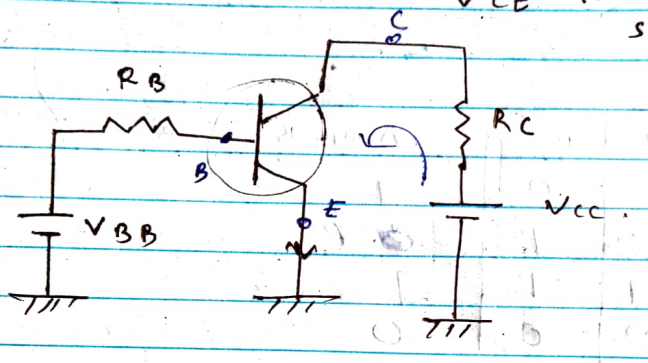
Main 2015.

It's DC current gain is 250

$R_C = 1K\Omega$, $V_{CC} = 10V$.

What is the minimum base current for V_{CE} to reach saturation?

Ans.



Common

Given = As Emitter.

$$\therefore \beta = \frac{I_C}{I_B} = 250.$$

$V_{CC} = 10V$

$R_C = 10^3 \Omega$.

$$\therefore I_C = \frac{V_{CC}}{R_C} = 10\,mA$$

Saturation

$$I_B = \frac{I_C}{\beta} = \frac{10 \times 10^{-3}}{250}$$

$$= \frac{100 \times 10^{-5}}{25}$$

$$= 40 \times 10^{-6}$$

$$= 40\,\mu A$$

NOTE

We have $I_E = I_B + I_C$ — (1)

$\alpha = \frac{I_C}{I_E}$ & $\beta = \frac{I_C}{I_B}$.

Dividing eq (1) $\div I_C$

$\Rightarrow \frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$

$\rightarrow \frac{1}{\alpha} = \frac{1}{\beta} + 1$

$\Rightarrow \frac{1}{\alpha} - \frac{1}{\beta} = 1$ | $\beta = \frac{\alpha}{1-\alpha}$

$\alpha \simeq 0.95$ to 0.99

$\beta \simeq 20$ to 100

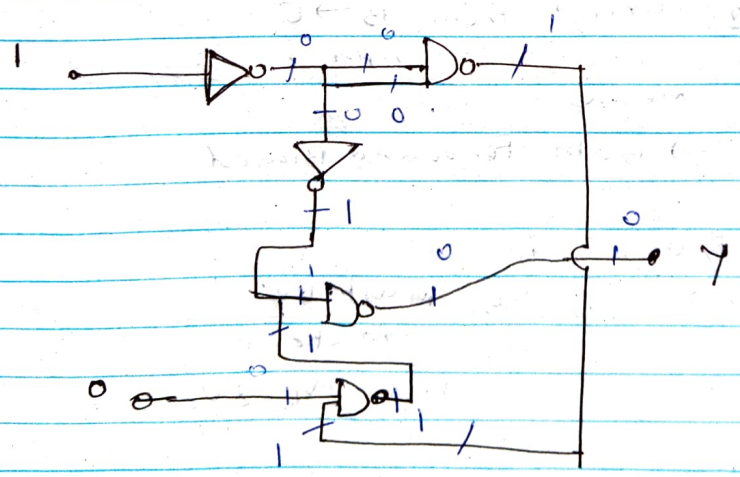
Gain = $\frac{R_{out}}{R_{in}}$

typically lies b/w ~~1 to~~ $10^2 - 10^3$.

$R_{out} \sim 100\,K\Omega$

$R_{in} \sim 1 - 10\,K\Omega$.

Q) Main 2020:



Y = ?

= 0

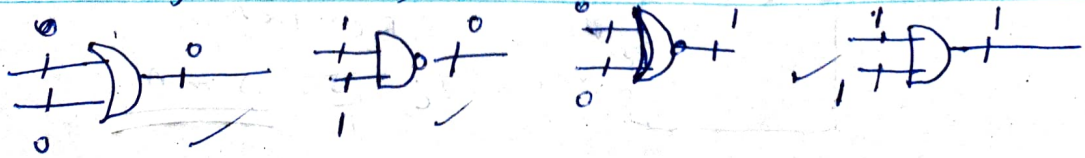
NAND

NOT

See computer Notes Also.

Note If asked for what values of input, to get output Y (say 1).
start from Y, then do backwards,

For eg:- Only possible →



Q) In the fig, given

V_{BB} can → 0 to 5.0 V.

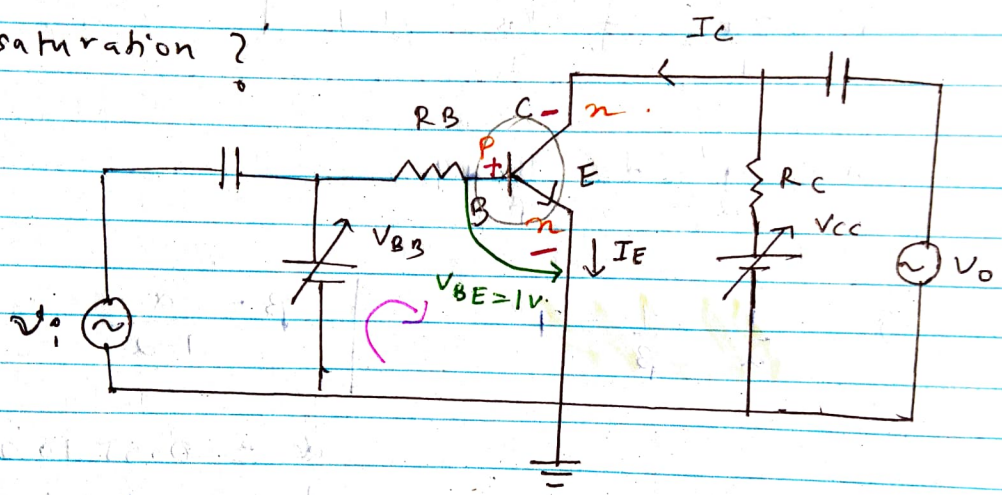
~~V_{cc} can → 0 to 5V~~

$V_{cc} = 5V$

$V_{\Theta} = \beta_{dc} = 200$, $R_B = 100\ k\Omega$.

$R_c = 1k\Omega$, $V_{BE} = 1V$.

The Minm. Base current and the input voltage at which the transistor will go to saturation ?



A: (1) It is Common Emitter config.

(2) current from B → E

∴ npn.

Here saturation means

→ Both Forward Biased.

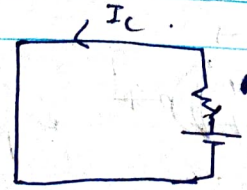
∴ $V_{BE} > 0$ & $V_{BC} > 0$] ie V_B must be greater than V_E & V_C.

And if V_{CE} also $= 0$

It will also be in sat. mode.

So, Think, CE is short.

Circuit



$V_{cc} = 5V$

$R_c = 1k\Omega$

$I_C = \frac{5}{1} = 5\ mA$

Now, $\beta_{dc} = \frac{I_c}{I_B}$. Base current.

$$I_B = \frac{I_c}{\beta} = \frac{5}{200} \times 10^{-3} = \frac{5}{40} = 25\,\mu A$$

So, $V_{BE} = 1V$ given. (ie $V_B > V_E$).

Now in that loop KVL.

$$V_{BB} - I_B R_B - 1 = 0$$

$$V_{BB} = 25 \times 100 \times 10^{-3} \times 10^{-6} + 1$$

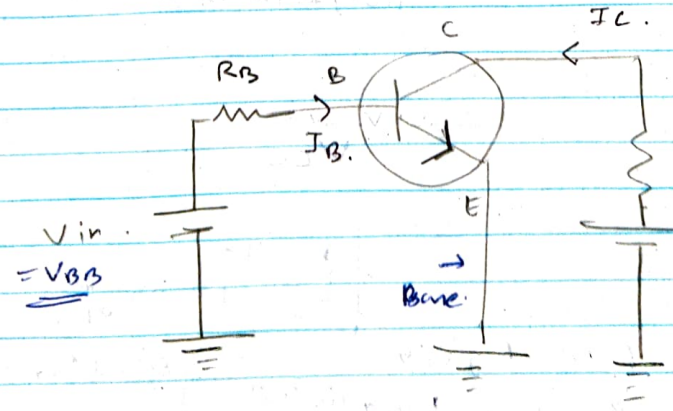
$$= 2500 \times 10^{-3}$$

$$= 2.5 + 1 = 3.5\,V$$

A 25 μA and 3.5V.

Q) An n-p-n transistor is used in common emitter configuration as an amplifier with 1 kΩ load resistance. Signal voltage of 10mV (V_{in}) is applied across the base-emitter. This produces a 3mA change in the collector current and 15 μA change in the base current of amplifier. The input resistance and voltage gain are?

A



$\Delta I_c = 3mA$

$\Delta I_B = 15\,\mu A$.

So, we can write

$\Delta I_B \cdot R_B = 10mV.$

$= \Delta V_{in}$

$$\Rightarrow R_B = \frac{10 \times 10^{-3}}{15 \times 10^{-6}}$$

$$R_B = \frac{2}{3} k\Omega.$$

(Base is Input)

As collector is always Output.

So we got

$R_{in} = \frac{2}{3} K\Omega$

$R_{out} = 1 K\Omega$ (given)

Now

Voltage Gain

$A_V = \beta \cdot R_{gain}$

$= \frac{\Delta I_C}{\Delta I_B} \cdot R_{gain}$ (same)

$\therefore R_{gain} = \frac{R_{out}}{R_{in}}$

$\beta = \frac{3 \times 10^{-3}}{5 \times 10^{-6}} \times \frac{3}{2}$

$= 10^2 \times 3$

$= 300 V$

Input Res

$= R_B = 0.67 K\Omega$.

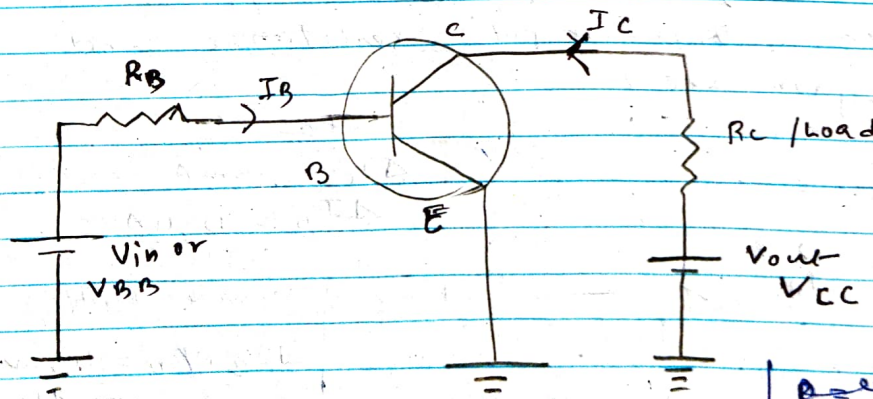
Q) An n-p-n transistor operates as a common emitter amplifier, with a power gain of 60dB. The circuit Resistance is 100Ω, and output load resistance = 10kΩ.

Common emitter current gain, $\beta = ?$

A ① npn. B → E (I).

② common Emitter :. Base → Input

Collector → output



Power gain.

$L = 10 \log_{10} P$

$60 dB = \beta^2 \times R_{gain}$

$R_B = 100 \Omega$, $R_{out} = 10 \times 10^3 \Omega$ (Rc)

$R_{gain} = \frac{10 \times 10^3}{100} = 10^2$

$60 = 10 \log_{10} P$

$P = 10^6$.

power gain

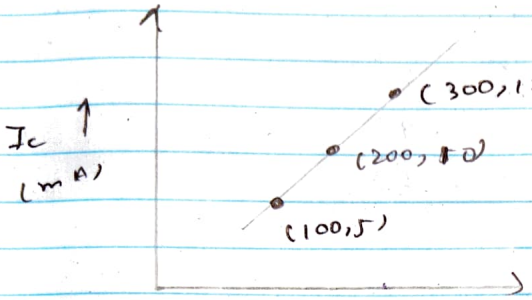
$\therefore \quad 10^4 = \beta^2 \cdot 10^2$

$\boxed{\beta = 100}$ ✓

Q) $R_{in} = 100\ \Omega$.

$R_{out} = 100\ K\Omega$.

Find: voltage gain & Power gain ?



$\beta = \frac{\Delta I_C}{\Delta I_B}$

$= \frac{(10-5) \times 10^{-3} \times 10^3}{(200-100) \times 10^{-6}}$

$= \frac{5}{100} \times 100$

$= 50$

$R_{gain} = \frac{100 \times 10^3}{100}$

$= 10^3$

$A_V = (50)^2 \times 10^3$

$= 5 \times 10^4$

$Pow = \beta^2 \cdot R_g$.

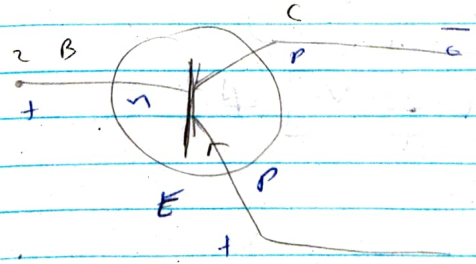
$= 2500 \times 10^3$

$= 2.5 \times 10^6$ ✓

Q) ~~An experiment~~

A multimeter, with +Ve and -ve terminals is used to measure ~~very~~ resistance b/w ~~diff~~ terminals of ~~resistor~~ transistors.

2016. If terminal 2 is base of transistor, then which is correct for PNP transistor?



if Base → High and any one low then becom Reverse Biased.

if

(2) Base → low.

then Rest become high.

Forward resistance Low.

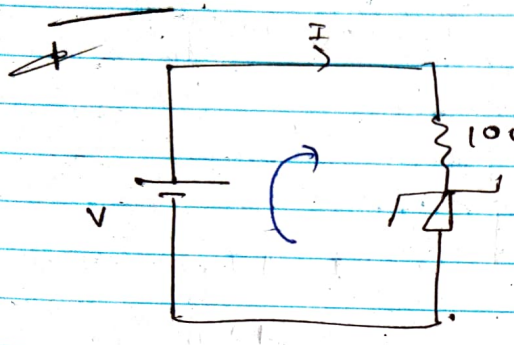
✓ +ve terminal 2, -ve terminal 1, resist = High

-ve terminal 2, +ve terminal 2, Resi = Low

Q) An experiment is performed to determine the I-V charact. of a zener diode, which has a protective resistance of $R = 100\Omega$, and a maximum power of 0.8 dissipation rating of 1W.

The min. voltage Range of DC source in circuit is?

Main-2016



$P = I^2 R = 1$

For Diode

$R = \frac{1}{I^2}$.

KVL

$V - I(100) - I \cdot \left(\frac{1}{I^2}\right) = 0$

$V - I(100) - \frac{1}{I} = 0$.

$\Rightarrow VI - I^2(100) - 1 = 0$.

$\Rightarrow I^2(100) - VI + 1 = 0$.

Now $I \rightarrow$ real.

$\therefore D \geq 0$.

$V^2 - 4(100) \geq 0$

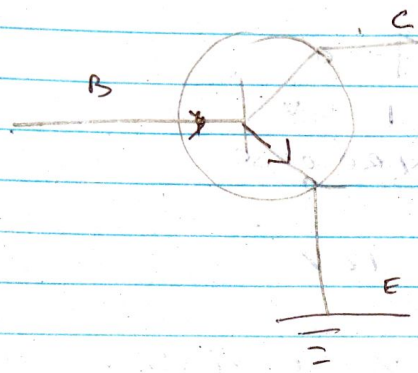
$V^2 \geq 400$

$\boxed{V \geq 20}$

Ans $\rightarrow$ $\boxed{0\text{-}24\ V}$ A

N

Q) A realistic graph depicting variation of the reciprocal of input resistance ~~(top)~~ in an ~~(inp)~~ input characteristic in a common emitter transistor configuration is?



B→E

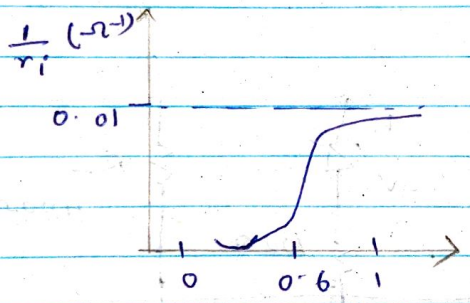
From options

$V_{BE} = 0.6$ for Breakdown

$r_{dy} = \frac{\Delta V}{\Delta I}$

$\frac{1}{r} = \frac{\Delta I}{\Delta V}$

0.7 ~ Knee voltage



Q) In silicon transistor Base current is changed by 20μA, this changes ~~(in)~~ V_{EB} voltage by 0.02V, and the collector current changes by 2mA. If transistor is used as an amplifier with $R_{load} = 5k\Omega$, voltage gain?

A $\Delta I_B = 20\mu A$

$\Delta V_{EB} = 0.02V$

$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{2\times10^{-3}\times10^{2}}{20\times10^{-6}} = 10^2$

$\Delta V_{EB} = \Delta I_B \times R_{in}$

$R_{in} = \frac{0.02\times10^{3}}{20} = 1k\Omega.$

$R_{gain} = \frac{R_{load}}{R_{in}} = 5$ ✓

Common Emitter, configs.

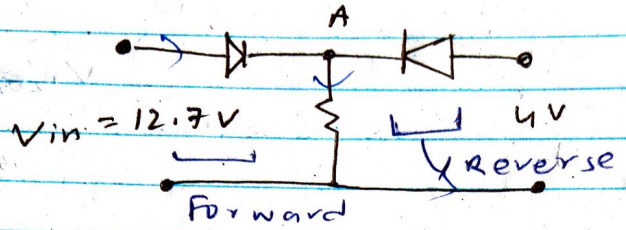
$\therefore \Rightarrow A_V = \beta \cdot R_{gain}$

$= 5\times100 = 500$

Q) Both the diodes used in circuit are ideal. have negligible resistance when these are forward biased.

Built in potential in each diode is 0.7 V,

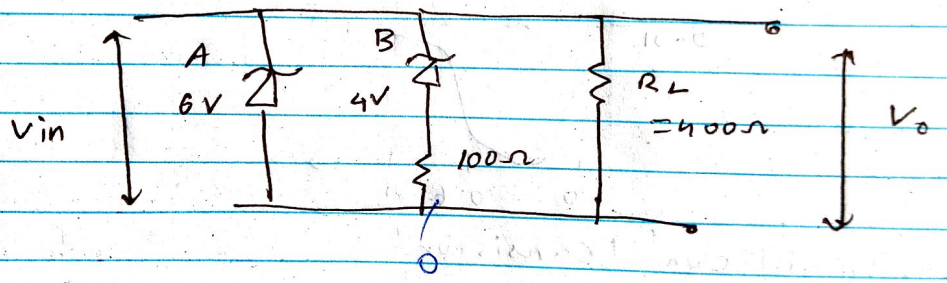
For input voltages shown in figure, the voltage (in V) at A.



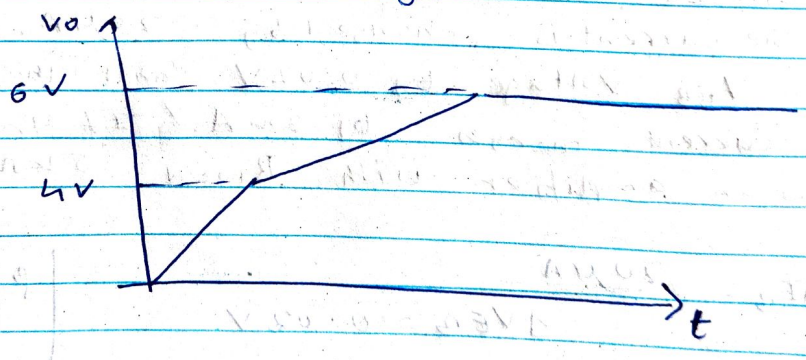
$V_A = 12.7 - 0.7 = 12\ V$

Q) The output voltage V_o variation with input voltage linearly increasing with time, is given by

$V_{in} = 0V$ at $t = 0$.



Ans



when V_i changes b/w 4V to 6V, 4V zener will breakdown and P.D across this be comes constant.

Now current in circuit increase abruptly after reaching 6V.

Q) In a pn junction diode, current I can be expressed as

$$I = I_0 \exp\left(\frac{eV}{2K_B T} - 1\right)$$

I_0 is called Reverse Saturation current.
$V \rightarrow$ voltage across the diode and is positive for forward bias and negative for reverse, $I \rightarrow$ current through diode,
$K_B \rightarrow$ Boltzmann ($8.6 \times 10^{-5} eV/K$ or 1.38×10^{-23})
T = absolute temp.

If for a given diode $I_0 = 5 \times 10^{-12} A$
$T = 300K$.

(a) What will be forward current at a forward voltage of 0.6V ?

(b) ΔI ? if $V = 0.7$ V.

(c) dynamic Resistance?

(d) I_2? if Reverse bias voltage 1V → 2V.

a) $V = 0.6$ V

$$I = 5 \times 10^{-12} \exp\left(\frac{1.6 \times 10^{-19} \times 0.6}{2 \times 300 \times 1.38 \times 10^{-23}} - 1\right)$$

$$= (5e{-}12)\, e^{+10.62} \qquad \frac{0.6 \times e}{8.6 \times 10^{-5}}$$

$$= 2.06 \times 10^{-7} = 0.2\ \mu A$$

$$= 5 \times 10^{-12} \exp\left(\frac{1.6 \times 10^{-19} \times 0.6}{2 \times 300 \times 1.38 \times 10^{-23}} - 1\right)$$

$$= 5 \times 10^{-12} \cdot e^{\exp(10.59)}$$

$$= 1.986 \times 10^{-7} \simeq$$

(b) Similarly

(c) $\Delta R = \frac{\Delta V}{\Delta I}$.

(d) For both the voltages, the current I will be almost equal to I_0, showing almost infinite dynamic Resistance.

Q) The number of silicon atoms per m^3 is 5×10^{28}. This is doped simultaneously with 5×10^{22} atoms per m^3 of Arsenic and $5 \times 10^{20}/m^3$ of Indium. Calculate the number of electrons and holes.

Given that $n_i = 1.5 \times 10^{16}/m^3$.

Is the material n-type or p-type?

A : As → n type n_{e^-}

$n_{As} = 5 \times 10^{22}$

In → p type n_{H^+}

$n_{In} = 5 \times 10^{20}/m^3$

Each As will add one extra e^- while each In will produce one hole. Neutralise.

In Si, $n_{e^-} \simeq n_{H^+}$.

So, As, $n_{As} > n_{H^+ In}$

∴ More $n_{e^-} > n_{H^+}$

$n_{e^-, excess} = 5 \times 10^{22} - 5 \times 10^{20}$

$= 495 \times 10^{20}$

$= 4.95 \times 10^{22}$

Now

$n_{e^-} \cdot n_{H^+} = n_i^2$

$\therefore n_{H^+} \simeq 4.75 \times 10^9$

A