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⇒ Semiconductors :-

Electronic circuit - Flow of charge ~~in~~ carrier either in semiconductor or in vaccume.

Electrical circuit - Flow of electrons in a conductor.

Q) Why Si & Ge ~~show~~ ~~property~~ ~~of~~ are semiconductors ?

Ans) ~~As they have weak lattice structure~~
The energy gap in Ge & Si are of the order of 1eV. Electrons can be easily excited from valence band to the conduction band to enable them to conduct electricity.

⇒ Extrinsic semiconductors - Semiconductors that are doped with specific impurities.

P type - (P for Positive) - majority charge carrier are holes (+ve charge carrier)
↳ Doping of trivalent elements take place
Eg - B, In etc.

n type - (n for negative) - majority charge carrier are ~~holes~~ electrons.
↳ Doping of pentavalent elements take place
Eg - P, Sb etc.

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- We can know how much charge carrier we have doped with measurement of time as we generally know the rate at which we are injecting the impurity.

⇒ Formation of p-n junction.

⇒ n- type semiconductors :-

When an atom of +5 valency element occupies the position of an atom in the crystal lattice of Si, four of its e^- bond with the four silicon neighbours while the fifth remains very weakly bound to its parent atom. This is because the four electrons participating in bonding are seen as part of the effective core of the atom by the 5th e^-. As a result the IE req. to set this e^- free is very small & even at room temp. it will be free to move in the lattice of semiconductors. Thus, the pentavalent is donating one extra electron for conduction & hence is known as donor impurity.

n_e – no. of conduction $e^{\ominus}$
n_h – no. of holes.

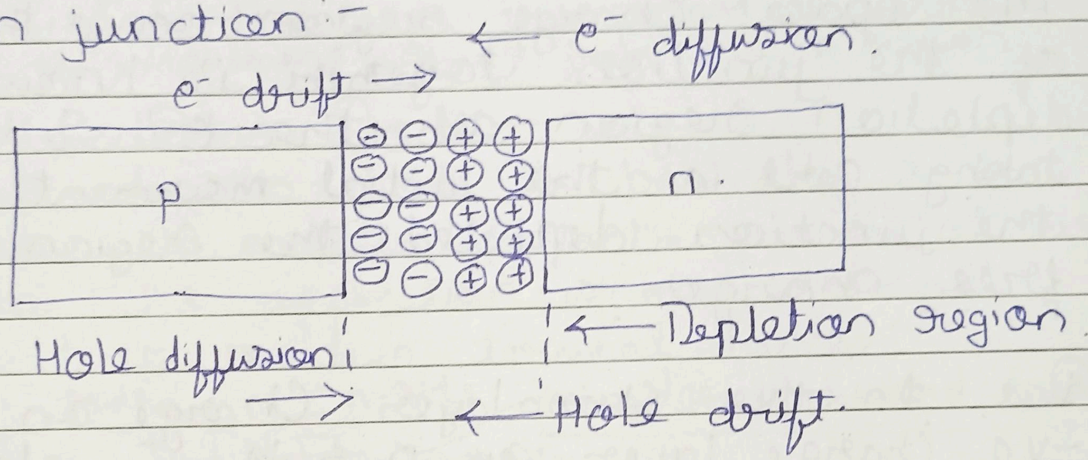
$$n_e >> n_h$$

⇒ p-type – trivalent foreign atom becomes effectively negatively charged when it shares fourth $e^{\ominus}$ with neighbouring Si atom.

$$n_h >> n_e.$$

$$n_e n_h = \underbrace{(n_i)^2}_{}$$ intrinsic concentration of $e^{\ominus}$

⇒ p-n junction :-



~~We Know~~ Consider a p-type Si wafer. By adding precisely a small quantity of pentavalent impurity, part of p-Si wafer can be converted into n-Si. The wafer now contains p-regions & n-regions. & a metallurgical junction b/w p-, and n-~~rg~~ region.

~~Due~~ Holes diffuse from p-side to n-side (p→n) and e^- diffuse from n-side to p-side (n→p). This motion of Charge carriers gives rise to diffusion current accross the junction.

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When an e^- diffuses from $n \rightarrow p$, it leaves behind an ionised doner on n-side. This ionised donor (+ve charge) is immobile as it is bonded to the surrounding atoms. As the e^- continue to diffuse from $n \rightarrow p$, a layer of positive charge on n-side of the junction is developed.

The space-charge region on either sides of the junction together is known as depletion region as the $e^{\ominus}$ & holes taking part in the initial movement across the junction depleted the region of its free charges.

Due to +ve ~~Charo~~ layer charge on n side & -ve charge layer on p side an electric field is developed. And due to this field e^- on p-side where they are minority charge carrier are ~~pu~~ drifted to n side this motion is called drift. Thus a drift current, which is opposite in direction to the diffusion current.

Initially, diffusion current is large & drift current is small. As the diffusion process continues, the space-charge regions on either side of the junction extend, thus increasing the electric field strength & hence drift current. This process continues until the ~~difuss~~ diffusion current equals the drift current. Thus a p-n junction is formed.

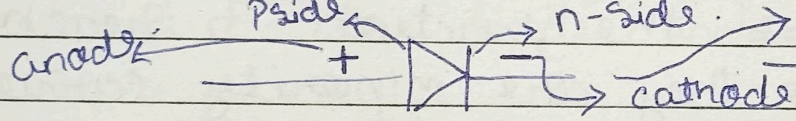
into the p region, it is often called a barrier Potential.

- In a p-n junction under Equilibrium there is no net current.

- The loss of $e^{\ominus}$ from the n-region (n material is thus positive relative to the p material) & the gain of $e^{\ominus}$ by the p-region causes a difference of potential across the junction of the two regions. ~~known as barrier~~ potential. Since this potential tends to Prevent the movement of $e^{\ominus}$ from the n region

⇒ Semiconductor Diode -

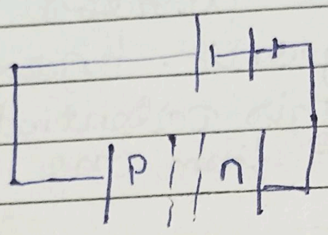
- A Semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. It is a two terminal device.

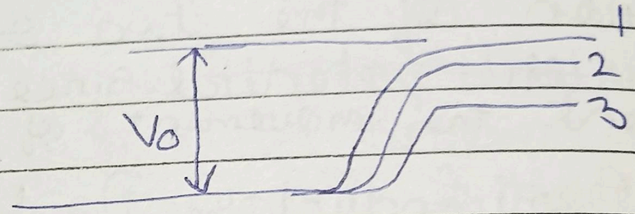


- The direction of arrow indicates the conventional direction of current (when diode is in forward bias (~~+ve terminal connected to +ve & of~~ barrier potential is connected to ~~+ve terminal of ex supplied voltage~~).

↳ p-n junction diode under forward bias:-
: P-side is connected to the +ve terminal of the battery.
The applied Voltage mostly drops across the depletion region & the voltage drop across the p-side & n-side of the junction is negligible. (This is because the resistance of the depletion region - a region where there are no charges - is very high compared to the resistance of n-side

and p-side.) The direction of the applied voltage (V) is opposite to the built-in potential V_0. As a result, the depletion layer width decreases and the barrier height is reduced. The effective barrier height under forward bias is $(V_0 - V)$.





- Due to the applied voltage, $e^{\ominus}$ from n-side cross the depletion region and reach p-side (where they are minority carriers.) Similarly, holes from p-side cross the junction & reach the n-side (where they are minority carriers)

- Due to this concentration gradient, the injected $e^{\ominus}$ on p-side diffuse from the junction edge of p-side to the other end of p-side. Likewise, the injected holes on n-side diffuse from the junction edge of n-side to other end of n-side.

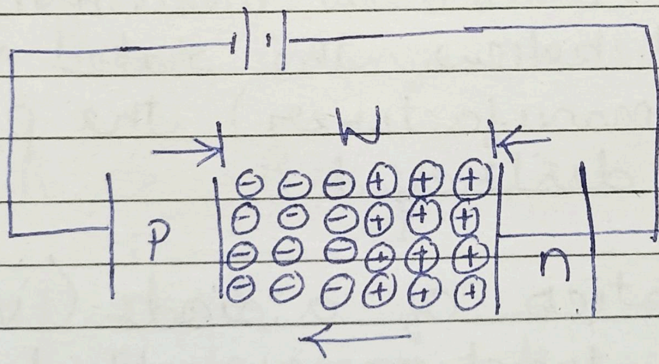
- This motion of charged carriers on either side gives rise to current. The total diode forward current is sum of hole diffusion current and conventional current due to e^- diffusion. The magnitude of this current is usually in mA.

reverse
→ p-n junction diode under forward bias—

- When External voltage V is applied & +ve terminal of External voltage is connected to n-side of p-n junction then it is said to be in reverse bias.

- The direction of applied voltage is same as the direction of barrier potential. As a result, the barrier height increases and the depletion region widens due to change in the Electric field. The effective barrier height under reverse bias is $(V_0 + V)$, This suppresses the flow of e^- from $n \to p$ & holes from $p \to n$

- Thus, diffusion current decreases enormously compared to the diode under forward bias.



- The electric field direction of the junction is such that if e^- on p-side or holes on n-side in their random motion come close to the junction, they will be swept to its majority zone. This drift of carriers gives rise to current. The drift current is of the order of few µA. This is quite low because it is due to the motion of carriers from their minority side to their majority side across the junction.

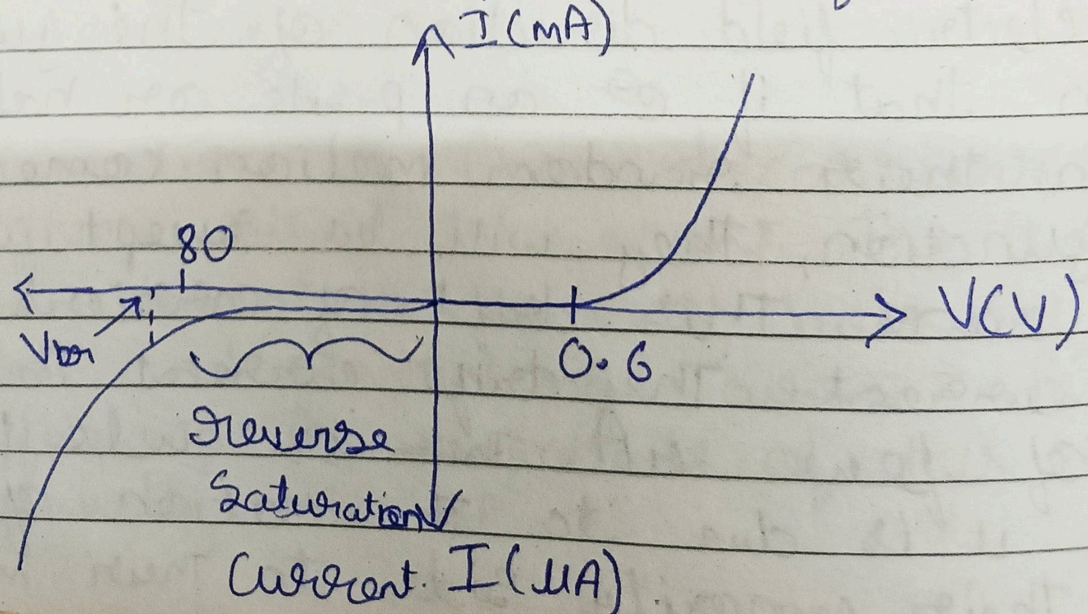
- The diode reverse current is not very much dependent on the applied voltage.

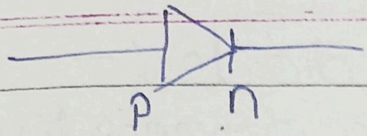
- The current is not limited by the magnitude of the applied voltage but is limited due to the concentration of the minority carrier on either side of junction.

- The current under reverse bias is essentially voltage independent upto a critical reverse bias voltage, known as breakdown voltage (V_{br}). When $V = V_{br}$, the diode reverse current increases sharply.

* If the reverse current is not limited by an external circuit below the rated value (specified by the manufacturer) the p-n junction will get destroyed.

→ V-I Characteristics of a diode (variation of current as a function of applied voltage)





* ~~Aft~~ In forward bias, after the Characteristic voltage, the diode current increases significantly (Exponentially), ~~even~~ This voltage is called the threshold voltage or cut-in voltage.

- p-n junction diode primerly allows the flow of current only in one direction (forward bias). The forward bias resistance is low as compared to reverse bias resistance.

$$r_d = \frac{\Delta V}{\Delta I}$$

where

$r_d \Rightarrow$ dynamic resistance for diode.

ΔV - Small change in voltage.

$$V = IR \Rightarrow R = \frac{V}{I}.$$

⇒ Ideal diode –

An ideal diode has the same Characteristics curve as an ideal switch, which conducts when applied potential and is open-circuited (i.e $I = 0$) when there is no supply. This means that the ideal diode offers zero resistance in forward bias & ∞ (infinite) resistance in reverse bias.

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In forward bias ideal diode :-
└ In forward bias ideal diode :- It will have following properties - ~~Zer~~ zero resistance , Infinite amount of current & zero threshold Voltage.

└ Ideal diode When reverse biased - It offers characteristictics such as infinite resistance, zero reverse leakage current & no reverse breakdown.

⇒ linear System :- graph Straight line hona Chaiye aur origin se start hona chaiye -

└ A linear system follows the laws of superposition. Apart from this system is a combination of two types of laws -

① Law of additivity ② Law of homogeneity
$$y(\alpha x) = \alpha y(x).$$

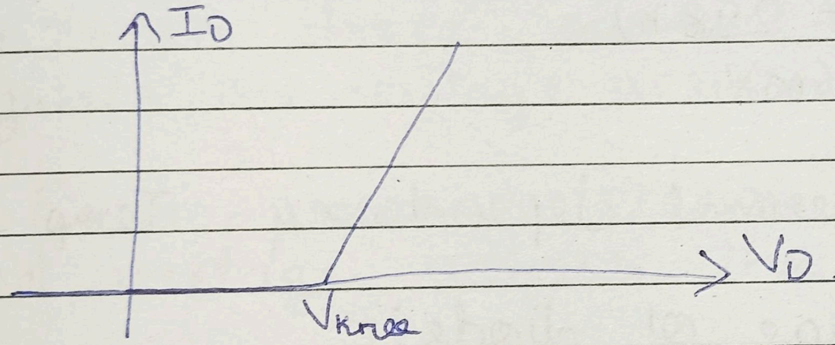
└ Also system should follow -
└ The output should be zero for zero input
└ There should not be any non linear operator present in system.
Eg of Non-linear operator →
a) Trignometric operator ⓑ Exponential, log & Mod, Sq, Cube Etc.

Resistance, Capacitance & Inductance is Eg of linear System.

↳ Diode is a unilateral device because if we Change the polarity of of applied voltage it's behaviour is also changed.

↳ Practical diode is non-linear system, and the methods we know to solve circuits are for linear system (i.e KVL, KCL etc) So we have th modify the diode so we can solve it.

⇒ Piece-wise linear Model :-



In practical diode system is non-linear as it's V-I graph is increases exponentially i.e it's resistance is variable. So to make it linear we take an approximation, in which we will take a range of resistance & then we find it's mean, which will be constant hence a linear system.

:- I_d = diode current {capital I → static current.

I means supply is DC. small i → dynamic current}.

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$$I_d = I_s \left(e^{\frac{V_D}{\eta V_T}} - 1 \right)$$

Where: I_d = diode current.
I_s = Reverse/leakage saturation current
η = ideality factor — by default $\eta = 1$

V_D = diode voltage ; V_T = Thermal Voltage.

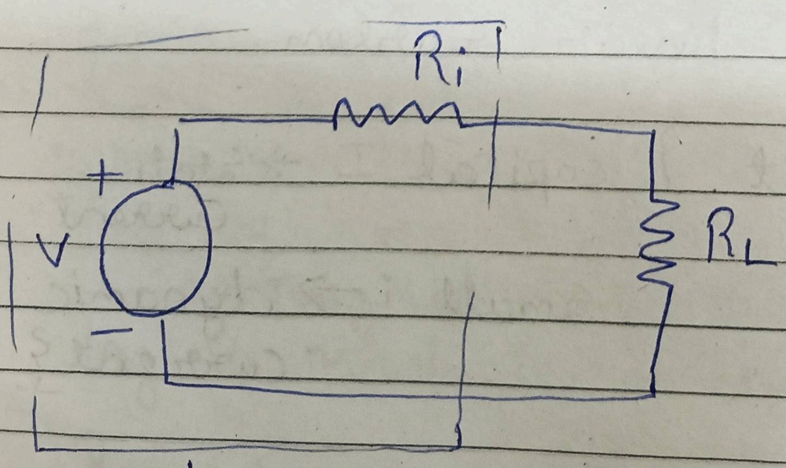
$V_T = \frac{KT}{q}$ { K → boltzman constant. 1.38×10^{-23} J/K.
T → temp. $q - 1.6 \times 10^{-19}$ C }

at R.T ($T = 298$ K)
$V_T = 26$ mV.

V_T → Tells thermal dependency, Temp

→ Different type of diode:—

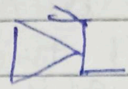
① Zener diode —
high no. of Charge carrier — Zener breakdown is caused due to,



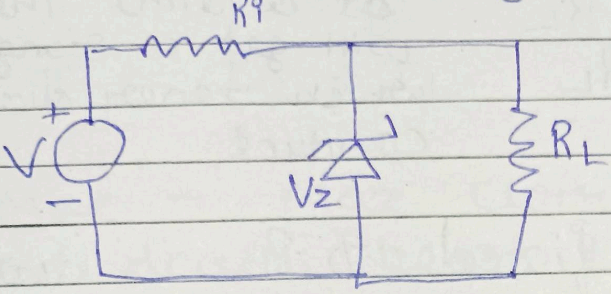
n no. of sources
& no. of resistance

↳ It represents
a circuits which may contain ↑

Voltage regulator - Zener diode (in reverse bias)



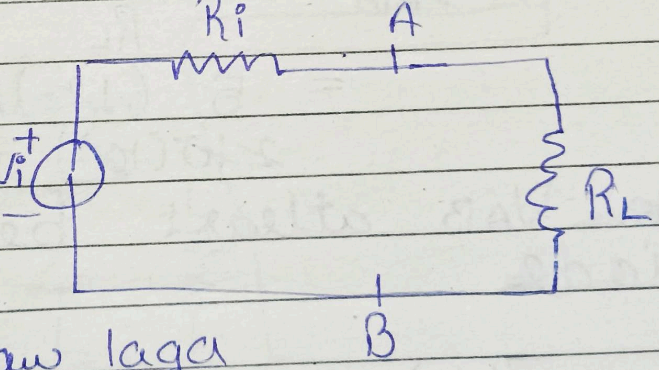
Vz - Zener* voltage | reverse breakdown



Q) All the parameters are constant, will ~~zie~~ Zener diode ~~conduct~~ be able to regulate the voltage across the load.

L First remove zener diode & find voltage across the load.

$$V_{AB} = \frac{V \times R_L}{R_i + R_L}$$



(Series mai voltage → KVL & Ohm law laga ke VAB nikal sakte hai).

> Zener diode will conduct if & only if $V_{AB} \geq V_Z$.

~~for~~ This was case 1 - R_L & Vi was fixed

Zener diode tabhi conduct karega voltage

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Potential drop across it is greater than breakdown Voltage / zener voltage

In the above case all the parameters were constant Now if Vi & R_L will be variable at one at a time Then we will get a range at which zener diode will conduct.

↳ $V_{AB} = \frac{V_i \times R_L}{R_i + R_L}$

* Case 2 – Vi is fixed & R_L is variable

* case 3 – Vi is Variable & R_L is fixed

Case 3 – ~~for~~ So Vi will come in Range

for $(V_i)_{min}$: ~~VAB~~ we know to conduct

$V_{AB} \geq V_Z$

So for min VAB

$V_{AB} = V_Z$

$\Rightarrow V_{AB} = \underline{(V_{AB})_{min}}$

$$\boxed{(V_i)_{min} = \frac{V_Z (R_i + R_L)}{R_L}}$$

$$= \frac{5 (\cancel{12}) 10^3 \; 6}{\cancel{2} \cancel{10} (10^3)}$$

As VAB atleast be V_Z so to conduct diode

for $(V_i)_{max}$:–

let say V_i' is greater than $(V_i)_{min}$

$$\boxed{V_Z = V_{R_L} = I_L R_L}$$

Kyonki diode conduct kar raha hai toh ~~load ke across~~ Voltage regulate karega.

V_{R_L} toh V_Z he rahega as zener diode is conducting as V_i' is $> V_{i\,min}$

very imp. topic.

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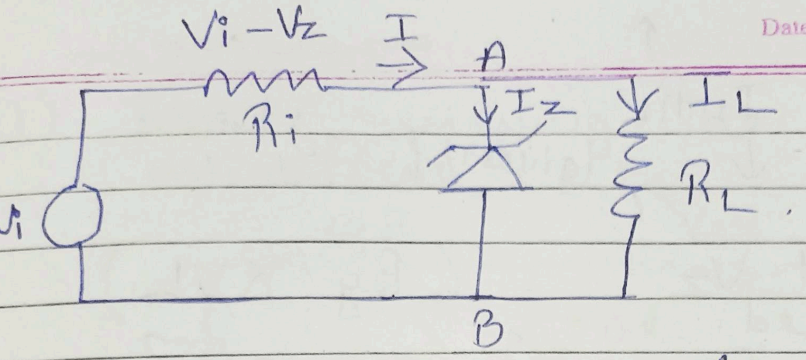


$$I = I_Z + I_L. \quad (KCL)$$

$(I_Z)_{max}$ – max current that zener diode can bear. {device specific}.

So $I_{max} = (I_Z)_{max} + I_L$

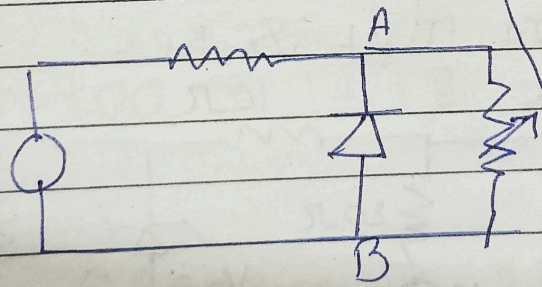
I_L toh constant hai isliye jab I_Z ki value max hogi tabhi I bhi max hoga.

(KVL) $V_i = V_Z + V_{Ri}$

$(V_i)_{max} = V_Z + V_{Ri(max)}$

$$\boxed{(V_i)_{max} = V_Z + ((I_Z)_{max} + I_L)R_i}$$

case-2 :- Variable load.



$$V_{AB} = \frac{V_i \times R_L}{R_i + R_L} \Rightarrow V_Z = \frac{V_i \times (R_L)_{min}}{R_i + (R_L)_{min}}.$$

$R_i V_Z + V_Z (R_L)_{min} = R_{L\,min} V_i$.

$$\boxed{\frac{(R_i) V_Z}{V_i - V_Z} = R_{L\,min}}$$

So it will be fixed. Samfoundary

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$V_{R_L} = V_Z = I_L R_L$ (given) fixed.

$\underbrace{V_i}_{\text{fixed (given)}} = \underbrace{V_{R_i}}_{\text{fixed}} + V_Z$ (By KVL)

$\underbrace{I}_{\text{fixed}} = I_Z + I_L$. $\{\because V_i = R_i I\}$ (By KCL)

So (I_Z) can go upto $(I_Z)_{max}$ & as $I_Z \uparrow$, I_L will $\downarrow$.

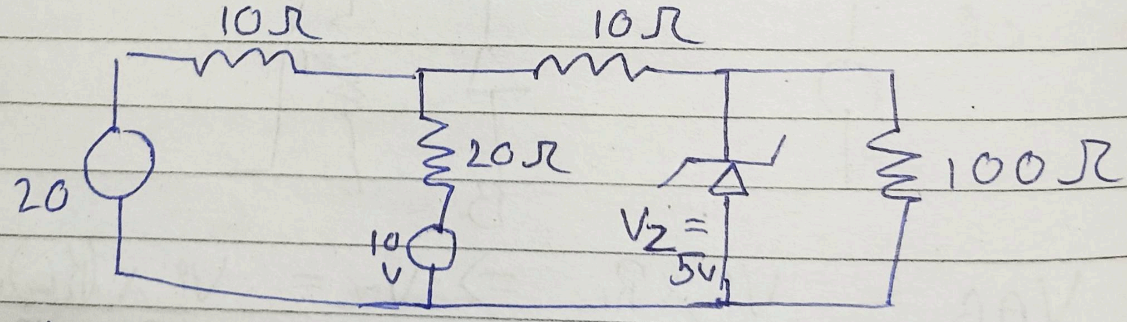
$$R_L = \frac{V_Z}{(I_L)_{min}}$$

$$\boxed{(R_L)_{max} = \frac{V_Z}{I - (I_Z)_{max}}}$$

Zener mai thaivanize circuit rahega.

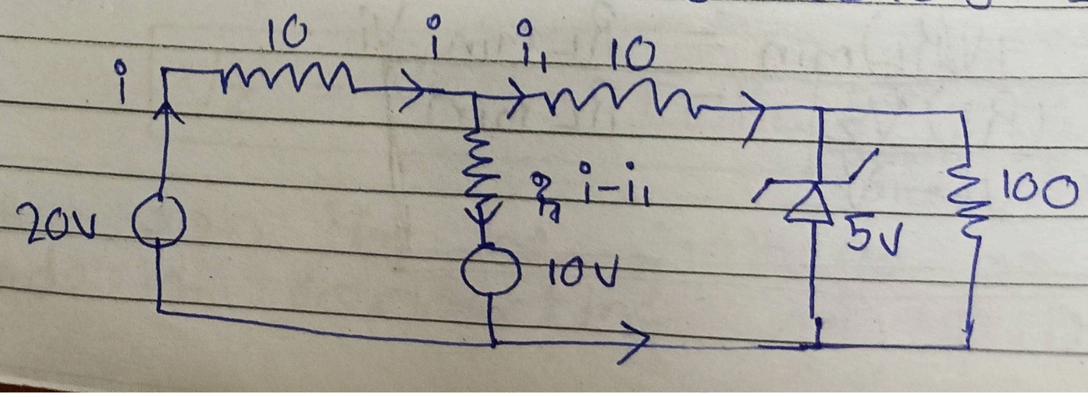
Phele V_{AB} open circuit voltage nikalna hai with KVL, & KCL.

Q1)



what is V ~~across~~ across Load.

Sol)



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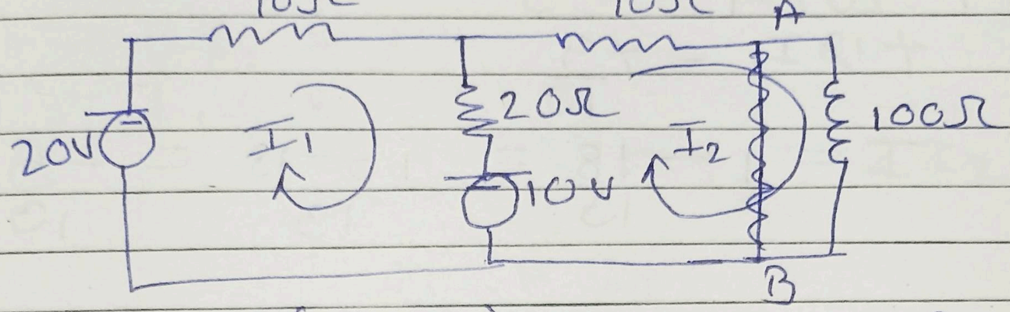
Sol) First removing the diode for calculations –



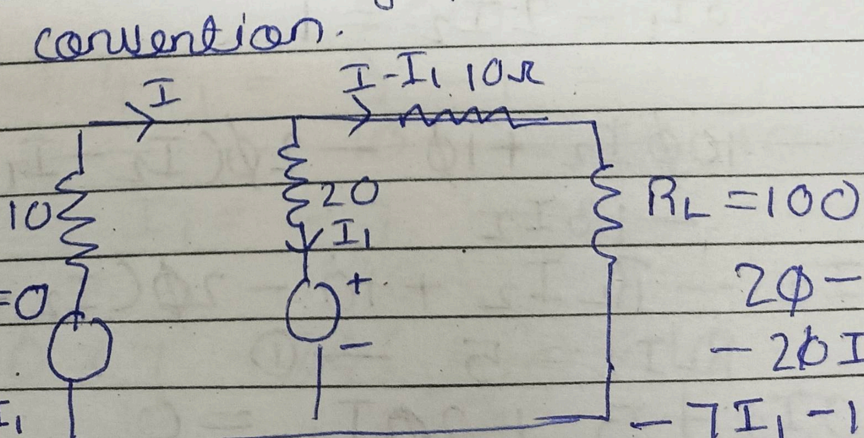
$$-10I_1 - 20(I_1 - I_2) - 10 + 20 = 0$$
$$-3\cancel{0}I_1 + 2\cancel{0}I_2 = -1\cancel{0}$$
$$2(\; 3I_1 - 2I_2 = 1 \quad —①$$

$$-10I_2 - 100I_2 + 10 - 20(I_2 - I_1) = 0$$
$$-13\cancel{0}I_2 + 2\cancel{0}I_1 = -1\cancel{0}$$

$$3(-2I_1 + 13I_2 = 1$$
$$-6I_1 + 39I_2 = 3$$
$$6I_1 - 4I_2 = 2$$
$$\overline{\quad 7 \cancel{35}I_2 = \cancel{5}}$$
$$I_2 = 1/7$$
$$V_{AB} = \frac{100}{7} \simeq 14.18 \Rightarrow V_{AB} > V_Z$$

So diode will conduct.

Sir) Rules – ① Starting pt ek lena hai.
② Sign convention.



$-1\cancel{0}(I-I_1)$
$-10\cancel{0}(I-I_1)$
$+1\cancel{0} + 2\cancel{0}I_1 = 0$
$2I_1 + 1 - 10I$
$-10I_1 - I + I_1$

$2\cancel{0} - 1\cancel{0}I$
$-2\cancel{0}I_1 - 1\cancel{0} = 0$
$-7I_1 - 10I = -1$

$I + 2I_1 = 1$ $\qquad$ $7I_1 + 10I = 1$

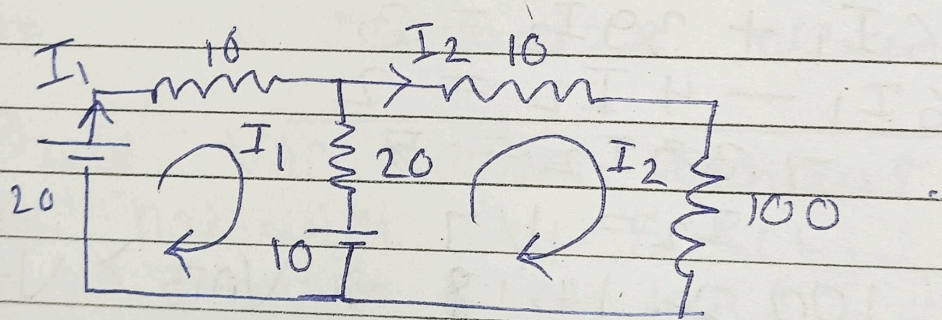
$$7I_1 + 10I = 1$$
$$-10(I + 2I_1 = 1)$$
$$(7-20)I_1 = -9$$
$$+13I_1 = +9 \Rightarrow I_1 = \frac{9}{13}$$

$$I = 1 - \frac{18}{13} = \frac{13-18}{13} = \frac{-5}{13}$$

$$\frac{-5}{13} - \frac{9}{13} = \frac{-14}{13}$$

— for same value of V_Z, if R_L is variable find $(R_L)_{min}$.

$$(R_L)_{min} = \frac{R_i V_Z}{V_i - V_Z}$$



$$-1\cancel{0}I_1 - 2\cancel{0}(I_1 - I_2) - 1\cancel{0} + 2\cancel{0} = 0$$
$$-3I_1 + 2I_2 = -1$$
$$3I_1 - 2I_2 = 1$$

$$\cancel{-10I_2 - 100I_2 + 10 - 20(I_2 - I_1) = 0}$$
$$\cancel{-13I_2}$$
$$-10I_2 - R_L I_2 + 10 - 2\cancel{0}(I_2 - I_1) = 0$$
$$R_L I_2 = 5 \quad \text{— (1)}$$
$$-30I_2 + 5 + 2\cancel{0}I_1 = 0$$
$$-6I_2 + 4I_1 + 1 = 0$$

~~For~~ ~~DAIA~~ If diode is conducting the voltage across load is 5V, $R_L I_L = 5V$

$$4I_1 - 6I_2 = -1$$
$$9I_1 - 6I_2 = 3$$
$$+5I_1 = +4$$
$$I_1 = \frac{4}{5}$$
$$\frac{12}{5} - 1 = 2I_2$$
$$\frac{7}{5\times 2} = I_2$$
$$R_L = \frac{5\times 10}{7} = \frac{50}{7}$$

— for variable V & $R_L = 100$.

find Vmin.

$$V - 10I_1 - 20(I_1 - I_2) - 10 = 0$$
$$V - 30I_1 + 20I_2 = 10$$

$$-1\cancel{0}I_2 - 10\cancel{0}I_2 + 1\cancel{0} - 2\cancel{0}(I_2 - I_1) = 0$$
$$-\cancel{10}^{2}I_2 - \cancel{5}^{1} + \cancel{10}^{2} - \cancel{20}^{4}(I_2 - I_1) = 0$$
$$-6I_2 + 1 + 4I_1 = 0.$$
$$4I_1 - 6I_2 = -1 \qquad I_2 = \frac{1}{20}$$
$$20\ 1\cancel{00} \times I_2 = \cancel{5}$$
$$4I_1 - \cancel{6}^{3} \times \frac{1}{\cancel{20}10} = -1$$
$$4I_1 = \frac{3}{10} - 1 = \frac{-7}{10}$$
$$I_1 = -\frac{7}{40}.$$
$$V + 3\cancel{0} \times \frac{7}{1\cancel{0}} + \cancel{20}\left(\frac{1}{2\cancel{0}}\right) = 10.$$
$$V = 9 - 21 = -12 \quad \} \times.$$

For V_{min} also diode is conducting, so $R_L I_2 = 5$

$$R_L I_2 = 5$$
$$I_2 = \frac{1}{20}$$

~~$V = 10 I_1$~~

$$-1\cancel{0}\left(\frac{1}{2\cancel{0}}\right) - 5 + 10 - 20\left(\frac{1}{20} - I_1\right) = 0$$

$$-\frac{1}{2} + 5 - 1 + 20 I_1 = 0$$

$$I_1 = -\frac{35}{200} = \frac{-7}{40}$$

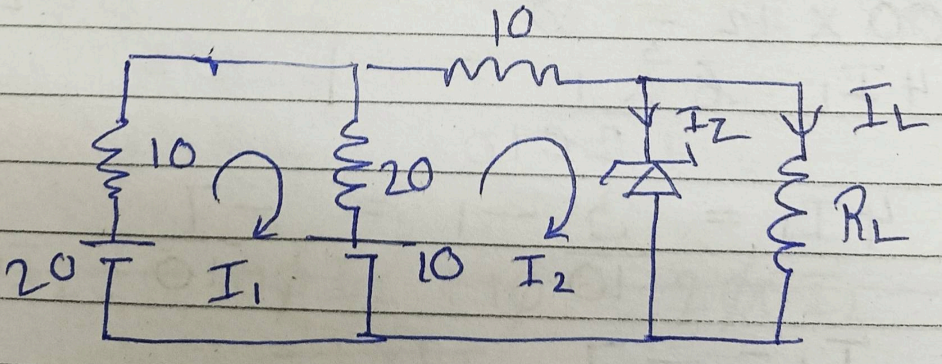
$$V + \frac{7}{4} - 20\left(\frac{-7}{40} - \frac{1}{20}\right) = 10$$

$$V - 20\left(\frac{-7-2}{40}\right) = 10 - \frac{7}{4}$$

$$V + \frac{9}{2} = \frac{33}{4} \Rightarrow V = \frac{33}{4} - \frac{9}{2}$$

$$\underline{\underline{V = 3.75\,V}} \qquad \frac{33-18}{4} = \frac{13}{4}$$

↳ If $V = 20$, $(R_L)_{max} = ?$ $(I_Z)_{max} = 400\,mA$



$$2\cancel{0} - 1\cancel{0} I_1 - 2\cancel{0}(I_1 - I_2) - 1\cancel{0} = 0$$

$$\cancel{2} - 3I_1 + 2I_2 - \cancel{1} = 0 - 1$$

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$-10I_2 - 5 + 10 - 20(I_2 - I_1) = 0$

$\cancel{I_2 = .4 + 5}$

$I_L R_L = 5.$

$-6I_2 + 1 + 4I_1 = 0.$

$4I_1 - 6I_2 = -1$

$6I_2 - 9I_1 = -3$

$+5I_1 = +\frac{4}{5}$

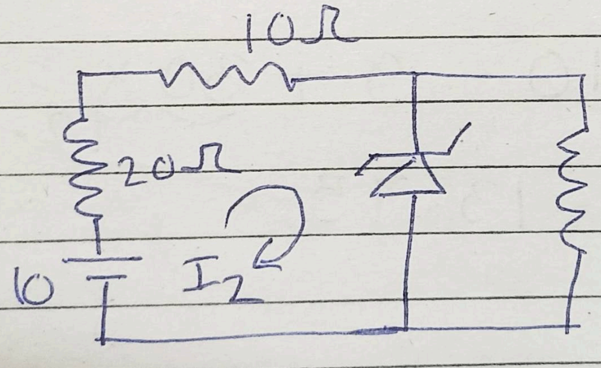
$+6I_2 = -1 - \frac{16}{5} = +\frac{21}{5}.$

$I_2 = \frac{7}{10}.$

$\frac{7}{10} - 0.4 = .3 = I_L = \frac{5}{R_L} = 16$

$16.67 = R_L$

Sir)



$\cancel{-10I_2 + 5}$

$-10I_2 - \underbrace{5}_{\text{diode}} + 10 - 20(I_2 - I_1)$

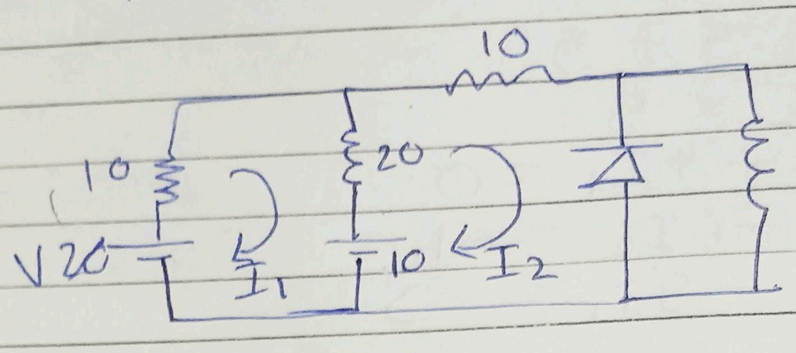
$5 = R_L I_L \Rightarrow R_L = \frac{5}{I_L} \Rightarrow (R_L)_{max} = \frac{5}{(I_L)_{min}}.$

& we know $I_2 = (I_Z) + I_L.$

for (I_L) min

$(I_L)_{min} = I_2 - (I_Z)_{max}$

For same values
Find
↳ V_{max}, $R_L = 100$,



$$I_2 = \frac{.4 + .05}{1} = 0.45$$

$$V - 10I_1 - 20(I_1 - I_2) - 10 = 0$$
$$V - 30I_1 + 20I_2 - \cancel{10} = 0 + 10$$

$$10 - 20(I_2 - I_1) - 10I_2 - 5) = 0$$
$$-30I_2 + 20I_1 = -5$$
$$20I_1 = -5 + 30 \times .45$$
$$I_1 = .425$$

$$V = 10 - 9 + \underbrace{30 \times}_{12.75}$$
$$= 13.75$$

Sir) $V - 10I_1 - 20I_1 - 10 = 0$

$$10 + 20I_1 - 10(\underbrace{I - I_1}_{.45}) - 5 = 0$$
$$20I_1 + 5 - 4.5 = 0$$
$$I_1 = \frac{-.5}{20} = -0.025$$
$$V - 30 \times \qquad I = .475$$
$$V = 24.25$$

MST-I → Unit I & II (aur 3 bhi agar complete hogai toh)

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$$I - I_1 = .45$$

$$V - 10I - 20I_1 - 10 = 0$$

$$10 + 20I_1 - 10(.45) - 5 = 0$$

$$20I_1 = -10 + 9.5 = -.5$$

$$I_1 = -\frac{.5}{20}$$

$$I = .45 - \frac{.5}{20} = .425$$

⇒ LED - It is p-n junction, Ga, In, As
└ when an electric current flows through it.
when current passes through an LED, the
e^-

⇒ Unit - 2.

⇒ Clippers → It clip out something from input

half wave rectifier is a clipper.
└ input sin & it clips out negative part of sin wave & returns clipped part i.e +ve part.

ideal diode in forward bias - ideal { close switch.
current ← pass karega
aur voltage zero hoga.