Electronics:

The controlled movement of electrons (inside/outside the material) using external fields (electrical/magnetic field). In short, electronics is electron mechanics.

Communication: Exchange of information.

Instead of using cathode & anode in vacuum tubes, semiconductors can be used to control the flow of electrons, as the former system is unreliable & bulky.

Elemental semiconductors: Ge, Si

compound semiconductors: GaAs, GaP ~~etc.~~, AlGaAs, etc.

E_c (Lowest level of conduction band)

E_g forbidden energy gap.

E_v (Highest level of valence band)

* The process of adding impurity to an intrinsic or pure conductor to enhance its conductivity is called doping.

Impurities (Dopants)

Donor type (N)	Acceptor type (P)
Ex: Pentavalent elements	Ex: Trivalent elements.
↓	↓
gives rise to N-type semiconductors	gives rise to P-type semiconductors.

Holes exist in valence band.

E_c

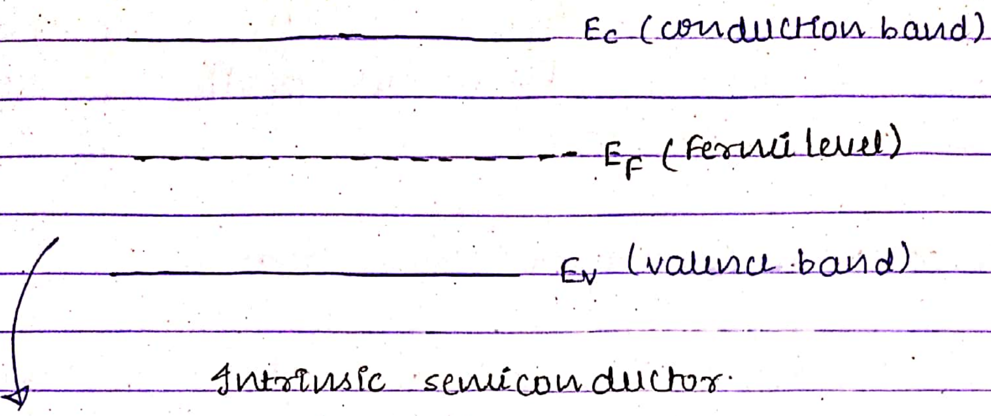
E_d (donor level)

E_v

E_c

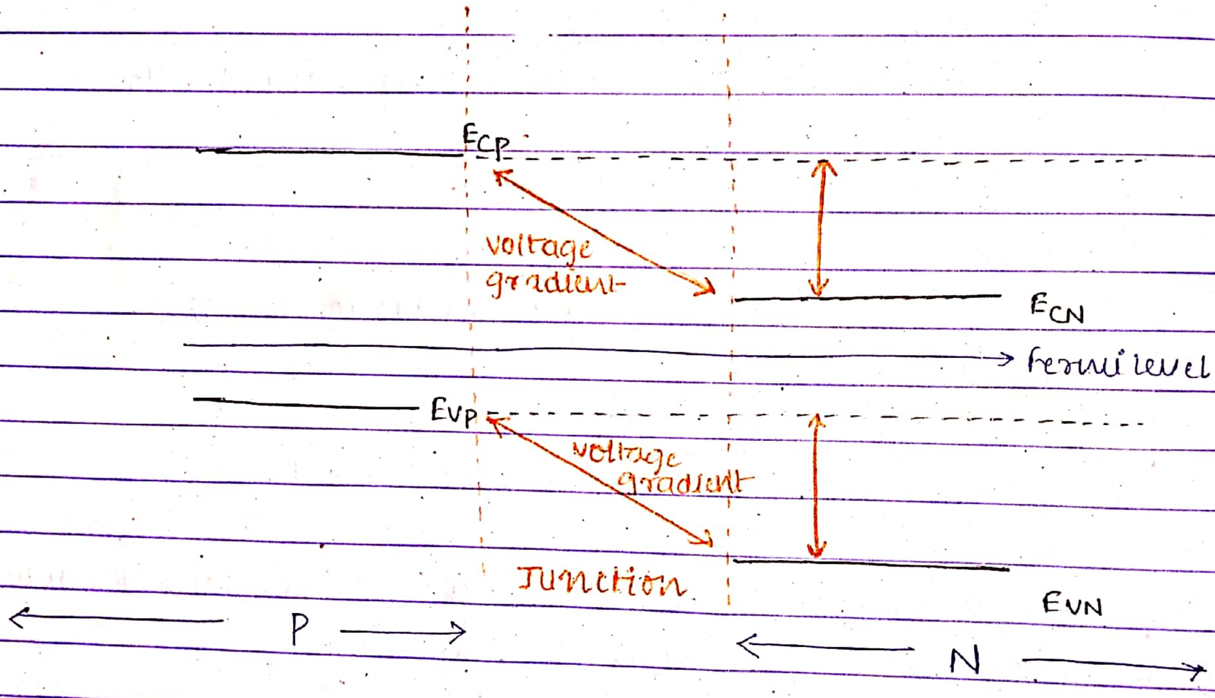
(Acceptor level) E_a

E_v



Intrinsic semiconductor.

The fermi level always remains at its position. When doped, either the conduction band or the valence band shifts.



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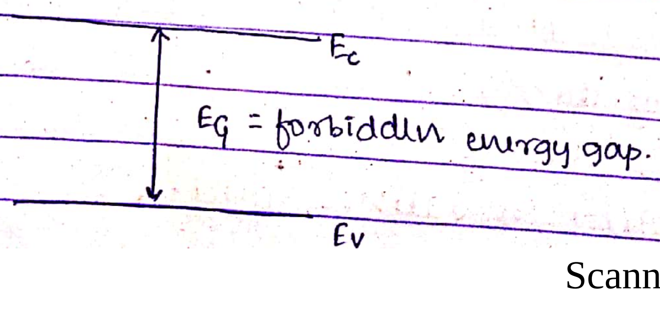
On the basis of conductivity

- Conductors
- Semiconductors
- Insulators.



$E_g = E_c - E_v$

E_g is temperature dependent.

At room temperature i.e. 300K & at absolute zero i.e. 0K the behavior of semiconductor will vary.

At absolute 0, semiconductor (intrinsic) behaves as an insulator.

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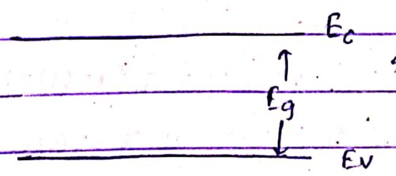

→ $E_g > 5eV$: insulators

→ $E_g = 0 eV$: conductors.

→ E_g lies in the order of 1eV : semiconductors

values of E_g at room temperature (300K):

→ Si : 1.12 eV

→ Ge : 0.66 eV

→ GaAs : 1.42 eV. (for compound semiconductors, $E_g < 4eV$)

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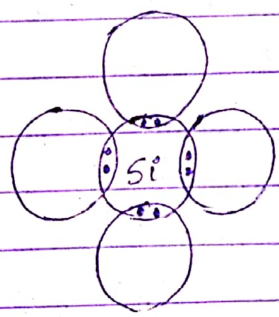

* As a solid, 'Si' exists as Si_4.

* If a minimum of 1.12 eV of energy is supplied, the covalent bond between two 'Si' ~~con~~ atoms breaks & electrons are free to jump from the valence band to the conduction band.

Fermi level lies between conduction & valence band. This shows the charge neutrality in the semiconductor (i.e. no. of holes = no. of electrons).

∴ Mathematically, $\boxed{E_F = \dfrac{E_c + E_v}{2}}$

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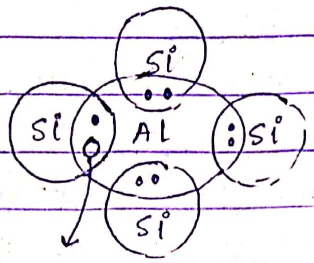
P-type extrinsic semiconductors:

* If trivalent impurity, say aluminium, is added,



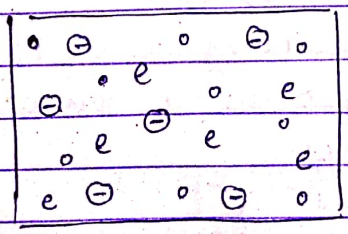
Hole (vacancy of electron)

* Thus, in P-type extrinsic semiconductors, holes (which eventually attains positive charge) are majority charge carriers.

* Immobile ions: the ions or electrons accepted by one vacancy (-vely charged) in P-type which result in the formation of a stable octet are tightly bound by the nucleus, thus, making ~~the ele~~ that particular electron immobile. (~~Represted~~ represented by ⊖)

Thermal energy is responsible for production of minority charge carriers, as this thermal energy is required to break the bond & free up the electron for its jump from valence band to conduction band.

* Pure semiconductor + Acceptor type / trivalent impurity = P-type extrinsic semiconductor



⇒ o : Holes
e : mobile electrons
⊖ : immobile electrons

P-type.

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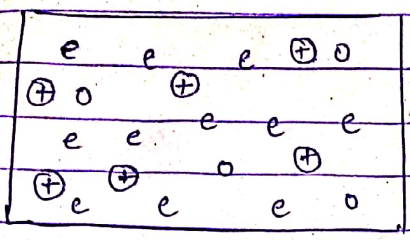
N-type semiconductors:



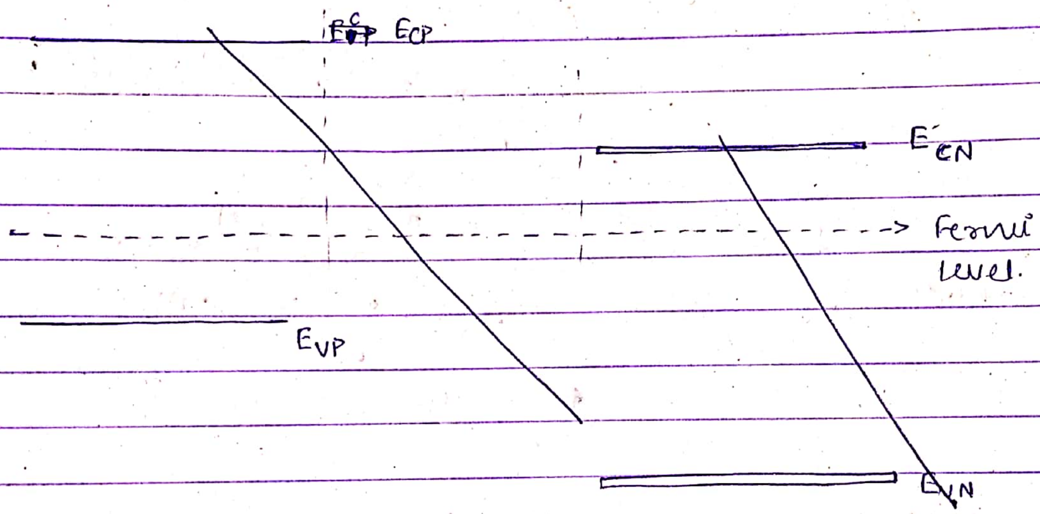
N-Type.

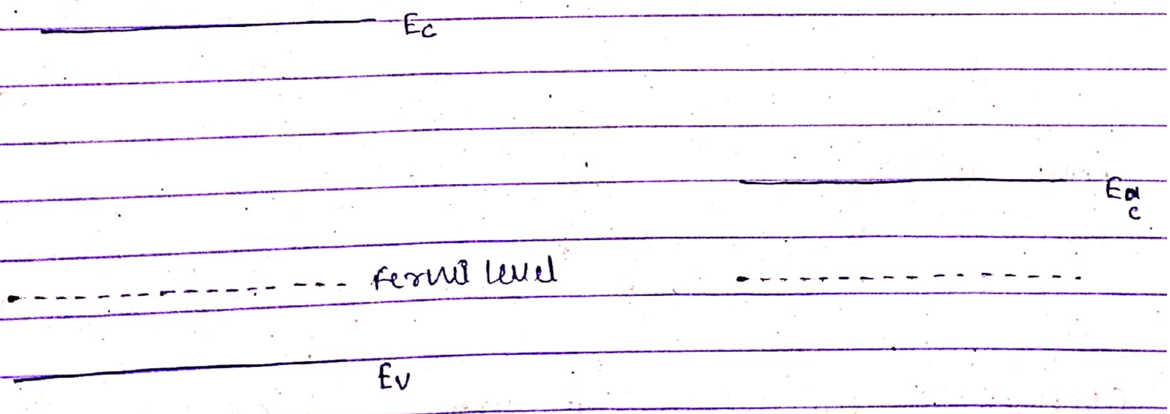
⇒ e : electrons

o : holes

⊕ : positively charged immobile ions.

Energy band diagram:

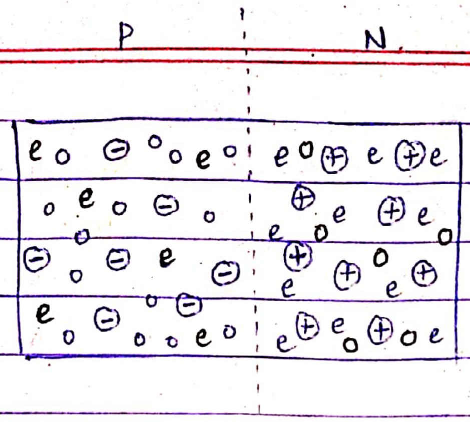




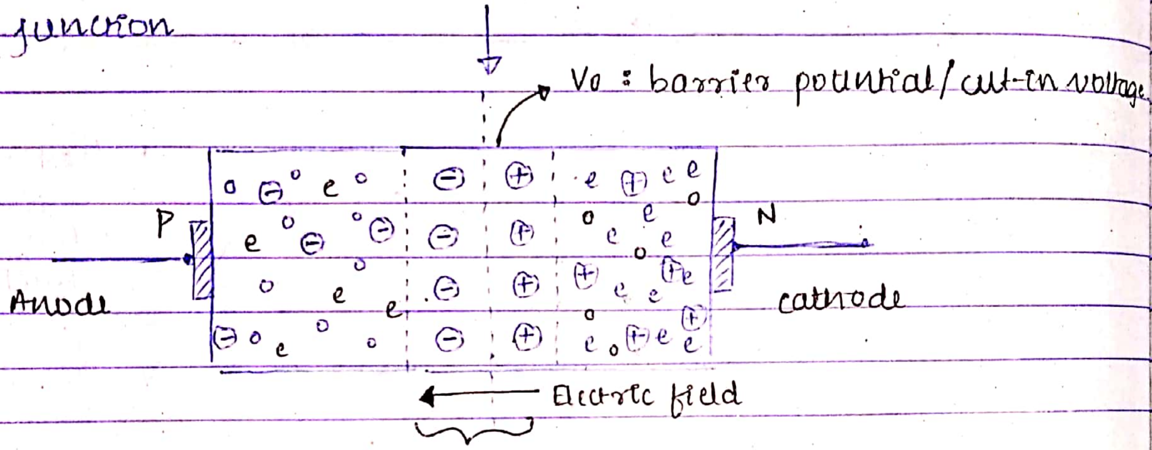
P-type

N-type.

P-N junction



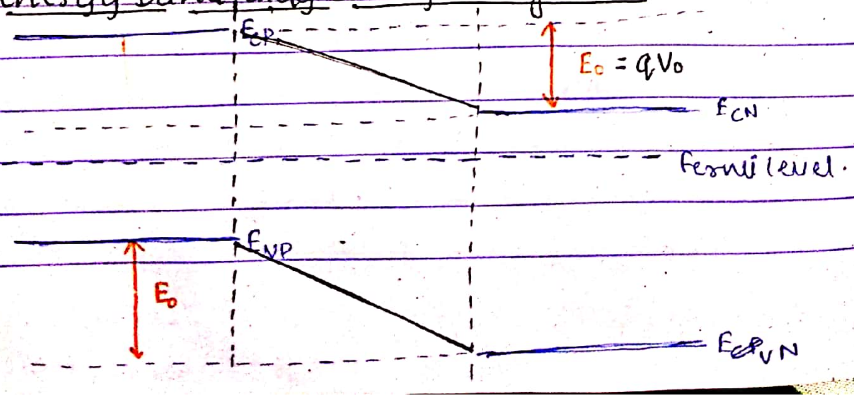
* Due to high concentration of majority charge carriers (both in P-type & N-type), the holes move towards 'N' type & electrons move towards 'P' type and hence recombine. Thus, what remains are the immobile ions in both the sides, near the junction



space charge region / no mobile charge carriers / transition region

* Thus, an electric field is created near the junction (due to the dipole). The potential of this electric field is called barrier potential.
* Placing metal contacts at the surfaces of P-type & N-type & introducing terminals at the ends, creates a device called diode.

Open-circuit energy band diagram of PN junction:

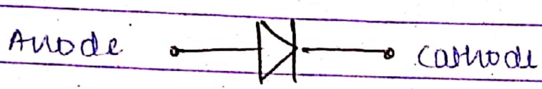


* E_0 amount of energy is required for electrons to jump from E_{CN} to E_{CP}.
* When, $V_{ext} < V_0$, a very small amount of current flows & is called leakage current. (due to minority charge carriers)
* for Germanium, $\boxed{V_0 = 0.3V}$

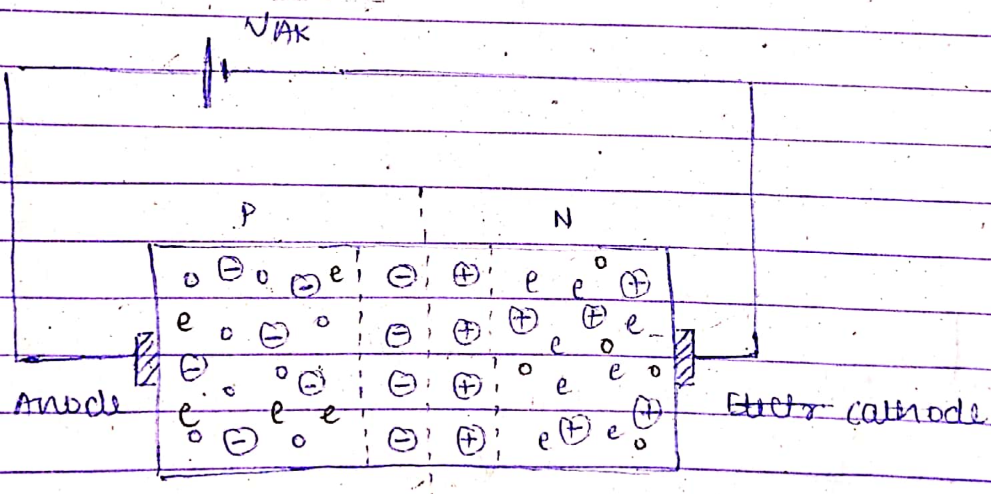
for silicon, $\boxed{V_0 = 0.7V}$

* 'V_0' is also called Threshold voltage (V_t) or knee voltage.

* Symbol:



P-N Junction diode



* ~~Ex~~ on applying external voltage, an electric field will be produced in direction of P → N.
* ~~Thus,~~ since, electrons move opposite to the direction of electric field, electrons move from N → P.

Biasness means disturbing the equilibrium to enhance the current flow.

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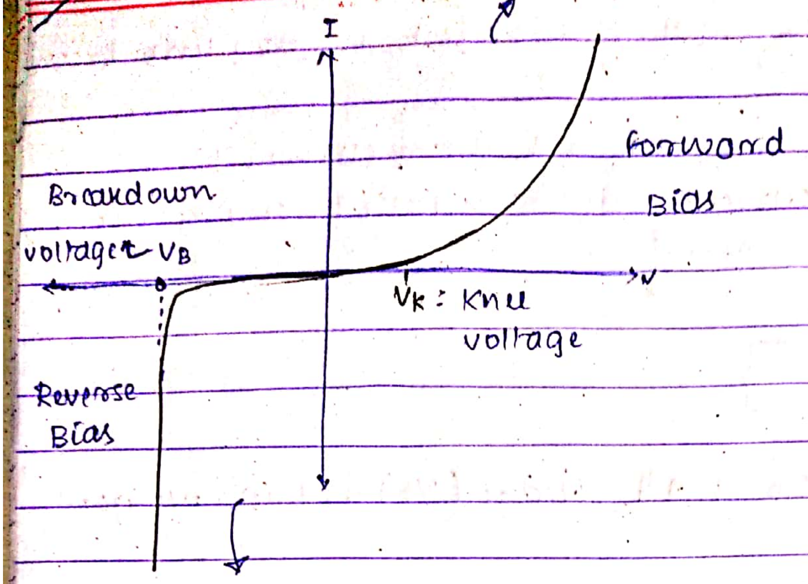
Due to majority charge carriers.

{ of mA order.



Due to minority charge carriers. { μA : Ge
nA : Si

I-V characteristic curve.

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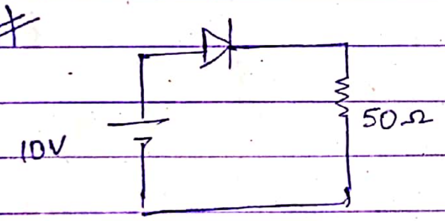
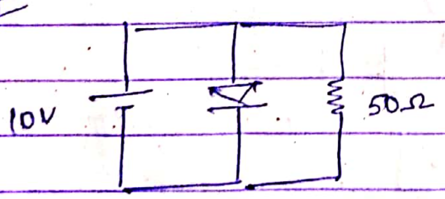


$$i = \frac{10 - 0.7}{50}$$

$$\boxed{i = \frac{9.3}{50}}$$

#



current always chooses a low resistance path ∴ All the current flows through the diode.

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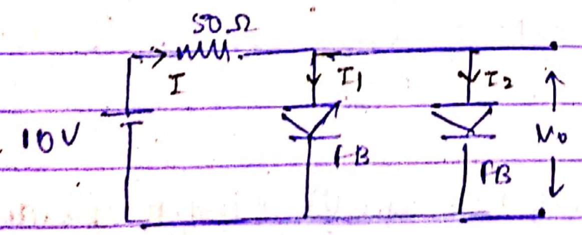
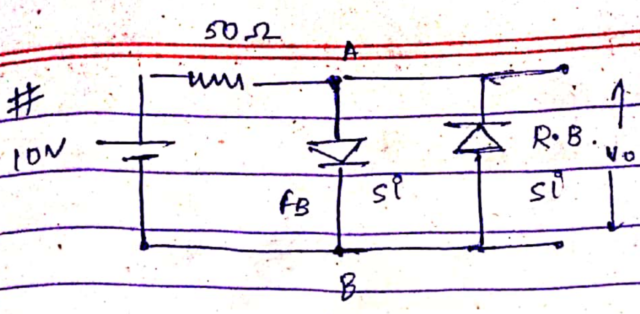


$V_0 = 0.7V$

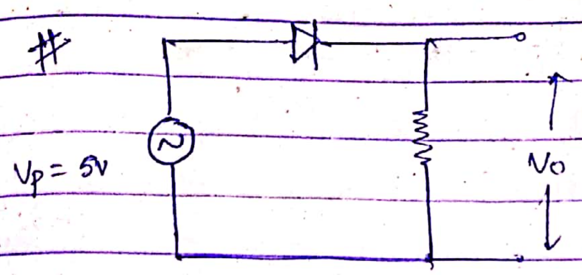
$$I = \frac{9.3}{50}$$

$$I_2 = \left(\frac{9.3}{50}\right)/2$$

$$I_1 = \left(\frac{9.3}{50}\right)/2$$



∵ R.B is open circuit, ∴ $V_o = 0$.
& $V_{AB} = 0.7V$.



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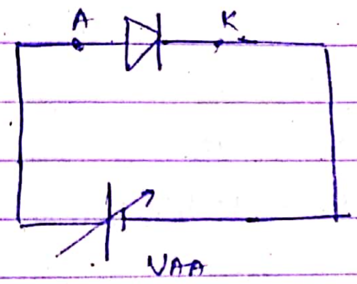
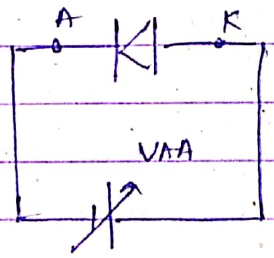




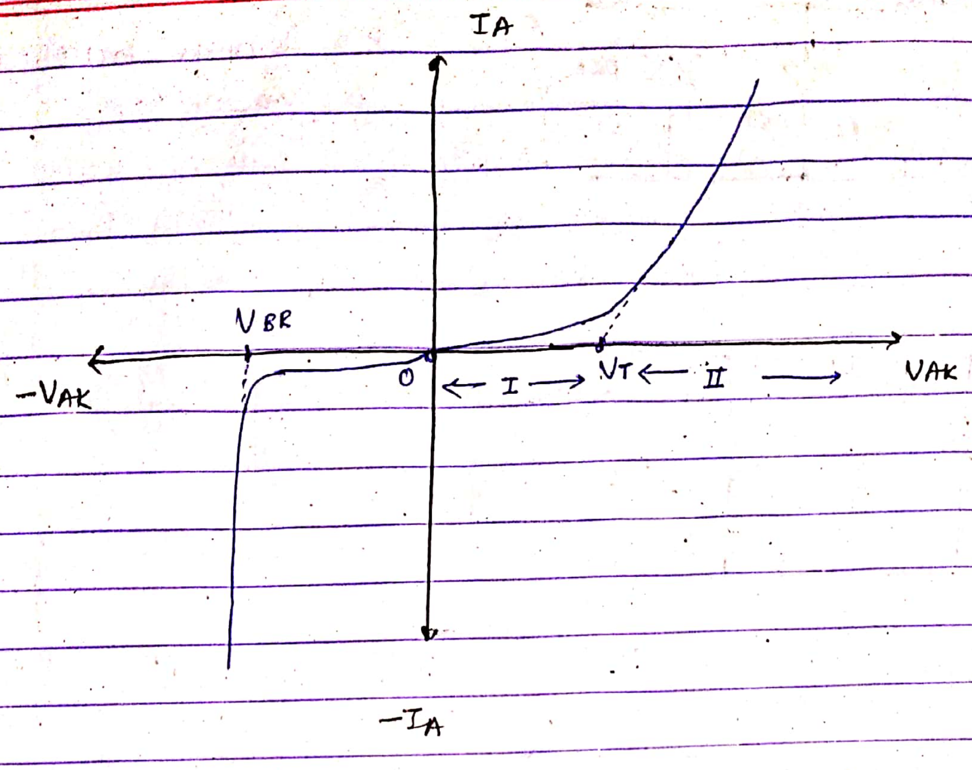
~~Reverse~~

Forward Bias

* In forward bias, there is repulsion between holes at the P side and holes on the P side tend to move towards the junction. Similarly, electrons in the N side tend to move towards the junction as a result of repulsion.
* No reduces

Reversed Bias.

* In reverse bias, there is attraction at the P as well as N sides, thus widening the gap i.e. depletion region
* No increases.



Forward Bias:

→ $0 < V_{AK} < V_T$: Low current forward bias state (I)
→ $V_{AK} > V_T$: High current forward bias state (II)

once the voltage reaches V_T, conduction begins; as the voltage reaches equal to ~~b~~ barrier voltage.

Reverse Bias:

* Initially, no current will flow. But, due to minority carriers, a "leakage current" or "reverse saturation current". Physically, due to high intensity of electric field, more no. of minority charge carriers are produced as a result of acceleration (due to electric ~~a~~ field) of charges. The collision of these charges can, probably, break the covalent bonds, resulting in damage of the junction. Thus, heavy current flows in opposite direction.

P^+ : heavily doped (impurity concentration is high)
P : slightly doped

The concentration of impurities changes the breakdown mechanism — either zener breakdown or avalanche breakdown.

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when heavily doped:

→ Intensity of electric field is very high at junction, due to which covalent bonds break and more no. of minority charge carriers are produced. They are accelerated & thus high current flows.

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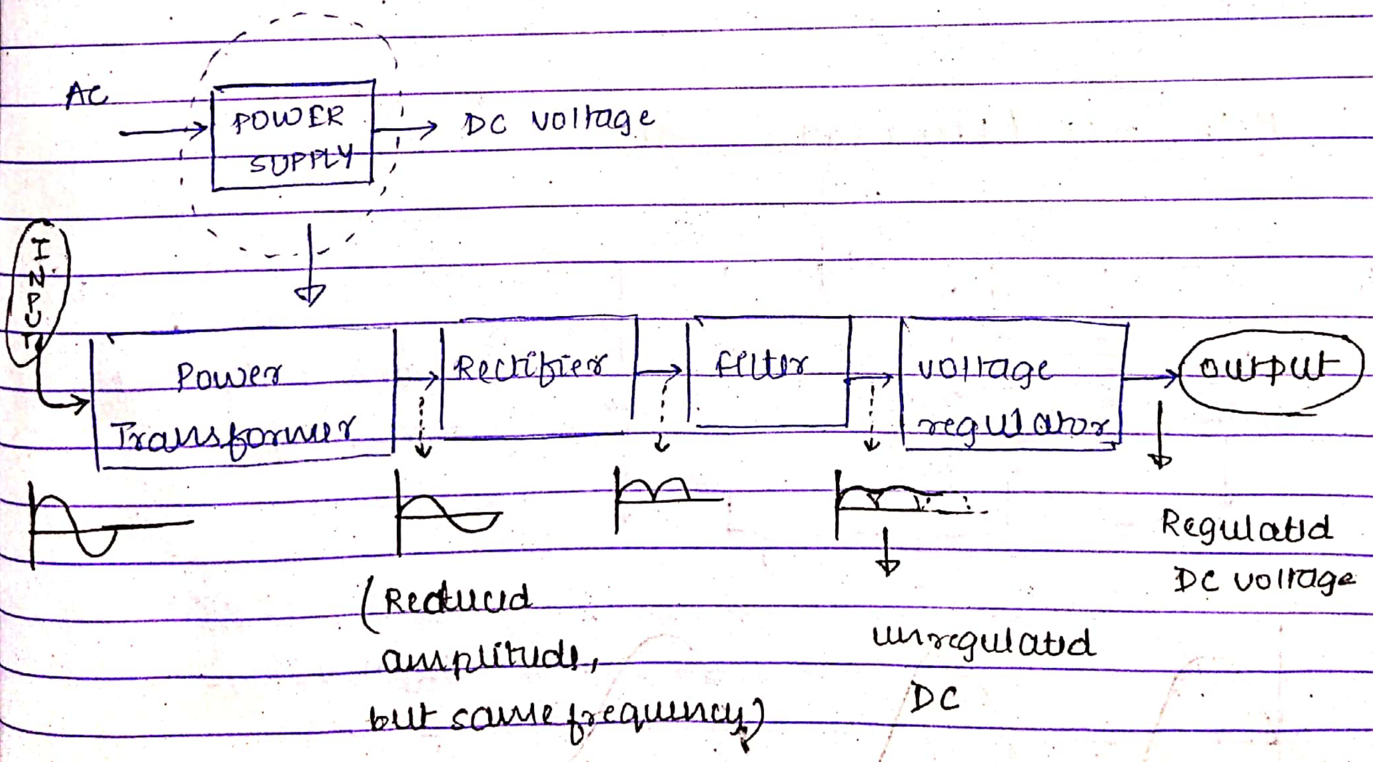
when lightly doped:

→ .



Block diagram of regulated DC Power supply

Ripples: AC variations in the output voltage.

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Rectifier/Rectification:

- controlled rectifier (output voltage can be controlled)
- uncontrolled rectifier
  - Half wave
  - Full-wave
    - centre type
    - Bridge.

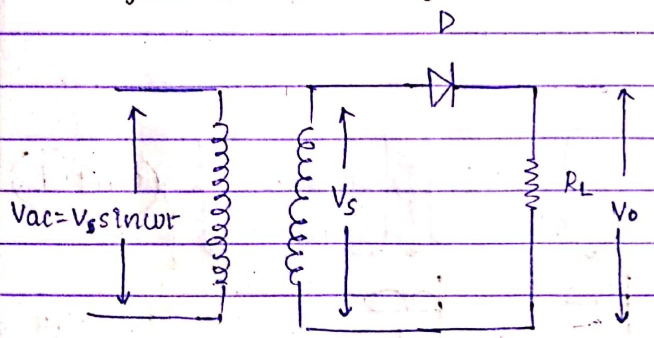
AC voltage ⇒ Rectifier ⇒ DC voltage

Power-converted circuit:
(AC → DC converted circuit)

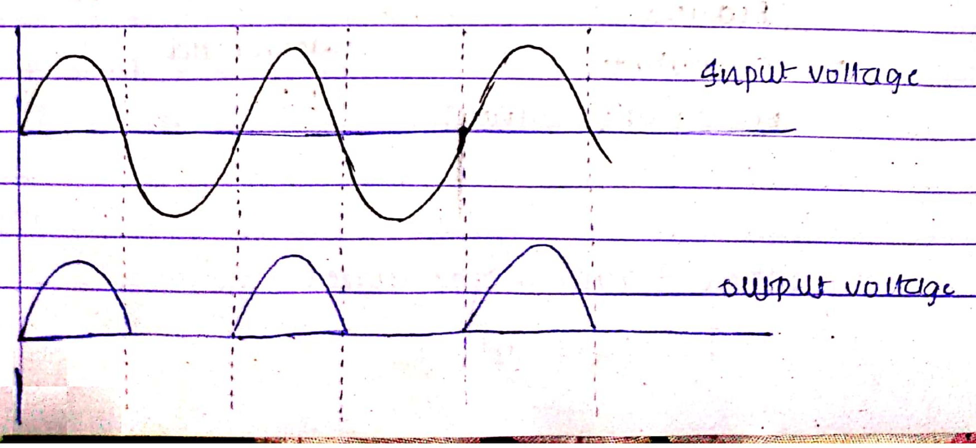
The process of converting alternating voltage to direct voltage is called rectification. The circuitory that accomplishes this task is called a rectifier.

The designing of any circuitory requires input & output specifi-cations.

Half-wave: (Ripple factor = 1.21)



Diode is a unidirect-ional device.



* In the positive half-cycle, the diode is forward biased ($\because$ P end of the semiconductor is connected to positive of the AC voltage) and similarly in the negative half-cycle, the diode is reversed bias and doesn't allow the passage of current.

(H.W)
Inductor as a Load:

$V = L\frac{di}{dt}$

$V = V_m \sin\omega t$

$I = I_m \sin(\omega t - \phi)$

$V = L\cdot\omega\cdot\cos(\omega t - \phi)$.

DC Average output voltage.

$2\pi = \omega$
T

$V_{avg} = \frac{\int_0^{\pi} V_m \sin\omega t \, dt}{2\pi} = \frac{V_m \int_0^{\pi} \sin\omega t \, dt}{2\pi}$

$= \frac{V_m}{2\pi}\left(\frac{-\cos\omega t}{\omega}\right)_0^{\pi}$

$\frac{V_m\left(-\cos\omega t\right)_0^{2\pi}}{2\pi\omega}$

$\frac{V_m}{2\pi}\cdot\left(\frac{-\cos\pi + \cos 0}{\pi}\right)$

$\frac{V_m}{2\pi\omega}\cdot\left(-\cos 2\pi\omega + \cos 0\right)2\pi$

$\frac{V_m}{2\pi}$

$\frac{V_m(}{\pi\omega}$

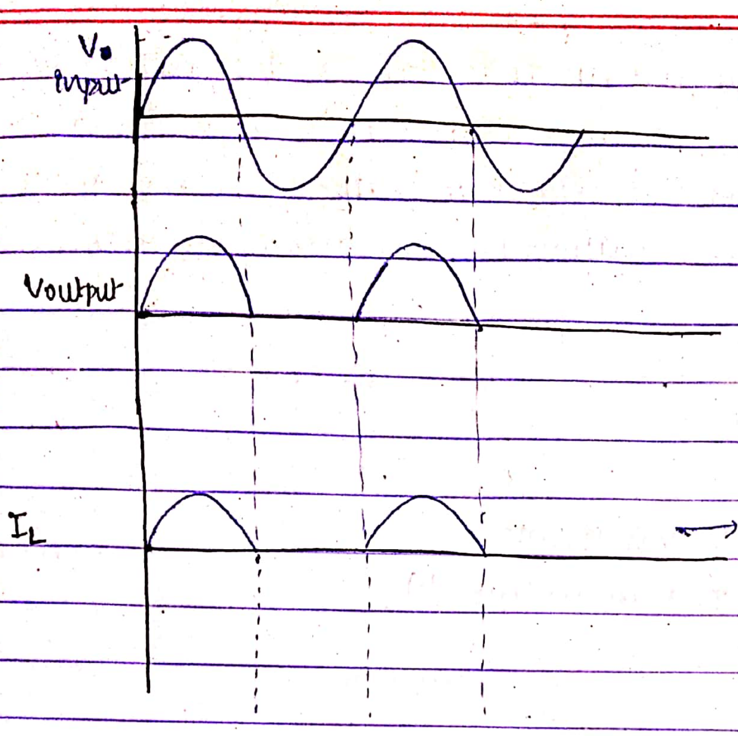
$V_{avg} = \frac{V_0}{\pi}\left(\text{or } \frac{V_m}{\pi}\right)$

We ignore the dynamic resistance 'R_s' of the diode.

$\therefore i = \frac{V}{(R_s + R_L)}$

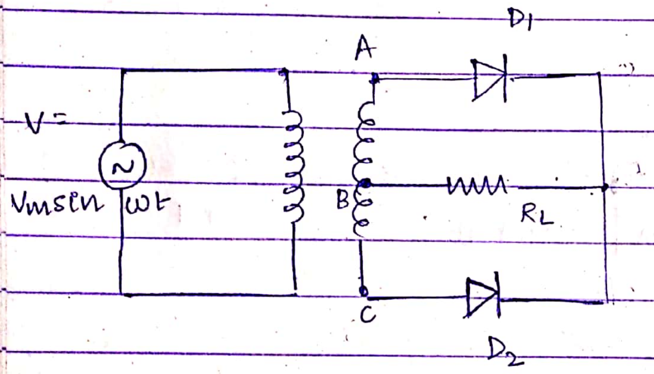
when diode is reversed bias, the peak voltage across the diode or the maxm voltage a diode can withstand in reversed bias state, it is peak inverse voltage. In half wave rectifier,

$\boxed{\text{PIV rating} = V_m}$



→ Reduced amplitude.

Full-wave centre tap rectifier:



P.I.V : Peak Inverse voltage

In full-wave rectifier, P.I.V. rating = 2Vm

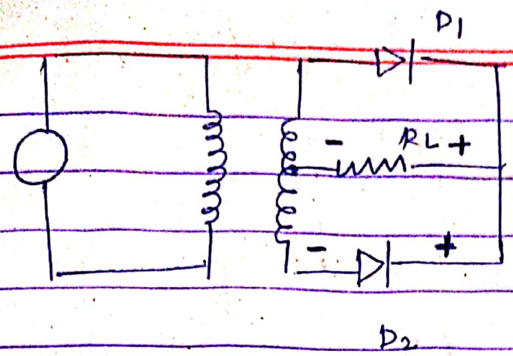
$V_{AB} = V_m$ $\quad$ $V_A - I_L R_L = V_B$

$V_{BC} = V_m$ $\quad$ $V_A - V_B = I_L R_L$

$V_C - I_L R_L = V_B$

$V_C - V_B = I_L R_L$

when diode D_1 conducts, (forward bias), it acts as short circuited. Therefore, ~~across the load resistance Vmsinωt entire Vmsin~~ the entire voltage directly appears across the load resistance, i.e. $V = V_m \sin \omega t$. And across D_2 (in reversed bias state), a voltage of $V = V_m \sin \omega t$ appears.



∴ $V_m \sin\omega t + V_m \sin\omega t$

$= 2V_m \sin\omega t$

P.I.V.

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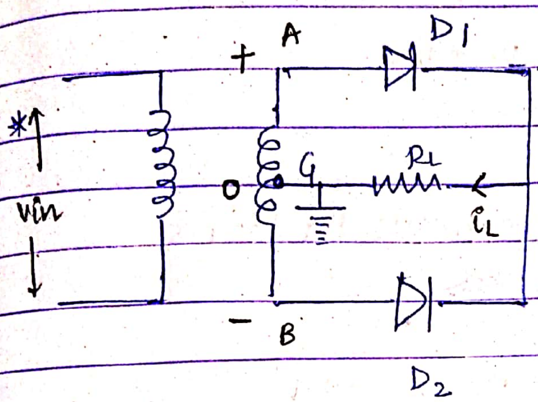
Full-wave centre-tap Rectifier:

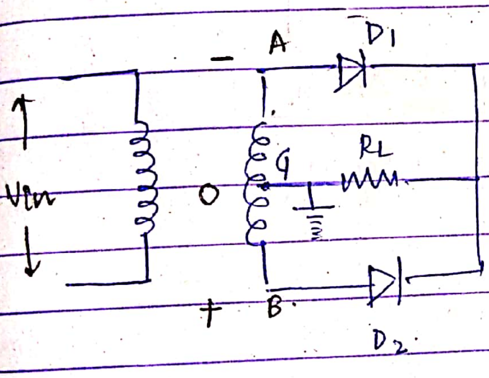
Grounding a circuit is important.



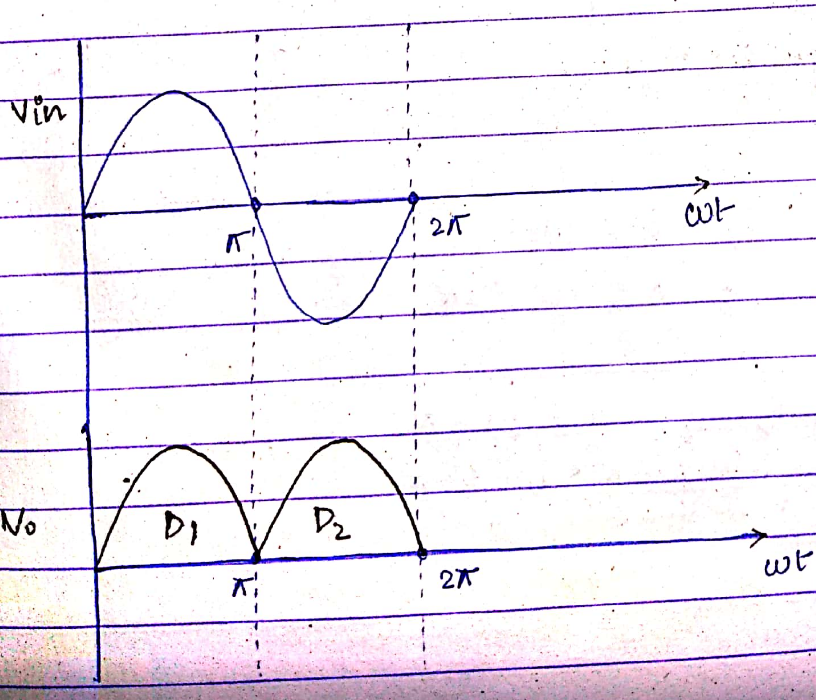
for positive half cycle:

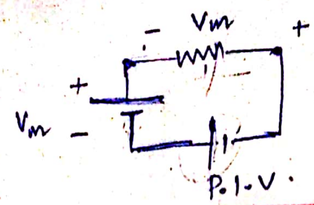
→ ∴ Peak voltage = +Vm (across A & C)

→ D1 is forward biased; hence acts as short circuited.



for negative half cycle:

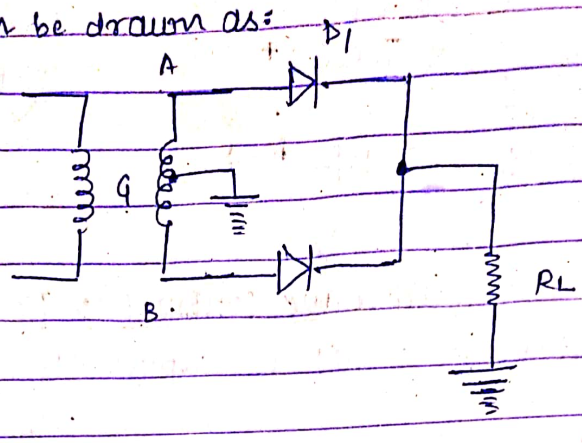




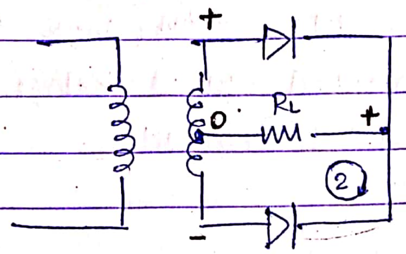
$-V_m - V_m - P.I.V = 0$

$P.I.V. = -2V_m$

same circuit can be drawn as:



$V_s = \frac{N_s}{N_p} . V_{in}$: Relation between V_s & V_{in}.



Applying KVL in loop 2

$P.I.V - V_m - V_m = 0$

$\boxed{\therefore P.I.V. = 2V_m}$

$\boxed{P.I.V. \geq 2V_m}$

(In the half cycle)

P.I.V. for centre-tap full wave rectifier

voltage between 'A' & 'B' will be 0.

~~DC~~ Average output ~~voltage~~:

(i) Half-wave

$i_L = I_m \sin(\omega_m t)$; $0 \leq \omega t \leq \pi$

$= 0$; $\pi \leq \omega t \leq 2\pi$

& $V_o = V_m \sin(\omega_m t)$; $0 \leq \omega t \leq \pi$

$= 0$; $\pi \leq \omega t \leq 2\pi$

$$* \therefore \underline{V_{dc}} = \frac{\int_0^{\pi} V_m \sin(\omega m t) \cancel{dt}\, d(\omega m t)}{2\pi}$$

$$= \frac{1}{2\pi} \int_0^{\pi} V_m \sin(\omega m t)\, d(\omega m t)$$

$$= \frac{V_m}{2\pi} \int_0^{\pi} \sin(\omega m t)\, d(\omega m t)$$

$$= \frac{V_m}{2\pi} \left[-\cos(\omega m t)\right]_0^{\pi} = \frac{V_m}{2\pi}\left[-\cos\pi + \cos 0\right] = \frac{V_m}{\cancel{2}\pi}(\cancel{2}) = \frac{V_m}{\pi}$$

$$\boxed{\therefore V_{dc} = \frac{V_m}{\pi}}$$ ⇒ Average output DC voltage for Half wave rectifier.

$$\boxed{V_d \approx 0.318 \cdot V_m}$$

$$* \underline{I_{dc}} = \frac{1}{2\pi} \int_0^{\pi} I_m \sin(\omega m t)\, d(\omega m t)$$

$$= \frac{I_m}{2\pi} \int_0^{\pi} \sin(\omega m t)\, d(\omega m t) = \frac{I_m}{2\pi} \left[-\cos(\omega m t)\right]_0^{\pi}$$

$$= \frac{I_m}{\cancel{2}\pi} \cdot \cancel{2} = \frac{I_m}{\pi}.$$

$$\boxed{I_{dc} = \frac{I_m}{\pi}}$$

let us the resistance of Diode = (forward biased) $= R_f$.
as of now

$$I_{dc} = \frac{I_m}{\pi}$$

$$\& \; V_{dc} = V_o = I_{dc} \cdot R_L = \frac{I_m}{\pi} \cdot R_L = \frac{V_m}{(R_f + R_L) \cdot \pi} \cdot R_L.$$

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$\because R_f << R_L$

$\therefore R_f + R_L \approx R_L$

~~$I_{dc} =$~~

$\therefore V_{dc} = \frac{V_m}{\cancel{R_L}\pi} \cdot \cancel{R_L}$

$\Rightarrow \boxed{V_{dc} = \frac{V_m}{\pi}}$

* P_{dc} = average DC power.

$= I_{dc}^2 \cdot R_L$.

* of I_{rms}:

$$\sqrt{\frac{1}{2\pi}\left[\int_0^\pi (\cancel{V_m}\, I_m \sin \omega mt)^2 \, d(\omega mt)\right]}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^\pi I_m^2 \sin^2(\omega mt)\, d(\omega mt)\right]}$$

$$= \sqrt{\frac{1}{2\pi}\left[I_m^2\right] \int_0^\pi \sin^2(\omega mt)\, d(\omega mt)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\int_0^\pi \frac{1-\cos(2\omega mt)}{2}\, d(\omega mt)\right]}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\int_0^\pi \frac{1}{2}\, d(\omega mt) - \frac{1}{2}\int_0^\pi \cos(2\omega mt)\, d(\omega mt)\right]}$$

$$= \frac{I_m}{2\pi}\left[\left(\frac{\omega mt}{2}\right)_0^\pi - \frac{1}{2}\left[\frac{\sin(2\omega mt)}{2}\right]_0^\pi\right]$$

$$= \sqrt{\frac{Im^2}{2\pi}} \left[\left(\frac{\pi}{2} - 0\right) - \frac{1}{2}\left(\frac{\sin 2\pi}{2} - \frac{\sin 0}{2}\right) \right] = \sqrt{\frac{Im^2}{2\cancel{\pi}}} \cdot \sqrt{\frac{\cancel{\pi}}{2}} = \frac{Im}{2}.$$

$$= \cancel{\frac{Im}{2\sqrt{2} \cdot \sqrt{\pi}}} =$$

$\therefore$ $V_{dc} = \frac{V_m}{\pi}$ $\qquad P_{dc} = I_{dc}^2 \cdot R_L$

$I_{dc} = \frac{I_m}{\pi}$ $\qquad P_{ac} = I_{rms}^2 (R_f + R_L)$

$I_m = \frac{V_m}{R_f + R_L}$

$I_{rms} = \frac{I_m}{2}$

* η = Rectification efficiency $= \frac{P_{dc}}{P_{ac}} = \frac{I_{dc}^2 \cdot R_L}{I_{rms}^2 (R_f + R_L)}$

$$= \frac{I_{dc}^2 \cancel{R_L}}{I_{rms}^2 \cancel{R_L} \left(\frac{R_f}{R_L} + 1\right)}$$

$$= \frac{I_{dc}^2}{I_{rms}^2} \cdot \frac{1}{\left(\frac{R_f}{R_L} + 1\right)}$$

Placing values for Half-wave rectifier,

$$\eta = \frac{\frac{\cancel{Im^2}}{\pi^2}}{\frac{\cancel{Im^2}}{4} \cdot \left(\frac{R_f}{R_L} + 1\right)} \times 100 = \frac{4}{\pi^2 \left(\frac{R_f}{R_L} + 1\right)} \times 100$$

$$= \frac{400}{\pi^2} \cdot \frac{1}{\left(\frac{R_f}{R_L} + 1\right)}$$

$\therefore$ $\cancel{R_f < \!< R_L}$ $\cancel{\%}$

$$= \underline{0.405 \times 100}$$

$$\eta = \frac{0.405 \times 100}{\left(\frac{R_f}{R_L} + 1\right)}$$

Efficiency of half wave rectifier.

It means that half-wave rectifier is able to convert only 40.6% of AC input power into DC output power.

$\because R_f << R_L$

$\therefore \frac{R_f}{R_L} \approx 0$

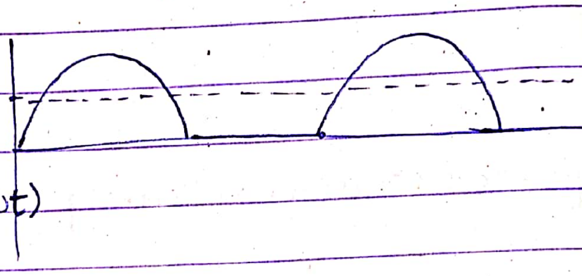
$$\boxed{\therefore \eta = 40.52\%}$$

* PIV(half-wave) = Vm

\#

Fluctuations about Average value is measured in terms of ripples.

$\xrightarrow{\text{ripple current}}$ $i' = i_L - I_{dc}$



$$i'_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (i_L - I_{dc})^2 \, d(\omega t)}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{2\pi} \left[i_L^2 + I_{dc}^2 - 2 i_L I_{dc}\right] d(\omega t)}$$

$$= \sqrt{\frac{1}{2\pi}\left\{ (I_m \sin \omega t)^2 + \frac{I_m^2}{\pi^2} - 2 \cdot I_m \sin(\omega t) \cdot \frac{I_m}{\pi} \right\} d(\omega t)}$$

$$= \sqrt{\frac{1}{2\pi}\left\{ I_m^2 \left(\sin^2 \omega t + \frac{1}{\pi^2} - \frac{2}{\pi} \sin \omega t \right)\right\} d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{2\pi} \cancel{I_m^2} \sin^2 \omega t \, d(\omega t) + \cancel{I_m} \frac{1}{\pi^2} \, d(\omega t) - \frac{2}{\pi} \sin \omega t \, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\int_0^{2\pi} \left(\frac{1 - \cos 2\omega t}{2}\right) d\omega t + \left[\frac{1}{\pi^2} \cdot \omega t\right]_0^{2\pi} - \frac{2}{\pi} (\cos \omega t)_0^{2\pi}\right.}$$

$$\sqrt{\frac{I_m^2}{2\pi}\left[\left(\frac{\omega t}{2}\right)_0^{2\pi} - \frac{1}{2}\left(\frac{\sin(2\omega t)}{2}\right)_0^{2\pi} + \frac{1}{\pi^2}\right]^{2\pi} - \frac{2}{\pi}\left(-1-1\right.}$$

$$i'_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} \frac{i_L^2}{(d\omega t)} - \frac{2I_{dc}}{2\pi}\int_0^{2\pi} i_L \, d\omega t + \frac{1}{2\pi}\int_0^{2\pi} I_{dc}^2 \, d\omega t}$$

$$= \sqrt{I_{rms}^2 - \frac{2I_{dc}}{2\pi} \cdot I_{dc} + I_{dc}^2}$$

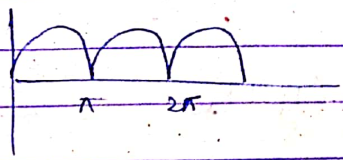
$$i'_{rms} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

* Ripple factor, $RF = \dfrac{i'_{rms}}{I_{dc}}$

$$= \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$= \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} = \cancel{1.21} \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} = 1.21.$$



(ii) <u>Full-wave Rectifier</u>

→ V_{dc}: $V_{dc} = \dfrac{1}{2\pi}\displaystyle\int_0^{\pi} V_m \sin(\omega t) \, d\omega t$

$$= \frac{V_m}{\pi}\left[-\cos(\omega t)\right]_0^{\pi}$$

$$= \frac{V_m}{\pi}\left(-\cos\pi + \cos 0\right) = \frac{2V_m}{\pi}.$$

* I_{dc} :

$$I_{dc} = \frac{1}{\pi}\int_0^{\pi} I_m \sin(\omega t)\, d(\omega t)$$

$$= \frac{I_m}{\pi}\left[-\cos(\omega t)\right]_0^{\pi} = \frac{2I_m}{\pi}$$

* I_{rms} : $\sqrt{\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2(\omega t)\; d(\omega t)}$

$$= \sqrt{\frac{I_m^2}{\pi}\int_0^{\pi} \sin^2(\omega t)\, d\omega t}$$

$$= \sqrt{\frac{I_m^2}{\pi}\int_0^{\pi} \frac{1-\cos(2\omega t)}{2}\; d\omega t}$$

$$= \sqrt{\frac{I_m^2}{\pi}\left[\int_0^{\pi}\frac{1}{2}\, d\omega t - \int_0^{\pi}\frac{\cos(2\omega t)}{2}\right] d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{\pi}\left[\left(\frac{\pi}{2}\right) - \frac{1}{2}\left(\frac{\sin(2\omega t)}{2}\right)_0^{\pi}\right]}$$

$$= \sqrt{\frac{I_m^2}{\pi}\cdot\frac{\pi}{2}} = \frac{I_m}{\sqrt{2}}.$$

* $P_{dc} = I_{dc}^2 \cdot R_L$

* $P_{ac} = I_{rms}^2 \cdot (R_f + R_L)$

* $\eta =$

$$\frac{P_{dc}}{P_{ac}} \times 100 = \frac{I_{dc}^2 \cancel{R_L}}{I_{rms}^2 \cancel{R_L}\left(\frac{R_f}{R_L}+1\right)} \times 100 = \frac{\frac{4I_m^2}{\pi^2} \times 100}{\frac{I_m^2}{2}} = \frac{4\cancel{I_m^2}}{\pi^2}\cdot\frac{2}{\cancel{I_m^2}} \times 100$$

$$= \frac{8}{\pi^2} \times 100$$

$\therefore \eta = 81.2\%$.

* Ripple factor:

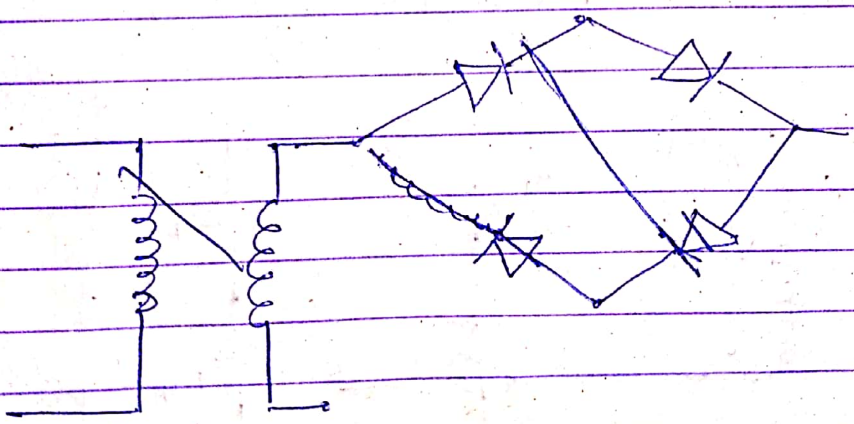
$$RF = \frac{i'_{rms}}{I_{dc}}$$

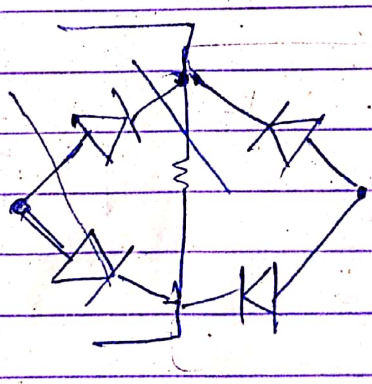
$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

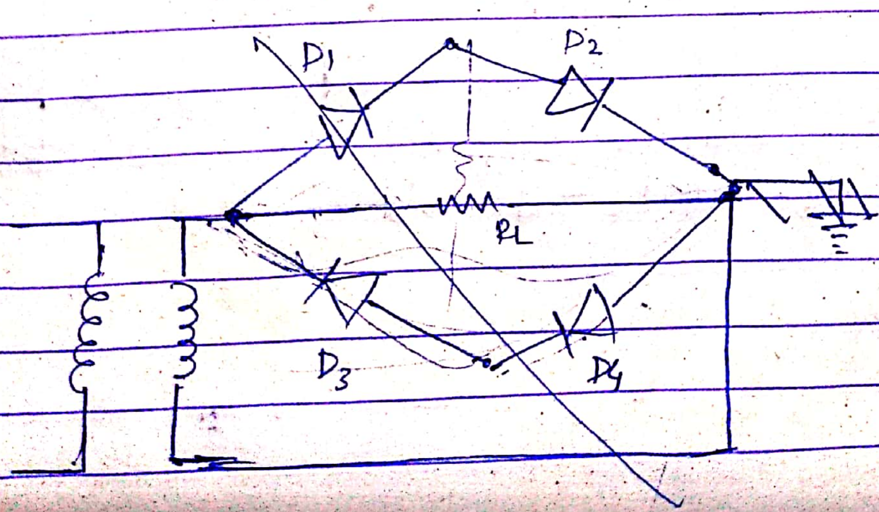
$$= \sqrt{\left(\frac{\cancel{I_m}^2}{2} \cdot \frac{\pi^2}{4\cancel{I_m}^2} - 1\right)}$$

$$= \sqrt{\frac{\pi^2}{8} - 1} = 0.48$$

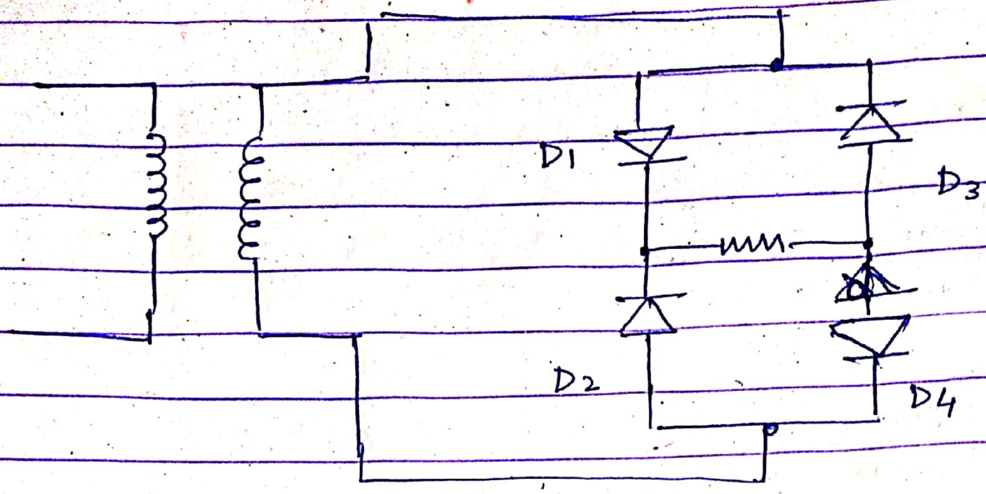
* P.I.V. $= 2V_m$.







Full-wave Bridge Rectifier



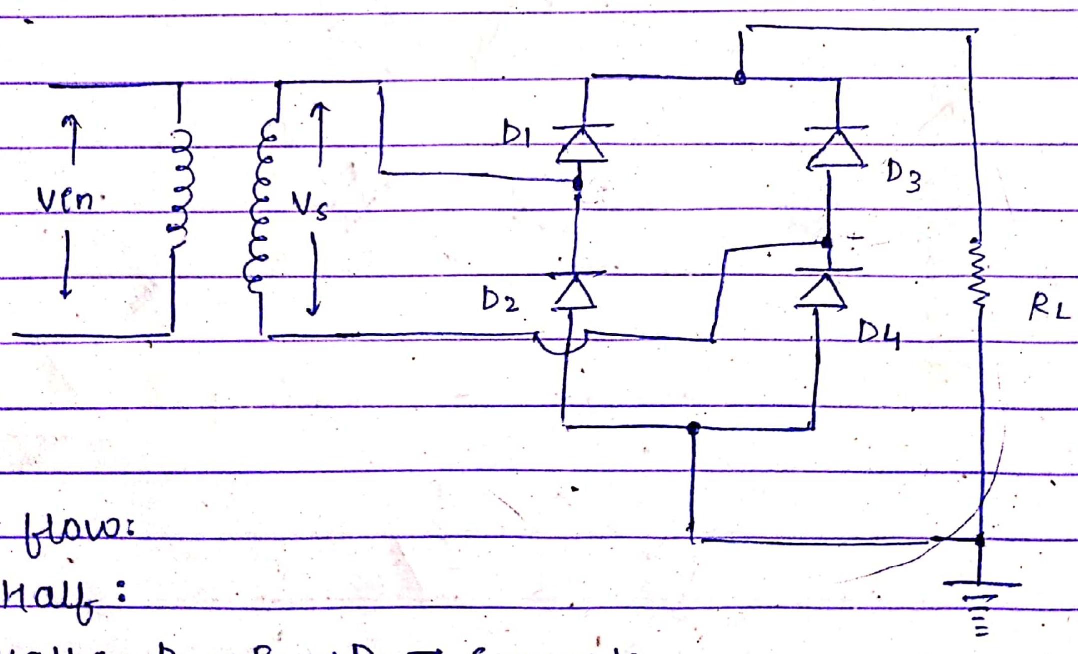
* During positive half cycle, D1 & D4 will conduct & during negative half cycle, D_3 & D_2 will conduct.

* The difference occurs in P.I.V. rating only.

* Diagonals are in forward biased during one half of the cycle.

Alternative arrangement (for bridge rectifier)

(i)

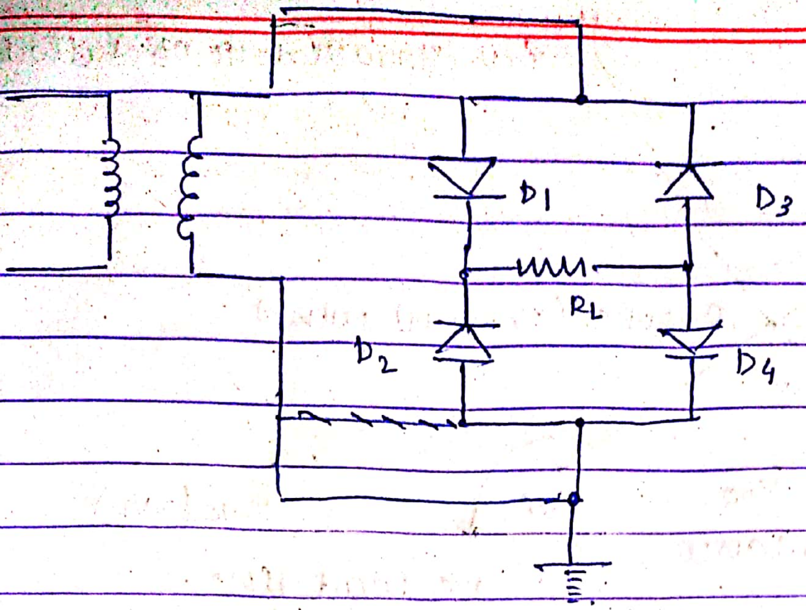


Current flow:

Positive Half :

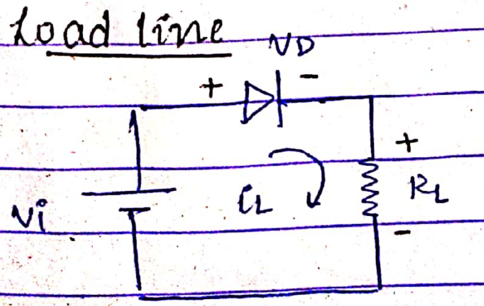
Negative Half : $D_3 \rightarrow R_L \rightarrow D_2 \rightarrow$ Ground.

(ii)



Parameter	Half-wave	full-wave centre-tap	full-wave bridge.
I_{dc}	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$	$\frac{2I_m}{\pi}$
V_{dc}	$\frac{V_m}{\pi}$	$\frac{2V_m}{\pi}$	$\frac{2V_m}{\pi}$
I_{rms}	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$	$\frac{I_m}{\sqrt{2}}$
γ	1.21	0.48	0.48
η	40.6%	81.2%	81.2%
P.I.V.	Vm	2Vm	Vm

Load line



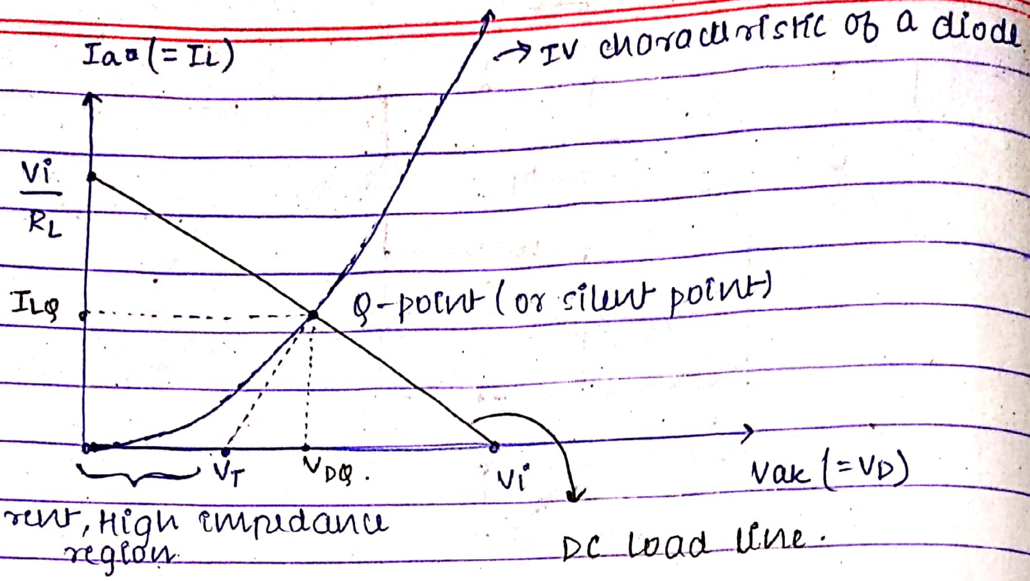
$-V_D - i_L R_L + V_i = 0$

$\therefore \boxed{V_D = V_i - i_L R_L}$

or

$\boxed{V_i = V_D + i_L R_L}$

Q-point : quotient point (= operating point



$V_d = V_i - i_L R_L$

Q-point can shift either by changing R_L or V_i.
In a proper circuitory (practical circuits), Q-point shouldn't shift by any parameter.

DC load line concept is applicable in transistor circuits.

$\boxed{i_L = \frac{V_i}{R_L} - \frac{V_D}{R_L}}$

DC load line is defined as:
variation of load current with voltage drop across the diode

The join of two points $\frac{V_i}{R_L}$ & V_i gives a straight line called DC load line.

Q-point plays a significant role in non-linear applications.

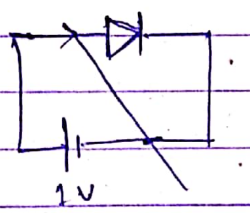
Q1. A silicon diode posses a current of 100mA at 1V. Find its bulk resistance. What would be its AC resistance for direct current of 0.1mA & 25mA.

2. A silicon diode has a forward voltage drop of 1.2V for a forward DC current of 100mA. It has a reverse current of 1μA for a reverse voltage of 10V. Calculate bulk & reverse

resistances of the diode.

3. The turn ratio (n_1/n_2) of a transformer used in half-wave rectifier is $\frac{n_1}{n_2} = \frac{12}{1}$. The primary is connected to the power mains 220V, 50Hz. Assuming the diode resistance in forward bias to be 0, calculate the DC voltage across the load. What is the P.I.V. of the diode?

4. In a centre-tap full-wave rectifier, the load resistance $R_L = 1K\Omega$ each diode has a forward bias resistance R_D of 10Ω. The voltage across half the secondary ~~btn~~ winding is 220 sin 314 t. Find the peak-value of current, DC or Avg. value of current, RMS value of current, ripple factor, the rectification efficiency

1. 

~~$V = iR$~~

~~$+1 - 100 \times 10^{-3} R = 0$~~

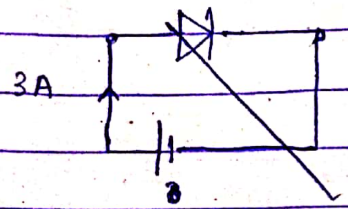
~~$1 = 10^{-1} R$~~

~~$R = 10\Omega$~~

5. A silicon diode dissipates ~~a~~ 3 watt for ~~for~~ DC current of 2A. Calculate the forward voltage drop across the diode & its bulk resistance.

5. # Bulk resistance = Resistance of P-type + Resistance of N-type

$R_B = R_P + R_N$.



~~$i^2 R = 3$~~

~~$4 \cdot R = 3$~~

~~$\boxed{R = 3/4}$~~

voltage drop across the diode

~~$= iR$~~

~~$= 2 \times \frac{3}{4} = \frac{3}{2}$~~

~~$= 1.5V$~~

Bulk resistance $= r_B = r_p + r_N$
Dynamic Resistance $=$ AC resistance $= r_B + r_j$

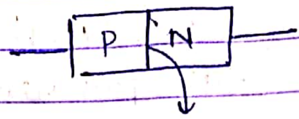
junction resistance

5. soln :

$P_d = V_F \cdot I_F$

$3 = V_F \cdot 2A$

$V_F = \frac{3}{2} V = 1.5V.$

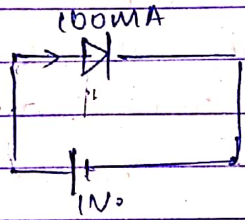


V_j = voltage drop across the diode-junction.

$$r_B = \frac{V_F - V_j}{I_F}$$

$$= \left(\frac{1.5 - 0.7}{2}\right)\Omega = 0.4\Omega.$$

1.



$$r_B = \frac{V_F - V_j}{I_F}$$

$$= \frac{1V - 0.7}{10^{-1}} = \frac{0.3}{0.1} = 3\Omega.$$

(i) Dynamic resistance $= r_B + r_j$

$$= 3\Omega + \frac{V_j}{i}$$

$$= 3\Omega + \frac{0.7}{100 \times 10^{-3}}$$

$$= 3\Omega + \frac{0.7}{10^{-1}}$$

$$= 3\Omega + \frac{0.7}{0.1} = 10\Omega$$

$$3\Omega + \frac{0.7}{0.1 \times 10^{-3}}$$

$$3\Omega + 7000\,\Omega$$

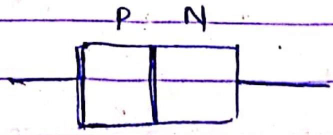
$$= 7003\Omega \times$$

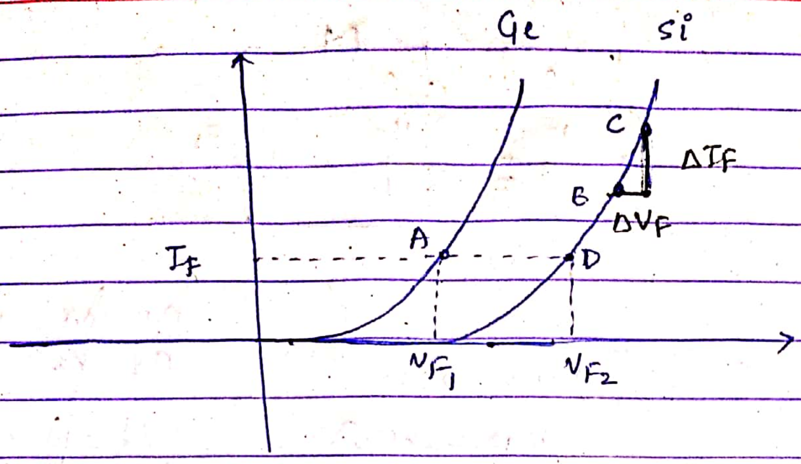
(ii) $r_D = r_B + r_j$

$$= 3\Omega + \frac{V_j}{25 \times 10^{-3}}$$

$$3\Omega + \frac{0.700}{0.025}$$

$$3\Omega + \frac{700}{25} \; 28 = 31\Omega \times$$





static resistance $= R_F = \frac{V_{F_1}}{I_F}$ (for Ge)

$= \frac{V_{F_2}}{I_F}$ (for Si)

But dynamic resistance $= \frac{\Delta V_F}{\Delta I_F} = r_{ac}$

$\cancel{i = i_0 e^{hv/KT} - 1}$

2. $V_F = 1.2V$

$I_F = 100mA$

$r_B = \frac{V_F - V_j}{I_F} = \frac{1.2 - 0.7}{100 \times 10^{-3}} = \frac{0.5}{0.1} = 5\Omega$

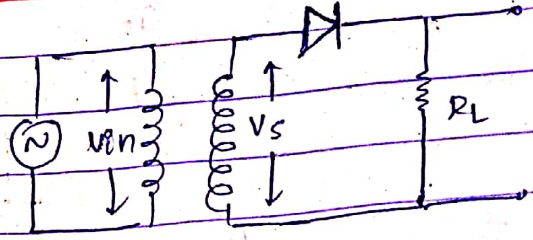
$r_B = 5\Omega$

$r_N = \frac{10}{10^{-6}} = 10^7 \Omega = 10 M\Omega$

8

3. Given: $\frac{n_1}{n_2} = \frac{12}{1}$

AC 220V, 50Hz



$V_{dc} = \frac{V_m}{\pi}$

$V_{rms} = 220$

$V_p = 220\sqrt{2}$

$= 311.08$

$(V_{in} = V_p \sin\omega t)$

$V_{dc} = \frac{220\sqrt{2}}{\pi}$

$V_m = \frac{311.08}{12}$

$V_m = 25.92V$

$(V_s = V_m \sin\omega t)$

$\frac{n_1}{n_2} = \frac{V_1}{V_2} = \frac{V_{in}}{V_s}$

$\frac{12}{1} = \frac{V_{in}}{V_s}$

$V_s = \frac{V_{in}}{12}$

$V_s = \frac{220\sqrt{2}}{12}$

$\frac{n_1}{n_2} = \frac{V_{in}}{V_s}$

$V_s = \frac{n_2}{n_1} \cdot V_{in} = \frac{1}{12} \cdot (V_P) = \frac{1}{12} \cdot (220\sqrt{2})$

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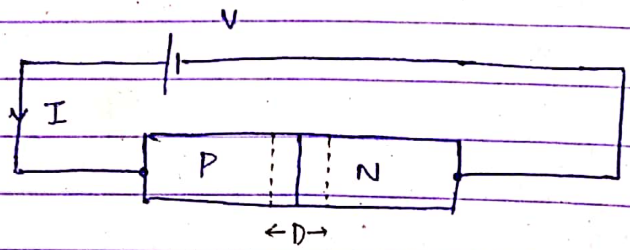


$I = \cancel{I_0[(\exp)]} \; I_0\left[e^{\frac{eV}{\eta K_B T}} - 1\right]$ — (A)

↓

Total current flowing through the device

I_0 : Reverse saturation current

η : Ideality factor — $\eta = 1$ (for Ge), $\eta = 2$ (for Si)

K_B : Boltzman constant

V : Applied voltage

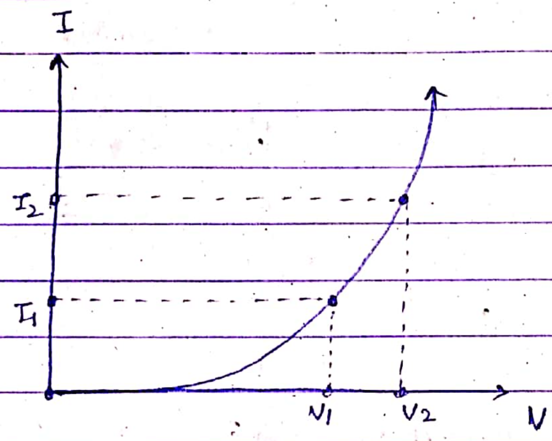
Equation 'A' can be written as:

$$I = I_0\left[e^{\frac{V}{\eta V_T}} - 1\right]$$; V_T = volt-equivalent temperature $= \frac{K_B \cdot T}{e}$

$$V_T = \frac{T}{11,600}$$

& at room temp; (300K)

$$\boxed{V_T = 0{\cdot}026V = 26mV.}$$



$$r_{ac} = \frac{dV}{dI}$$

finding $\frac{dI}{dV}$,

$$I = I_0 e^{\frac{V}{\eta V_T}} - I_0$$

$$\frac{dI}{dV} = \frac{I_0 \cdot e^{V/\eta V_T}}{\eta V_T}$$

$$\therefore \frac{dI}{dV} = \frac{I_0 e^{\frac{V}{\eta V_T}}}{\eta V_T}$$

$$\boxed{\therefore \frac{dV}{dI} = \frac{\eta V_T}{I_0} \cdot e^{-\frac{V}{\eta V_T}}}$$

from,

$$I = I_0 e^{\frac{V}{\eta V_T}} - I_0$$

$$\Rightarrow I + I_0 = I_0 e^{V/\eta V_T}$$

$$\therefore \cancel{dV}\ \frac{dI}{dV} = \frac{I + I_0}{\eta V_T}$$

$\because$ Reverse saturation current, 'I_0', is very small,

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$\therefore \frac{dI}{dV} = \frac{I}{\eta V_T}$.

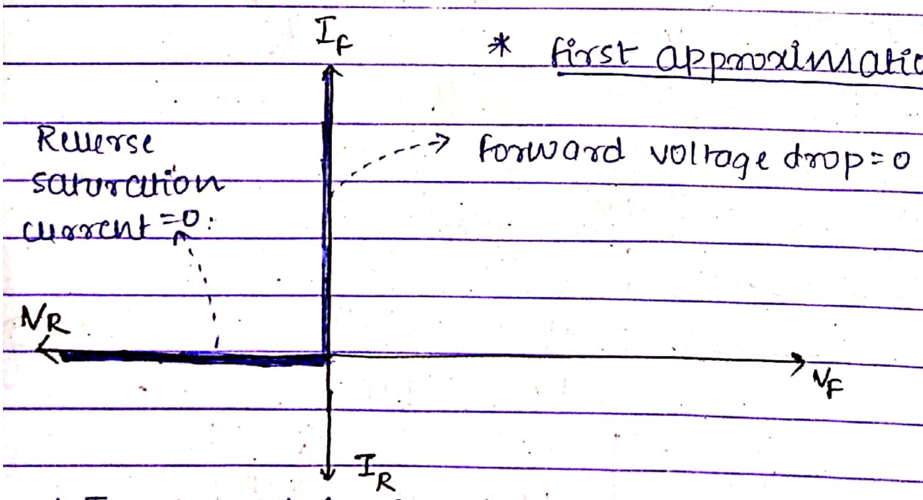
$$\boxed{\therefore r_{ac} = \frac{dV}{dI} = \frac{\eta V_T}{I}.}$$

$\therefore$ r_{ac} (Dynamic resistance)

Ge	Si
$\eta = 1$	$\eta = 2$
$\therefore r_{ac} = \frac{26\,mV}{I}$	$\therefore r_{ac} = \frac{26\,mV \times 2}{I}$
$\boxed{r_{ac} = \frac{26\,mV}{I}}$	$\boxed{r_{ac} = \frac{52\,mV}{I}}$

I.V. characteristic of ideal diode :

* First approximation :



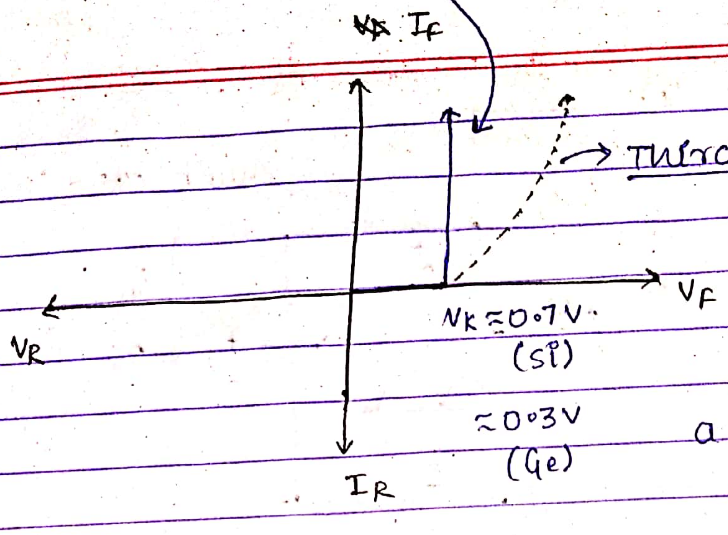
* I_0 should be 0.

* Vknee should be 0.

* for forward bias, diode is like short circuit.

* for reversed bias, diode is like open circuit.

* second approximation: At least a forward voltage drop of 0.7V.

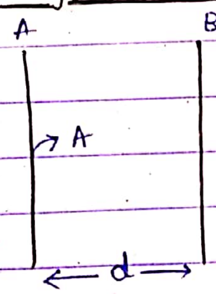


Third approximation:

$V_F = 0.7V + I_F r_B$

Bulk resistance is a material property.

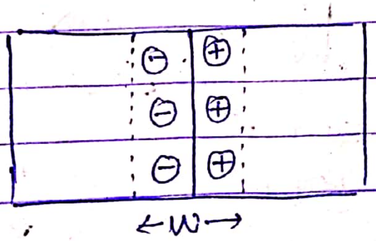
Diode-capacitance:



$$C = \frac{A\epsilon}{d}$$

C_D: Diffusion capacitance:

Due to high concentration of carriers, depletion region width decreases in forward bias condition.



C_T: Transition capacitance:

when reversed bias, transition capacitance develops as width of depletion zone increases.

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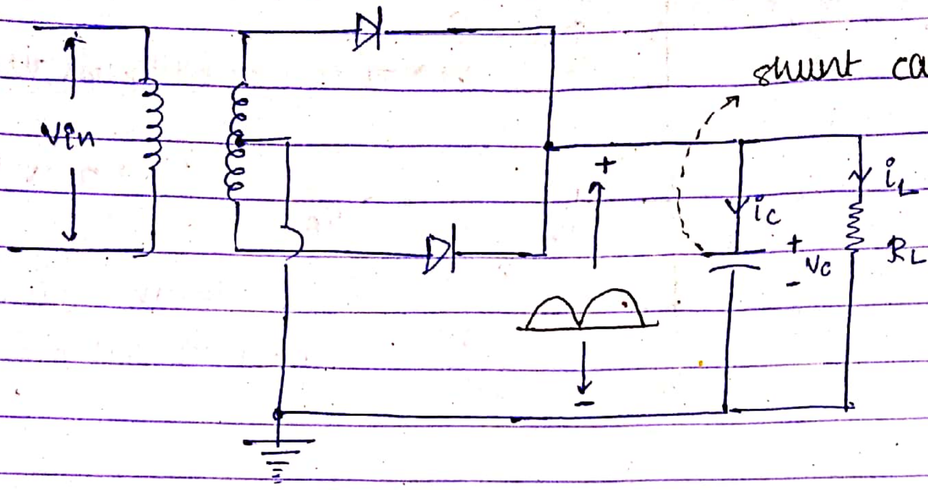
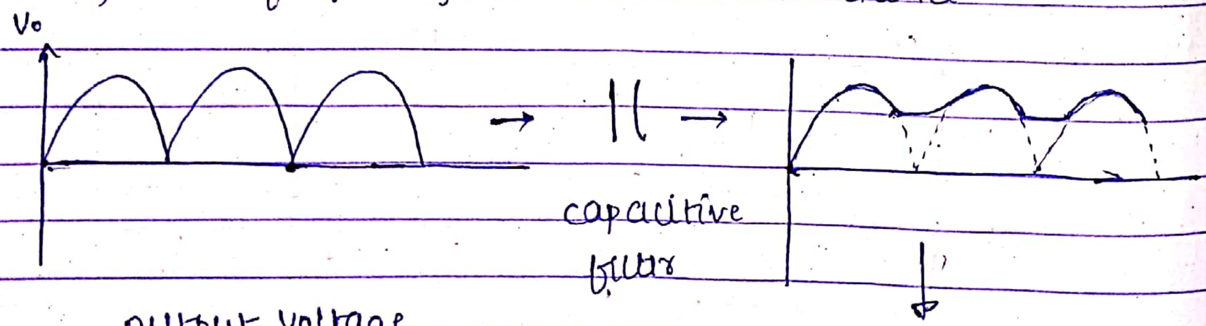


X_c (reactance) $= \frac{1}{2\pi f c}$.

for DC, $f=0$, ∴ reactance $\rightarrow \infty$.

→ capacitor acts as a 'filter' because it does'nt allow DC voltage (∵ $f_{DC}=0$) and hence allows AC voltage, ∵ for AC some frequency is defined.

→ Higher the frequency, lower will be reactance.



output voltage

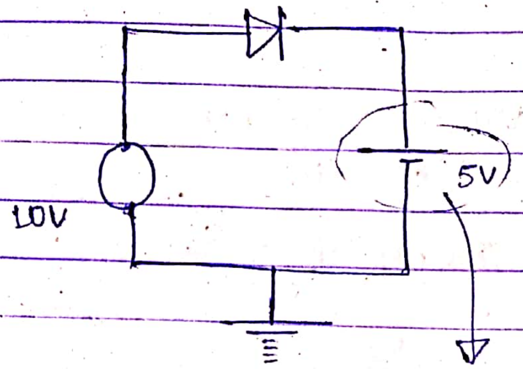
$$\boxed{r = \frac{1}{4\sqrt{3} f R_L C}}$$

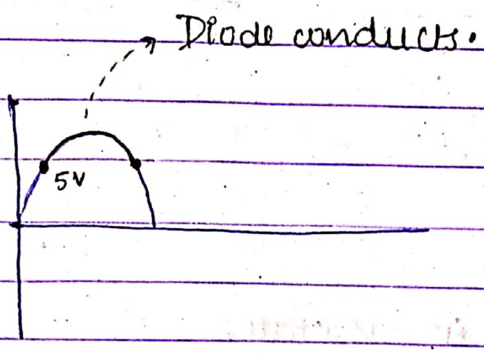
ripple factor (when capacitor is in parallel).

$$r = \frac{V_{rms,ac}}{V_{dc}}.$$

$V_{rms,ac} = r \cdot V_{dc}$

$$\boxed{V_{rms,ac} = \frac{V_{dc}}{4\sqrt{3} f R_L C}}$$





This is what the capacitor behaves like.

voltage (output) can vary due to:
(i) change in load resistance
(ii) fluctuation in input voltage
(iii) temperature change.

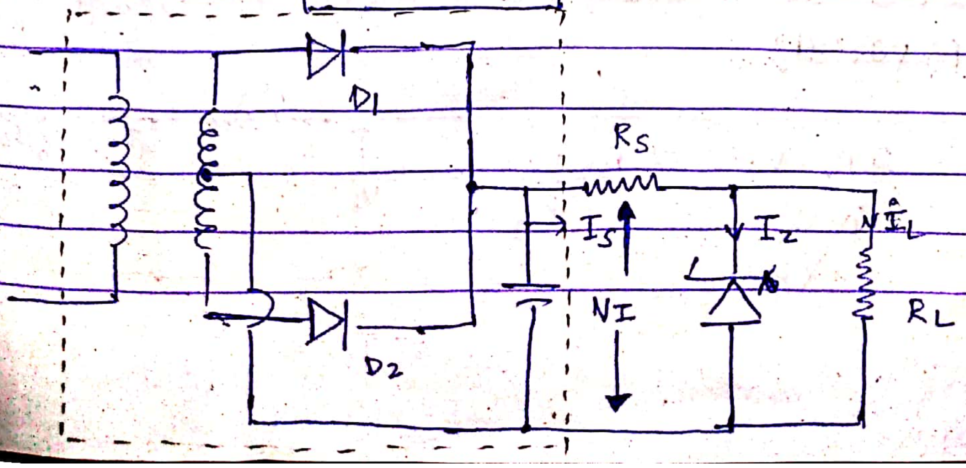
Voltage Regulation:

$$\frac{V_{NL} - V_{FL}}{V_{FL}} \times 100 \ \%$$

; V_{NL} : No Load voltage
; V_{FL} : Full load voltage.

For Ideal power supply, voltage regulation should be 0.

$$\boxed{\therefore V_{NL} = V_{FL}}$$



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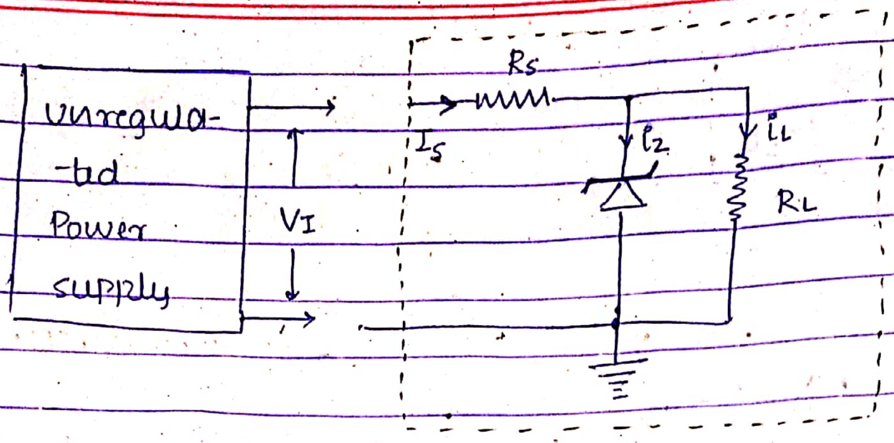
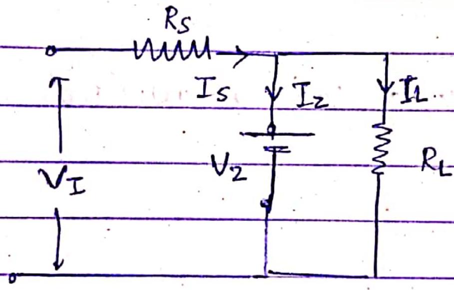
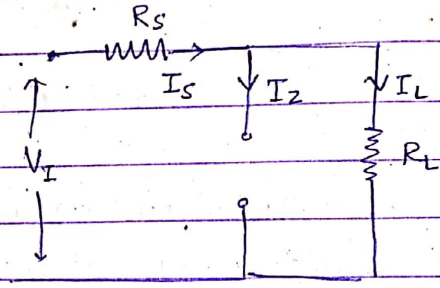


Voltage Regulator circuitory

When in on state, In off state,





$I_S = I_Z + I_L$; $V_L = I_L R_L = \frac{V_I \cdot R_L}{R_S + R_L}$

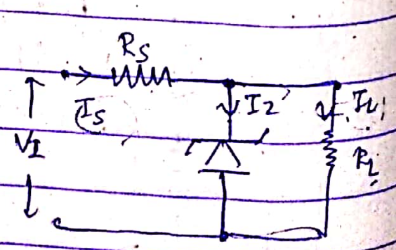
Principle :- The load is connected in parallel with the zener diode, the voltage across the load will be V_Z (breakdown voltage) when zener diode is in on state.

The zener diode is in on state only when $I_L R_L$ is at least V_Z.

How does the circuit maintain a constant voltage V_Z when load resistance is varied?

$I_L R_L = V_Z$ $\Rightarrow$ $I_L = \frac{V_Z}{R_L}$

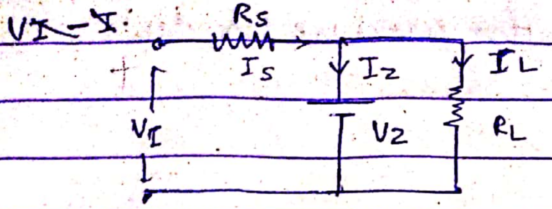
$\cancel{I_L = \frac{V_Z}{R_L}}$



$I_S = I_Z + I_L$

$I_L R_L = V_Z$

V-I:



$V_I - I_S R_S - V_Z = 0$

$-I_L R_L + V_Z = 0$

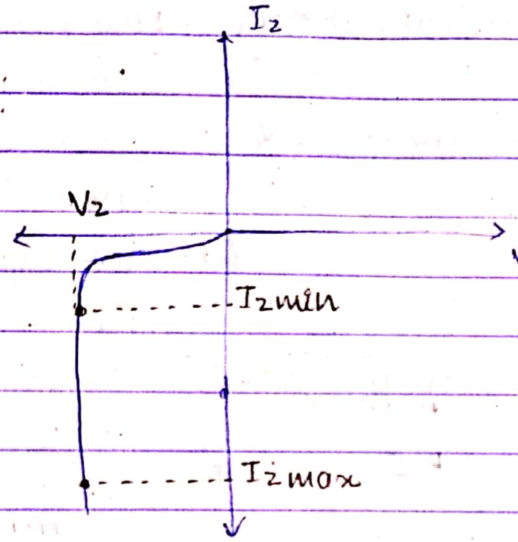
$\Rightarrow V_Z = I_L R_L$ — (1)

$V_I - (I_Z + I_L) R_S - V_Z = 0$

$V_I - I_Z R_S - I_L R_S - V_Z = 0$

$V_I - (I_Z + I_L) R_S - I_L R_L$

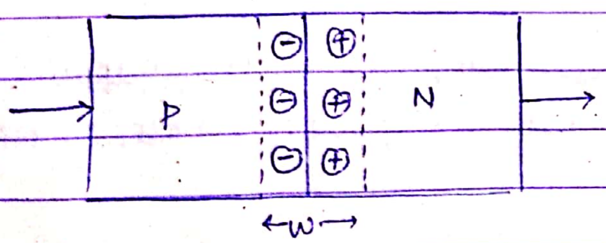
$V_I = (I_Z + I_L) R_S + I_L R_L$

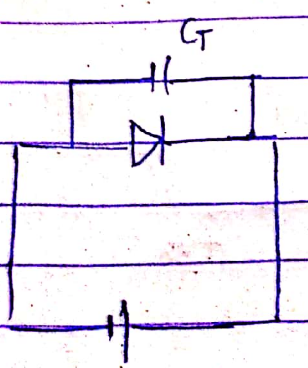


On changing R_L, the zener current changes. The maximum possible zener current is I_{Zmax}.

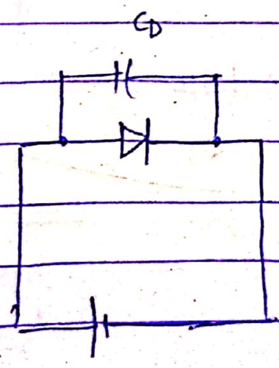
Capacitance:

value of diffusion capacitance >> transition capacitance.





Reversed Bias



Forward Bias

Generally, $C_T << C_D$: Reason being the increase in depletion region.

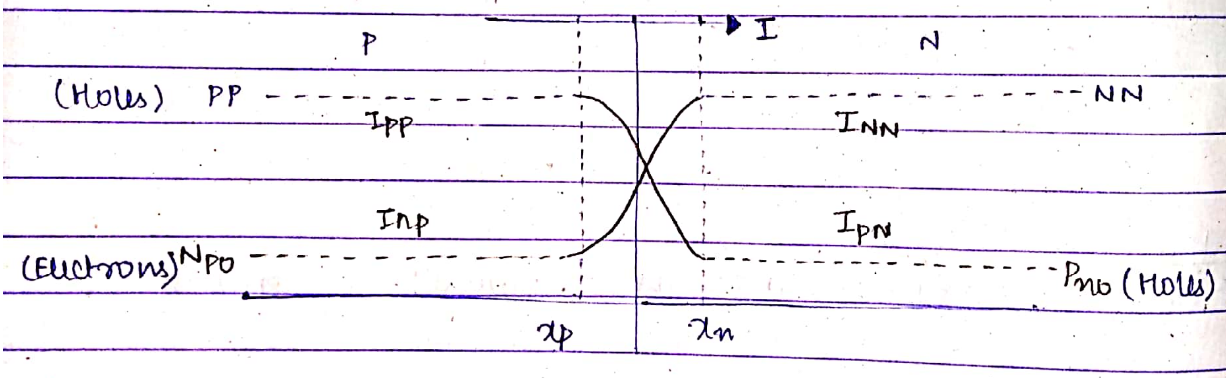
And capacitance $= C = \frac{A\epsilon}{W}$

$$C_D = \frac{\tau \cdot I}{\eta V_T} \quad \{ C_D \propto I \}$$

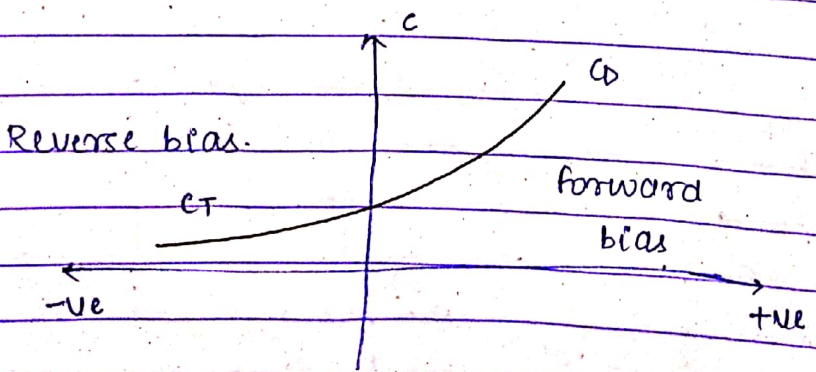
$$C_D = \frac{dq}{dV} \quad \text{(incremental capacitance)}$$

concentration of minority carriers $\propto \frac{1}{\text{distance}}$ (from the junction)

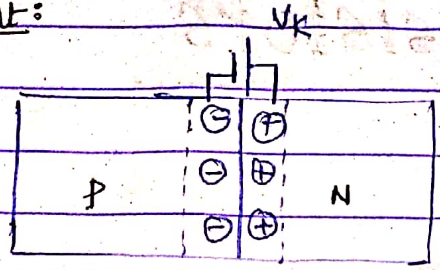
Concentration profile:



To maintain a constant current, the battery supplies charges (forward bias) because in forward bias, electrons & holes recombine.



Drift current:



$$\underbrace{\text{Diffusion current}}_{\substack{P \to N \\ \text{due to majority charge carriers}}} + \underbrace{\text{drift current}}_{\substack{N \to P \\ \text{due to minority carriers}}} = 0 \quad (\because \text{both are in opposite direction})$$

Due to thermal energy, some covalent bonds break and holes & electrons are created. The flow of these minority carriers gives rise to drift current in a direction opposite to diffusion current i.e. drift current is from N→P & diffusion current from P→N.