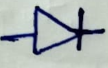
Module-4 : Semiconductor Devices

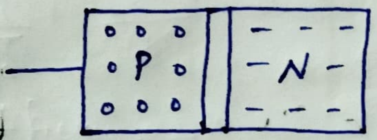
Topics to study :-

1. Basic semi-conductor Devices (5)
2. Half-wave and full-wave
3. Zener diode and its characteristics
4. BJT and its configurations and characteristics
5. P-n Junction Diode

P-n Junction Diode :-

Symbolic Representation : 

Internal Structure :



P-side → Holes

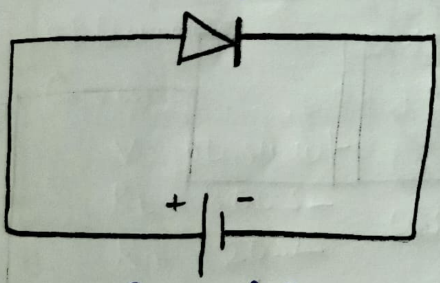
N-side → Electrons

Both sides are divided by a Junction.

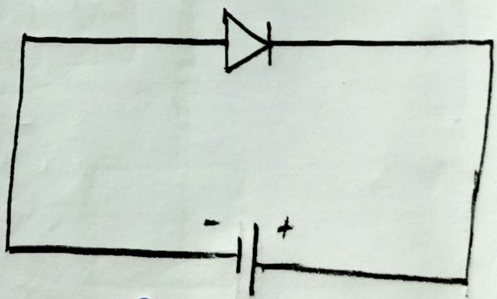
The junction layer decides the flow of electrons/current.

Thick layer — Reversed Biased (no current)

Thin layer — Forward Bias (More current)



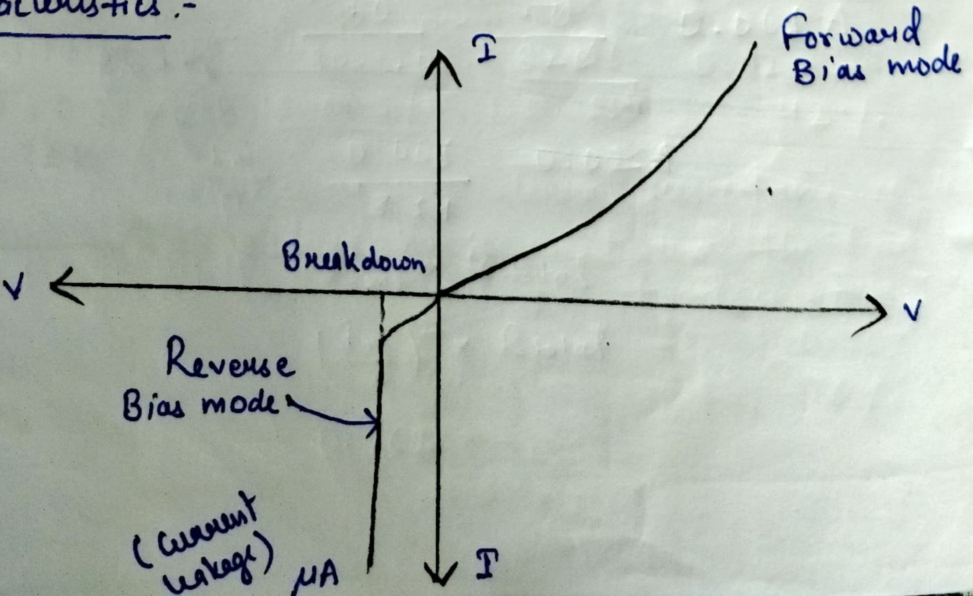
Forward Bias



Reverse Bias

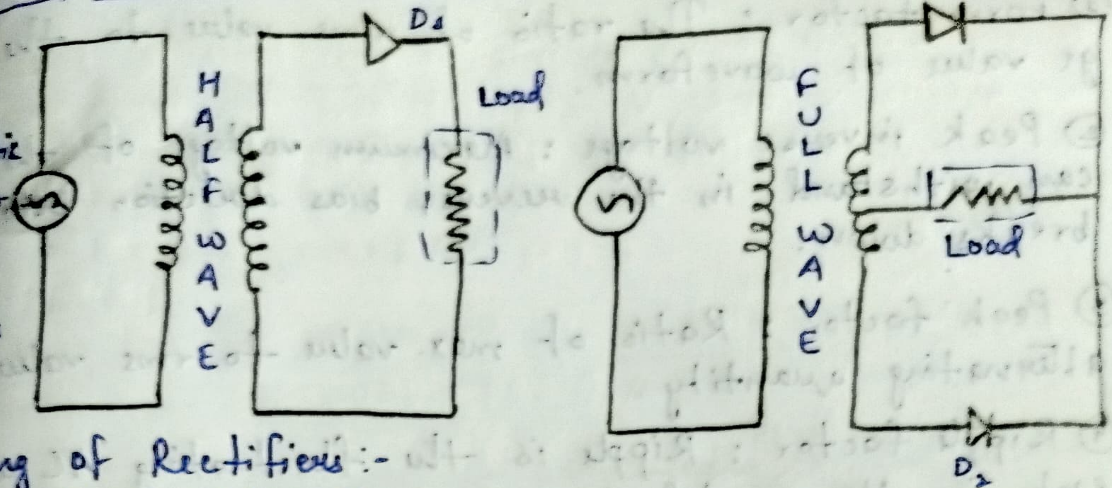
Conductivity range of good conductors = 10^{-8}

Characteristics :-



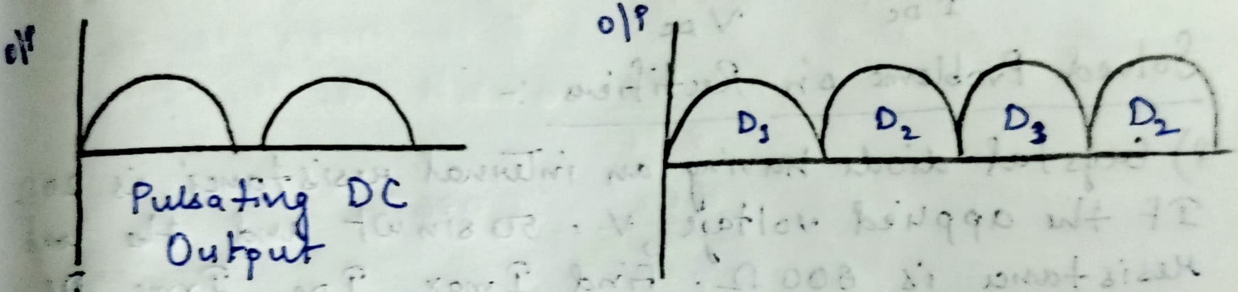
Half-wave and Full-wave Rectifier Circuit :-

Schematic representation of Rectifiers



Working of Rectifiers :-

Rectifiers are used to convert AC into DC



Differences btw. the Rectifiers :-

Half-Wave Rectifier	Full-Wave Rectifier
① Efficiency = 40.6 %	Efficiency = 81.2 %
② The peak inverse = maximum voltage (V_m)	The peak inverse voltage = 2 (max. V) [$2V_m$]
③ Ripple factor = 1.21	Ripple factor = 0.48
④ Form factor = 1.57	Form factor = 1.11
⑤ Peak factor = 2	Peak factor = 1.414
⑥ Average current = $\frac{I_m}{\pi}$	Avg. current = $\frac{2I_m}{\pi}$
⑦ $I_{rms} = \frac{I_m}{2}$	$I_{rms} = \frac{I_m}{\sqrt{2}}$
⑧ Less cost	More cost
⑨ Voltage regulation is good.	Voltage regulation is better.
⑩ $I_{DC} = \frac{I_m}{\pi}$	$I_{DC} = \frac{2I_m}{\pi}$

Important Definitions :-

① form factor : The ratio of rms value to the average value of waveform.

② Peak inverse voltage : Maximum voltage of the device can withstand in the reverse bias direction before it breaks down.

③ Peak factor : Ratio of max. value to rms value of alternating quantity.

④ Ripple factor : Ripple is the fluctuating AC component in the rectified output.

$$R.F = \frac{I_{rms}}{I_{DC}} = \frac{V_{rms}}{V_{DC}}$$

Solved Problems on Rectifiers :-

Q) Crystal diode having an internal resistance is 20Ω. If the applied voltage, V = 50 sin ωt and the load resistance is 800 Ω. Find I_{max}, I_{DC}, I_{rms}, AC power output, AC power input, DC output voltage and efficiency.

Sol:- Given,

$V = 50 \sin \omega t$

$R_L = 800\Omega$

$R_{in} = 20\Omega$

We know that,

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

$$I_m = \frac{V_m}{R_{in} + R_L} = \frac{50}{800+20} = \frac{5\cancel{0}}{82\cancel{0}} = 0.061\ A$$

And,

$$I_{DC} = \frac{I_m}{\pi} = \frac{0.061}{3.14} = 0.02\ A$$

AC power input = $I_{rms}^2 \times R_{total}$

$$= \left(\frac{I_m}{\sqrt{2}}\right)^2 \times R_{total}$$

$$= 0.762$$

DC power output $= I_{DC}^2 \times R_L$
$= (0.02)^2 \times 800$
$= 0.32$

DC output voltage $= I_{DC} \times R_L$
$= 0.02 \times 800$
$= 16$ V

Efficiency $= \dfrac{\text{DC power O/P}}{\text{AC power I/P}} = \dfrac{0.32}{0.762} = 0.42 \times 100$
$= 42\%$

Q) The internal resistance of both diodes is 20Ω each. $V_{rms} = 50V$, $R_L = 980\Omega$. Find out all the fundamentals.

Sol:- Given,
$V_{rms} = 50V$
$R_L = 980\Omega$
$R_{in} = 20\Omega$

$V_{rms} = \dfrac{V_m}{\sqrt{2}} \Rightarrow V_m = V_{rms} \times \sqrt{2}$

$V_m = 50 \times \sqrt{2} = 70.71V$

And,
$V = IR \Rightarrow I = \dfrac{V}{R}$

$I_m = \dfrac{V_m}{R_{in} + R_L} = \dfrac{70.71}{(20+20)+980} = \dfrac{70.71}{1020} = 0.07$ A

$I_{DC} = \dfrac{2I_m}{\pi} = \dfrac{2 \times 0.07}{3.14} = \dfrac{0.14}{3.14} = 0.0446$ A

$I_{rms} = \dfrac{I_m}{\sqrt{2}} = \dfrac{0.07}{\sqrt{2}} = 0.05$ A

AC power input $= I_{rms}^2 \times R_{total}$
$= (0.05)^2 \times 1020$
$= 2.55$

Efficiency $= \dfrac{2.128}{2.55}$
$= 0.8345 \times 100$
$= 83.45\%$

DC power output $= I_{DC}^2 \times R_L$
$= (0.0466)^2 \times 980$
$= 2.128$

DC output voltage $= I_{DC} \times R_L$
$= 0.0466 \times 980$
$= 45.668$ V

H.W (11)

Q) Crystal diode having an internal resistance is 10Ω. If the applied voltage, $V = 25 \sin \omega t$ and the load resistance is 400Ω. Find out all the fundamentals.

Sol:- Given,

$R_{in} = 10\Omega$

$V_m = 25\,V$

$R_L = 400\Omega$

We know that,

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

$I_m = \frac{V_m}{R_{in} + R_L} = \frac{25}{10+400} = \frac{25}{410} = 0.061\,A$

And,

$I_{DC} = \frac{I_m}{\pi} = \frac{0.061}{3.14} = 0.02\,A$

$I_{rms} = \frac{I_m}{2} = \frac{0.061}{2} = 0.0305\,A$

AC Power input $= I_{rms}^2 \times R_{total}$

$= (0.0305)^2 \times 410$

$= 0.3814$

DC Power Output $= I_{DC}^2 \times R_L$

$= (0.02)^2 \times 400$

$= 0.16$

DC Output Voltage $= I_{DC} \times R_L$

$= 0.02 \times 400$

$= 8\,V$

Efficiency $= \frac{\text{DC Power O/P}}{\text{AC Power I/P}} = \frac{0.16}{0.3814} = 0.42 \times 100$

$= 42\%$

Q) Crystal diode having an internal resistance is 40Ω. If the applied voltage, $V = 100 \sin \omega t$ and the load resistance is 1600Ω. Find out all the fundamentals.

Sol:- Given,

$R_{in} = 40\Omega$

$V_m = 100\,V$

$R_L = 1600\Omega$

We know that,

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

$I_m = \frac{V_m}{R_{in} + R_L} = \frac{100}{40 + 1600} = \frac{10\cancel{0}}{164\cancel{0}} = 0.061\ A$

And,

$I_{DC} = \frac{I_m}{\pi} = \frac{0.061}{3.14} = 0.02\ A$

$I_{rms} = \frac{I_m}{2} = \frac{\cancel{0.061}}{\cancel{2}} = 0.0305\ A$

AC Power input $= I^2_{rms} \times R_{total}$

$= (0.0305)^2 \times 1640$

$= 1.52561$

DC Power output $= I^2_{DC} \times R_L$

$= (0.02)^2 \times (40)^2$

$= 0.64$

DC Output Voltage $= I_{DC} \times R_L$

$= 0.02 \times 40$

$= 0.8\ V$

Efficiency $= \frac{DC\ Power\ O/P}{AC\ Power\ I/P} = \frac{0.64}{1.52561} = 0.42 \times 100 = 42\%$.

9) The internal resistance of both diodes is $20\ \Omega$ each. $V_{rms} = 25V$, $R_L = 490\Omega$. Find out all the fundamentals.

Sol:-

Given,

$V_{rms} = 25V$

$R_L = 490\ \Omega$

$R_{in} = 20\ \Omega$

$V_{rms} = \frac{V_m}{\sqrt{2}} \Rightarrow V_m = V_{rms} \times \sqrt{2}$

$V_m = 25 \times \sqrt{2} = 35.25\ V$

We know that,

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

$I_m = \frac{V_m}{R_{in} + R_L} = \frac{35.15}{20 + 490} = \frac{\cancel{35.15}}{5\cancel{10}} = 0.069\ A$

$I_{DC} = \frac{2I_m}{\pi} = \frac{2 \times 0.069}{3.14} = 0.044\,A$

$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{0.069}{\sqrt{2}} = 0.049\,A$

AC Power input $= I_{rms}^2 \times R_{total}$
$= (0.049)^2 \times 510$
$= 1.22451$

DC Power output $= I_{DC}^2 \times R_L$
$= (0.014)^2 \times 490$
$= 0.09604$

DC Output Voltage $= I_{DC} \times R_L$
$= 0.014 \times 490$
$= 6.86\,V$

Efficiency $= \frac{\text{DC Power O/P}}{\text{AC Power I/P}} = \frac{0.09604}{1.22451} = 0.07843 \times 100 = 78.43\,\%$

Q) The internal resistance of both diodes is $60\,\Omega$ each. $V_{rms} = 60\,V$, $R_L = 1000\,\Omega$. Find out all the fundamentals.

Sol:- Given,

$R_{in} = 60\,\Omega$

$V_{rms} = 60\,V$

$R_L = 1000\,\Omega$

$V_{rms} = \frac{V_m}{\sqrt{2}} \Rightarrow V_m = V_{rms} \times \sqrt{2}$

$V_m = 60 \times \sqrt{2} = 84.6\,V$

We know that,

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

$I_m = \frac{V_m}{R_{in} + R_L} = \frac{84.6}{60 + 1000} = \frac{84.6}{1060} = 0.0798\,A$

$I_{DC} = \frac{2I_m}{\pi} = \frac{2 \times 0.0798}{3.14} = 0.0508\,A$

$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{0.0798}{\sqrt{2}} = 0.0566\,A$

And,

AC Power Input $= I_{rms}^2 \times R_{total} = (0.0566)^2 \times 1060$
$= 3.3957$

DC Power Output = $I^2_{DC} \times R_L$
$= (0.0508)^2 \times 1000$
$= 2.58064$

DC Output Voltage = $I_{DC} \times R_L$
$= 0.0508 \times 1000$
$= 50.8\ V$

$$\text{Efficiency} = \frac{\text{DC Power O/P}}{\text{AC Power I/P}} = \frac{2.58064}{3.3957} = 0.76 \times 100 = 76\%$$

a) A full wave rectifier uses 2 diodes having internal resistance of $20\,\Omega$ each. The transformer rms secondary voltage from centre to each end is 50V. Find I_m, I_{DC}, I_{rms} and V_{DC}, if the load is $980\,\Omega$.

Sol:- Given,
$R_{in} = 20\,\Omega$
$V_{rms} = 50\ V$
$R_L = 980\,\Omega$

$$V_{rms} = \frac{V_m}{\sqrt{2}} \Rightarrow V_m = V_{rms} \times \sqrt{2}$$

$V_m = 50 \times \sqrt{2} = 70.71\ V$

We know that,
$$V = IR \Rightarrow I = \frac{V}{R}$$

$$I_m = \frac{V_m}{R_{in} + R_L} = \frac{70.71}{20 + 980} = \frac{70.71}{1000} = 0.07\ A$$

$$I_{D.C} = \frac{2 I_m}{\pi} = \frac{2 \times 0.07}{3.14} = 0.0455\ A$$

$$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{0.07}{\sqrt{2}} = 0.05\ A$$

And,
AC Power input = $I^2_{rms} \times R_{total}$
$= (0.05)^2 \times 1000$
$= 2.5$

DC Power output = $I^2_{DC} \times R_L$
$= (0.0455)^2 \times 980$
$= 2.028845$

Efficiency :-
$$= \frac{\text{DC Power O/P}}{\text{AC Power I/P}} = \frac{2.028845}{2.5} = 0.8115 \times 100 = 81.15\%$$

DC Power voltage = $I_{DC} \times R_L$
$= (0.0455) \times 980$
$= 44.6\ V$

Zener Diode :-

* Basic Semi-conductor device
* Operates only and also in Reverse direction
* Acts as voltage regulator.

↑ Always connected

Symbolic Representation : 

- Zener Diode is highly-doped semiconductor device which is designed to operate in the Reverse direction more.
- The voltage across the zener diode is always reversed when we apply reverse voltage to certain value, that is called zener | Breakdown Voltage.

Modes of Operation :-

Forward-bias mode : Acting as p-n junction diode

Reverse-bias mode : Only zener-diode

Types of Breakdown :-

① Avalanche Breakdown : Same characteristic as the p-n junction diode in the reverse direction. However, current increases rapidly in zener-diode, but the p-n junction diode is destroyed. [Normal diode too]

If we apply high reverse voltage to diode, high current will flow in reverse direction :

- If its normal diode, current destroys the diode.
- Zener diode works normally.

Minimum-breakdown voltage is 3V (approx.).

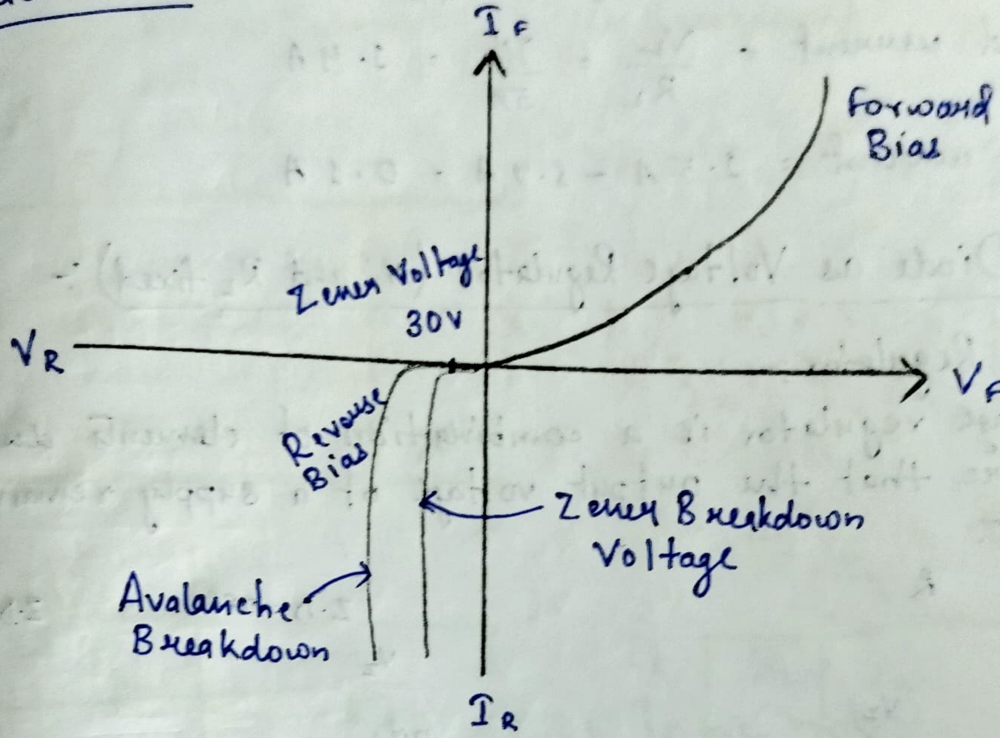
② Zener Breakdown : When some reverse voltage is applied, it goes to some certain voltage, then the electric field in the depletion region becomes strong, so it extracts e^- from the covalent bond.

The certain voltage of the zener diode is called zener voltage.

The valency e^- gains a sufficient energy from the strong electric field, then it breaks free from the parent atom.

Once the voltage reaches to zener breakdown voltage, after the breakdown, if we increase small voltage, reverse current will increase more.

Characteristics :-

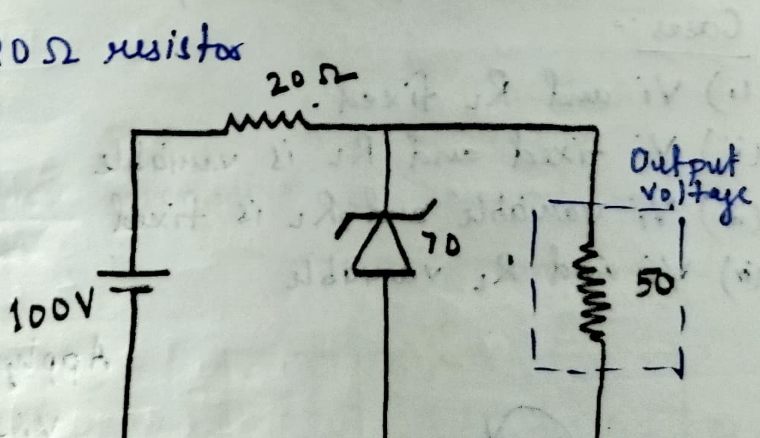


* Zener-diode acting as Voltage regulator.
- After breakdown voltage, current decreasing but same voltage.
- Connected in parallel with the Load.

The voltage across Load is zener voltage.

a) The input voltage of circuit = 100V ; Series resistance of zener diode = 20 Ω ; Breakdown voltage = 70V ; Load Resistance = 50Ω . Find out output :-

(a) Output voltage.
(b) Voltage drop across 20 Ω resistor
(c) Zener current



Sol:- Given,

$V_{in} = 100V$
$R_s = 20\,\Omega$
$R_L = 50\,\Omega$
$V_z = 70V$

(a) Output Voltage = V_z = 70 V
(b) $V_{20} = 100 - 70 = 30V$

(c) Zener current = Total current - Load current

From, $I = I_z + I_L$

Total current $= \frac{100-70}{20} = \frac{30}{20} = 1.5\,A$

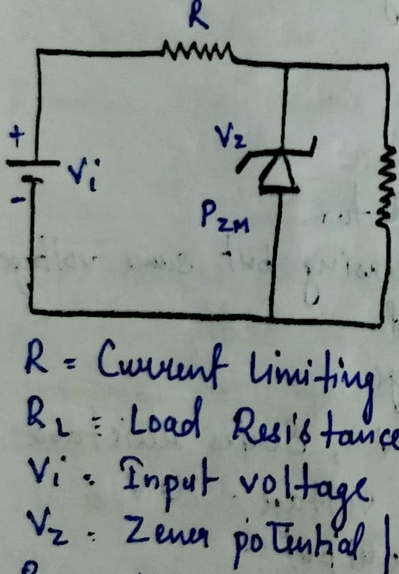
Load current $= \frac{V_L}{R_L} = \frac{70}{50} = 1.4\,A$

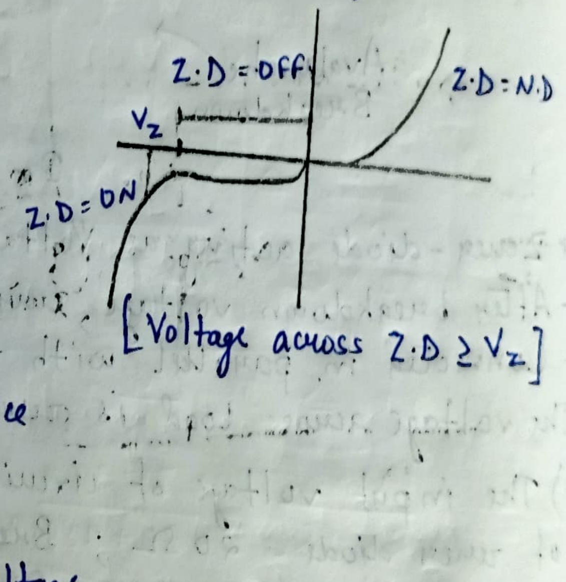
Zener current $= 1.5\,A - 1.4\,A = 0.1\,A$

Zener Diode as Voltage Regulator (V_i and R_L fixed) :-

Voltage Regulator :-

A voltage regulator is a combination of elements designed to ensure that the output voltage of a supply remains constant.



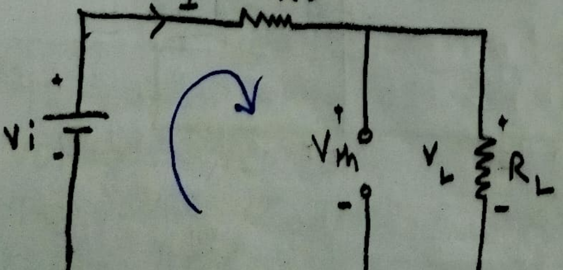


[Voltage across Z.D ≥ V_z]

R = Current limiting resistance
R_L = Load Resistance
V_i = Input voltage
V_z = Zener potential | Zener Voltage
P_{ZM} = Maximum power dissipation capability of Z.D.

Cases :-

(i) V_i and R_L fixed.
(ii) V_i fixed and R_L is variable
(iii) V_i variable and R_L is fixed
(iv) V_i and R_L variable



Applying KVL in loop,

$V_i - IR - IR_L = 0$

$V_i - I(R + R_L) = 0$

$I = \frac{V_i}{R + R_L}$

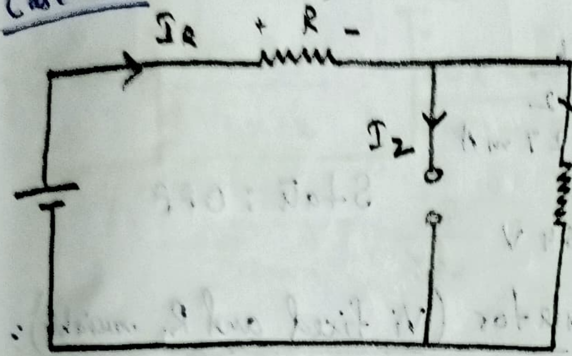
Now,

$V_{th} = V_L = I R_L = V_i \frac{R_L}{R+R_L}$

Case-I : $V_{th} \geq V_z \longrightarrow$ ON (Breakdown)

Case-II : $V_{th} < V_z \longrightarrow$ OFF (No Breakdown)

Case-II :-



$V_R = I_R R$; $V_L = I_L R_L$

$I_Z = 0$

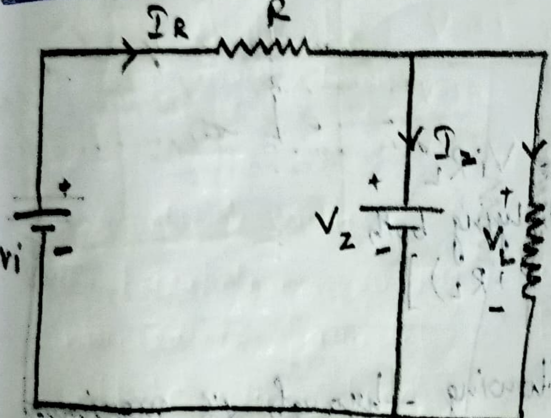
$P_Z = V_Z I_Z = 0$

$I_R = I_L + I_Z$

$I_R = I_L$

$I_R = \frac{V_i}{R+R_L} = I_L$

Case-I :-



$I_R = I_L + I_Z$

$I_Z = I_R - I_L$

$I_R = \frac{(V_i - V_Z)}{R}$; $I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L}$

$I_Z = \frac{V_i - V_Z}{R} - \frac{V_Z}{R_L}$

$P_Z = I_Z V_Z = \left(\frac{V_i - V_Z}{R} - \frac{V_Z}{R_L}\right) V_Z$

* $P_Z < P_{ZM}$

Q) For the zener diode network, determine V_L, V_R, I_Z, P_Z.

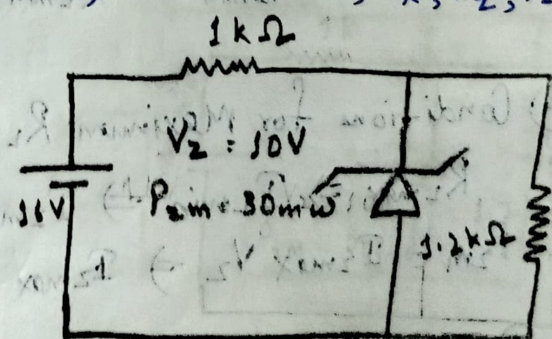
Given,

$V_i = 16V$; $V_Z = 10V$

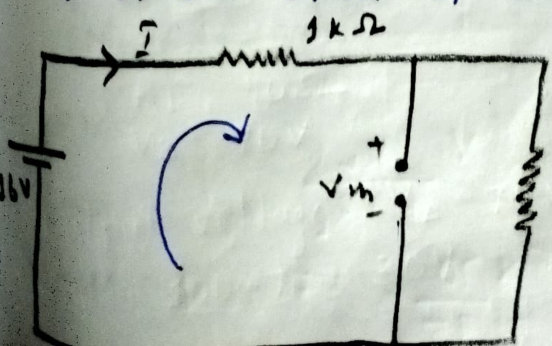
$R = 1k\Omega$

$R_L = 1.2k\Omega$

$P_{ZM} = 30\,mW$



To find out state of Z.D,



Applying KVL in loop,

$16 - I \times 1 - I \times 1.2 = 0$

$16 - 2.2 I = 0$

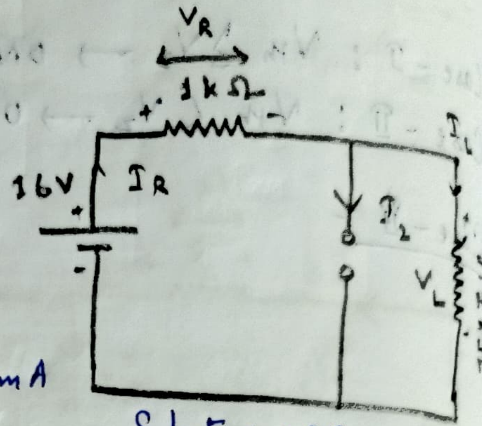
$I = \frac{16}{2.2} = 7.27\,mA$

$V_{th} = V_L = I_L R_L = 7.27 \times 1.2 = 8.72\ V$

Here,

$V_Z > V_{th}$ [$10V > 8.72V$]

$\therefore$ Zener Diode is OFF.



State : OFF

$I_Z = 0$; $P_Z = I_Z V_Z = 0$

$I_R = I_L + I_Z \Rightarrow I_R = I_L$

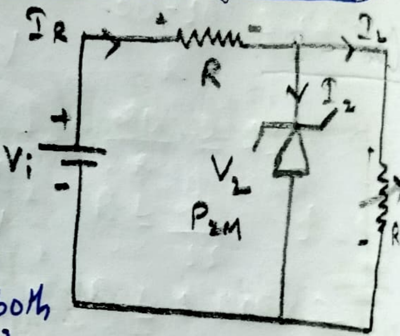
$I_R = \dfrac{V_i}{R + R_L} = \dfrac{16}{1 + 1.1} = \dfrac{16}{2.2}$
$= 7.27\ mA$

$V_R = IR = 7.27 \times 1 = 7.27\ V$

$V_L = I_L R_L = 7.27 \times 1.2 = 8.64\ V$

Zener Diode as Voltage Regulator (V_i fixed and R_L variable):

Condition for Minimum R_L :-



① $V_{th} = \dfrac{V_i R_L}{R + R_L} = V_Z = V_L$

$V_Z = \dfrac{V_i R_L}{R + R_L} \Rightarrow V_Z (R + R_L) = V_i R_L$

[After multiplying both sides by $(R + R_L)$]

$V_Z R + V_Z R_L = V_i R_L$

$R_{L\,(min.)} = \dfrac{V_Z R}{V_i - V_Z} \Rightarrow$ Current flowing through is maximum

$I_{L(max)} = \dfrac{V_L}{R_{L\,min}} = \dfrac{V_Z}{R_{L\,min}}$

$I_R = I_{Z\,min} + I_{L\,max}$

$I_{Z\,min} = -I_{L\,max} + I_R$

$= \dfrac{(V_i - V_Z)}{R} - I_{L\,max}$

② Condition for Maximum R_L :-

$R_{L\,max} \Rightarrow I_{L\,min} \Rightarrow I_{Z\,max}$

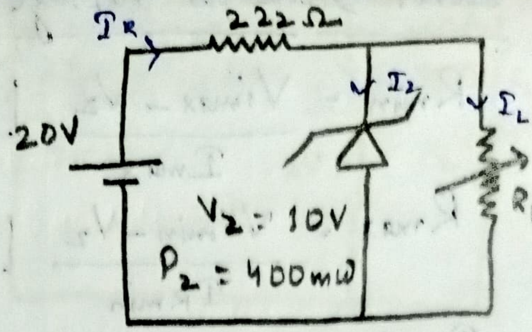
$P_{ZM} = I_{Z\,max} V_Z \Rightarrow I_{Z\,max} = \dfrac{P_{ZM}}{V_Z}$

$I_{L\,min} = I_R - I_{Z\,max}$

$= \dfrac{(V_i - V_Z)}{R} - \dfrac{P_{ZM}}{V_Z}$

$R_{L\,max} = V_L / I_{L\,min} = \dfrac{V_Z}{I_{L\,min}}$

Q) Determine the minimum and maximum values of load Resistance R_L.



Given,

$V_i = 20V$

$R = 222\Omega$

$V_Z = 10V$

$P_Z = 400mW$

$$R_{Lmin} = \frac{V_Z R}{V_i - V_Z} = \frac{10 \times 222}{20-10} = \frac{\cancel{10} \times 222}{\cancel{10}} = 222\Omega$$

$$I_{Lmax} = \frac{V_Z}{R_{Lmin}} = \frac{10}{222} = 45mA$$

$$P_{Zm} = I_{Zmax} V_Z$$

$$I_{Zmax} = \frac{P_{Zm}}{V_Z} = \frac{400}{45} = 40mA$$

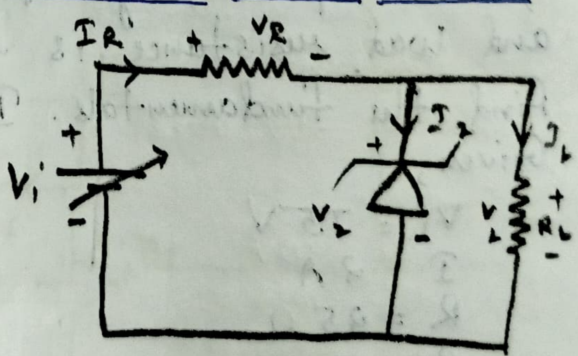
$$I_{Lmin} = I_R - I_{Zmax} \qquad I_R = \frac{V_i - V_Z}{R} = \frac{20-10}{222}$$

$$= 45 - 40$$

$$= 5mA \qquad I_R = \frac{10}{222} = 45mA$$

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}} = \frac{\cancel{10}\ V}{\cancel{5}\ mA} = 2k\Omega$$

Zener Diode as Voltage Regulator (Variable V_i and fixed R_L) :-



① Condition for Min. V_i :-

$V_{th} \geq V_Z \rightarrow ON$

$V_{th} < V_Z \rightarrow OFF$

To turn ON (min), $V_{th} = V_Z$

$$V_i \frac{R}{R+R_L} = V_Z$$

$$V_{i(min)} = \frac{V_Z}{R}(R+R_L) \qquad I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L}$$

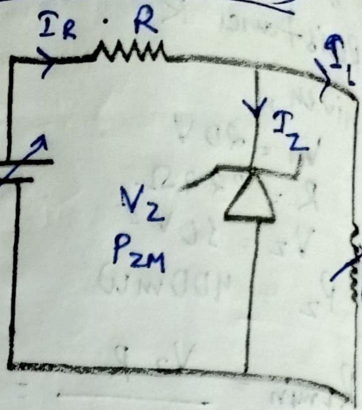
② Condition for Max. V_i :-

$$I_{Rmax} = I_{Zmax} + I_L$$

$$V_{imax} - V_{Rmax} - V_Z = 0 \Rightarrow V_{imax} = V_{Rmax} + V_Z$$

$$V_{imax} = I_{Rmax} R + V_Z$$

Zener Diode as Voltage Regulator (V_i and R_L variable):

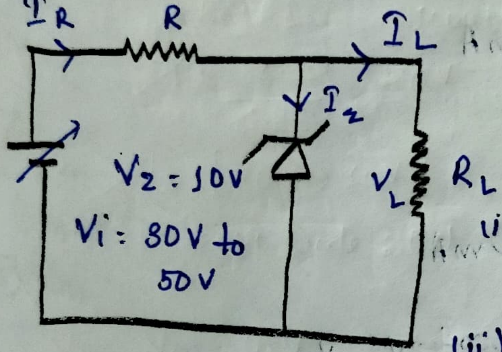


$R_{min} = \dfrac{V_{imax} - V_Z}{I_{max}}$ [Minimum]

$R_{max} = \dfrac{V_{imin} - V_Z}{I_{Rmin}}$ [Maximum]

$I_R \geq I_Z + I_L$ [Always true]

$\dfrac{V_i - V_Z}{R} \geq I_Z + I_L$



$I_L = 10mA$

$I_Z = 1mA$

(i) $V_i = 30V$

$V_Z = 10V$

(ii) $V_i = 50V$

$V_Z = 10V$

$\dfrac{30-10}{R} \geq 1 + 10$

$\dfrac{20}{R} \geq 11$

$R \leq \dfrac{20}{11} = 1.818k\Omega$

$R \leq 1.818 k\Omega$

$\dfrac{50-10}{R} \geq 1 + 10$

$\dfrac{40}{R} \geq 11 \Rightarrow R \leq \dfrac{40}{11} = 3.636 k\Omega$

$R \leq 3.636 k\Omega$

Range of series resistance : $1.818 k\Omega$ to $3.636 k\Omega$

Q) The input voltage of circuit = 75V. The resistance and load resistance is 25Ω and 70Ω respectively. Find the fundamentals. $I = 2A$

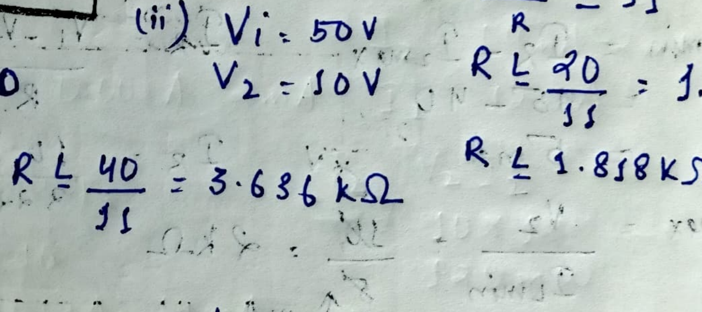
Given,

$V_i = 75V$

$I = 2A$

$R = 25\Omega$

$R_L = 70\Omega$



To find V_Z,

$75 - 25 \times 2 = V_Z$

$V_Z = 75 - 50$

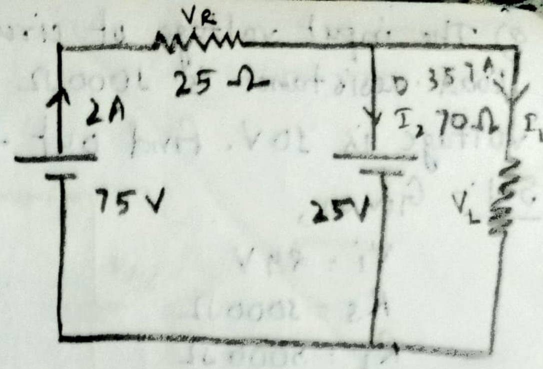
$V_Z = 25V$

And,

$V_{th} = V_i \dfrac{R_L}{R + R_L}$

$= 75 \times \dfrac{70}{95} = 55.26 V$

Here,
$V_{th} > V_Z$ [55.26 V > 25 V]



State of Zener Diode : ON

Now,

$V_Z = V_L = 25\,V$

$I_L = \frac{V_L}{R_L} = \frac{25}{70} = 0.357\,A$

Also,

$I_Z = I_R - I_L$

$= 2A - 0.357A$

$= 1.643\,A$

$V_R = I_R \times R$

$= 2 \times 25$

$= 50\,V$

$P_Z = V_Z I_Z = 25 \times 1.643$

$P_Z = 41.075\,W$

H.W (12)

Q) The input voltage of circuit = 100V. The resistance and the load resistance is 1000 Ω and 2000 Ω respectively. Breakdown voltage = 50V. Find the fundamentals.

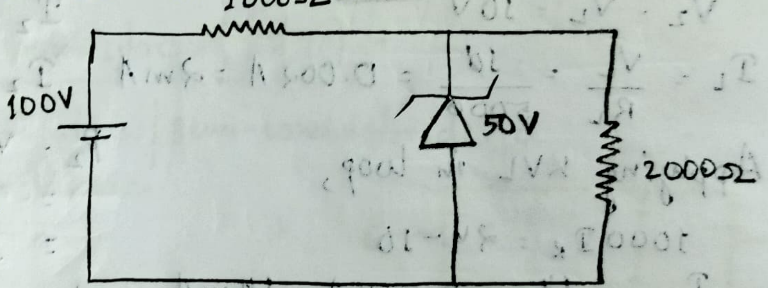
Sol:- Given,

$V_i = 100V$

$R_S = 1000\,\Omega$

$R_L = 2000\,\Omega$

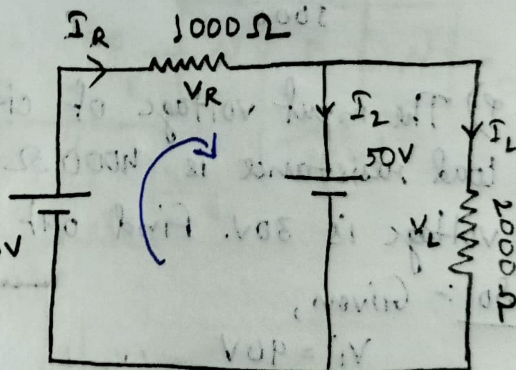
$V_Z = 50V$



Here,

$V_{th} = V_i \times \frac{R_L}{R_S + R_L} = \frac{100 \times 2000}{1000 + 2000}$

$V_{th} = 100 \times \frac{2000}{3000} = 66.667\,V$



$V_{th} > V_Z$ [66.667V > 50V]

State of Zener Diode : ON

Now,

$V_Z = V_L = 50V$

$I_L = \frac{V_L}{R_L} = \frac{5\cancel{0}}{200\cancel{0}} = \frac{1}{40} = 0.025\,A$

Applying KVL in loop,

$1000\,I_R = 100 - 50$

$I_R = \frac{5\cancel{0}}{100\cancel{0}} = \frac{1}{20}$

$= 0.05\,A$

$I_Z = I_R - I_L$

$I_Z = 0.05A - 0.025A$

$I_Z = 0.025\,A$

$P_Z = V_Z I_Z$

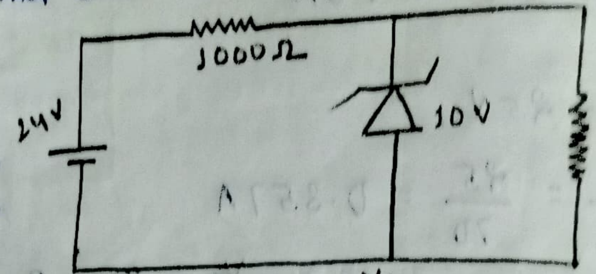
$= 50 \times 0.025$

$= 1.25\,W$

$V_R = V_i - V_Z = 100V - 50V = 50V$

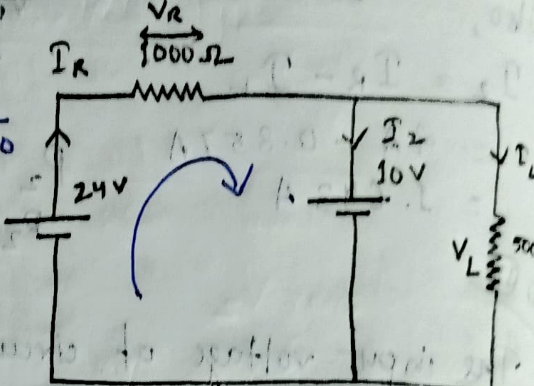
Q) The input voltage of circuit is 24 V. The resistance and Load resistance is 1000 Ω and 5000 Ω respectively. Breakdown voltage is 10 V. Find out the fundamentals.

Sol:- Given,



$V_i = 24V$
$R_S = 1000\Omega$
$R_L : 5000\Omega$
$V_Z = 10V$

Here,



$V_{th} = V_i \frac{R_L}{R_S + R_L} = \frac{24 \times 5000}{1000+5000}$

$V_{th} = \frac{\cancel{24}^{4} \times 5000}{6000} = 20V$

$V_{th} > V_Z$ [$20V > 10V$]

State of Zener Diode : ON

Now,

$V_Z = V_L = 10V$

$I_L = \frac{V_L}{R_L} = \frac{10}{5000} = 0.002A = 2mA$

Applying KVL in loop,

$1000 I_R = 24 - 10$

$I_R = \frac{14}{1000} = 0.014A = 14mA$

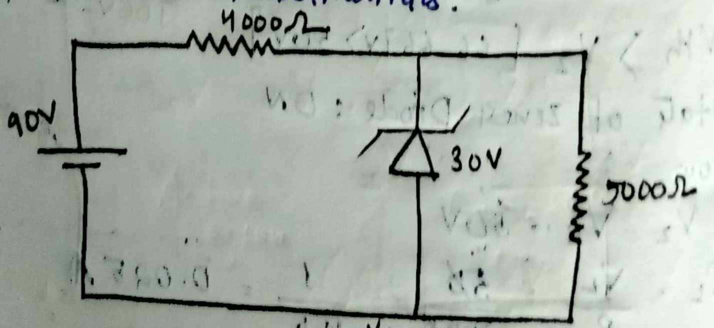
$I_Z = I_R - I_L$
$I_Z = 14mA - 2mA$
$I_Z = 12mA$

$P_Z = V_Z I_Z$
$= 10 \times 12$
$= 120 mW$

$V_R = V_i - V_Z = 24 - 10$
$V_R = 14V$

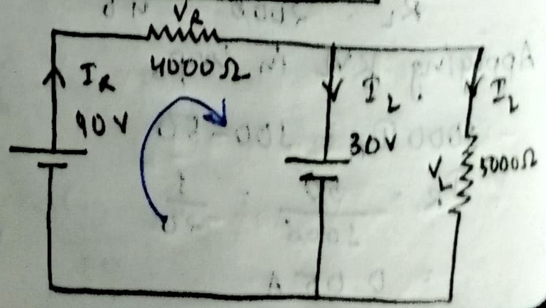
Q) The input voltage of circuit is 90V. The resistance and load resistance is 4000 Ω and 5000 Ω respectively. Breakdown voltage is 30V. Find out the fundamentals.

Sol:- Given,



$V_i = 90V$
$R_S = 4000\Omega$
$R_L = 5000\Omega$
$V_Z = 30V$

Here,



$V_{th} = V_i \times \frac{R_L}{R_S + R_L} = \frac{90 \times 5000}{4000+5000}$

$V_{th} = \frac{\cancel{90}^{10} \times 5000}{\cancel{9000}} = 50V$

$V_{th} > V_Z$ [$50V > 30V$]

State of zener Diode : ON

Now,

$V_Z = V_L = 30V$

$I_L = \frac{V_L}{R_L} = \frac{3\cancel{0}}{500\cancel{0}} = 0.006A = 6mA$

Applying KVL in loop,

$4000 I_R = 90 - 30$

$I_R = \frac{6\cancel{0}}{400\cancel{0}} = 0.015A = 15mA$

$I_Z = I_R - I_L$

$= 15mA - 6mA$

$= 9mA$

$P_Z = V_Z I_Z$

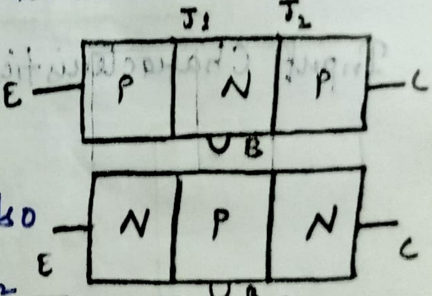
$= 30 \times 9$

$= 270 mW$

$V_R = V_i - V_Z = 90 - 30 = 60V$

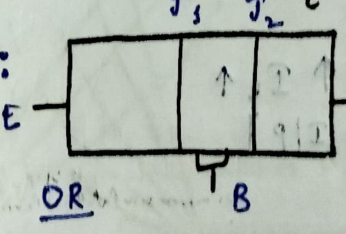
Bipolar Junction Transistors (BJT) :-

* Two junction transistors | semi-conductor device
* Two p-n junction diodes
* Three Terminals
* Acts as current controlled device
* Acting as an amplifier | switch also

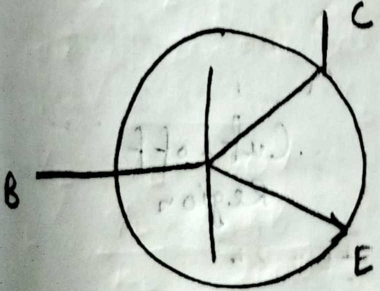


[Types]

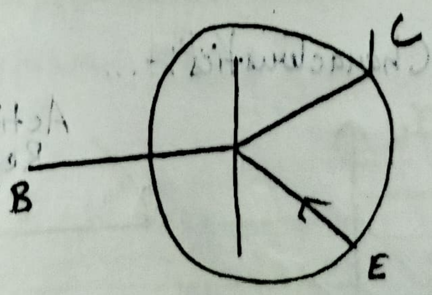
Symbolic Representation :



OR

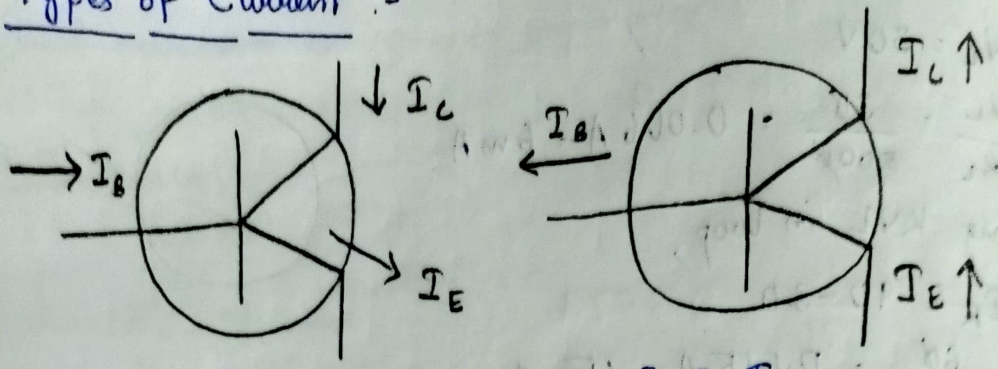


NPN Type



PNP Type

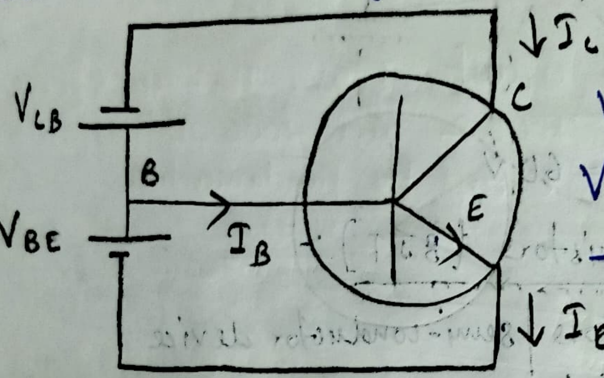
Types of Current :-



NOTE :- $I_E = I_B + I_C$

Types of Configurations :-

① Common Base Configuration :-



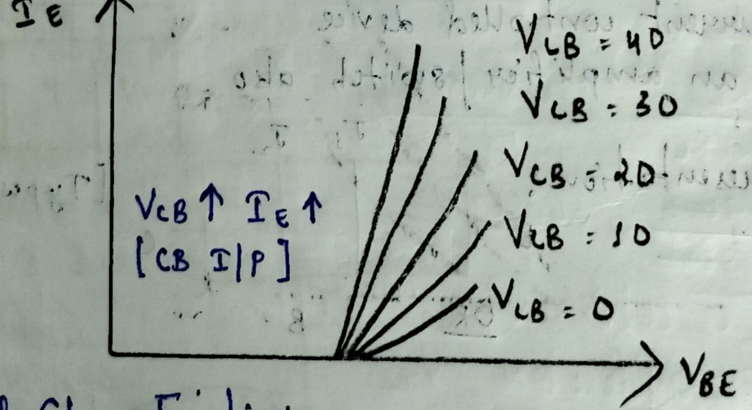
V_{BE} and I_B : Inputs

V_{CB} and I_C : Outputs

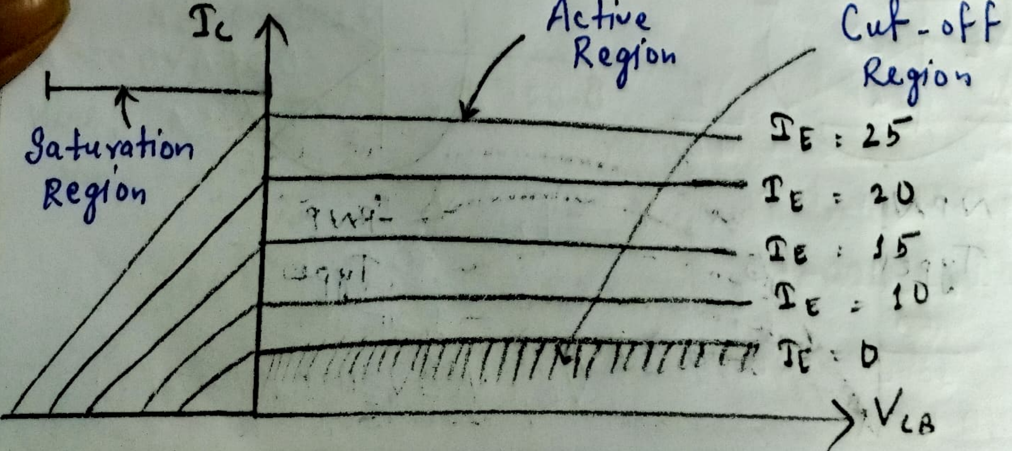
→ A graph of I_E v/s V_{EB} for various V_{CB} values

→ V_{CB} increases, I_E increases slightly.

Input Characteristics :-



Output Characteristics :-



Types of Regions :-

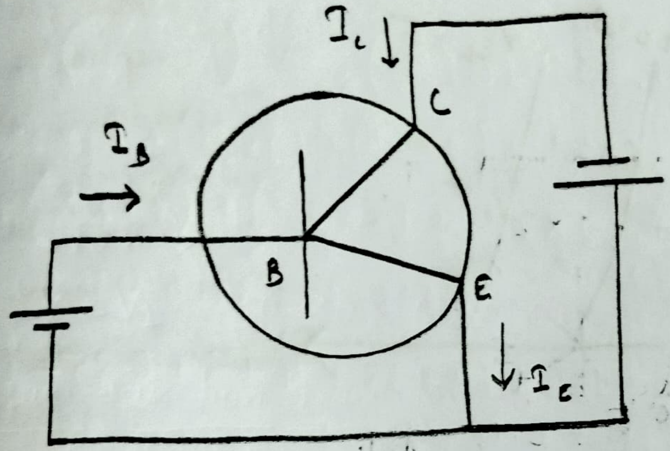
① Active Region — Both collector voltage and collector current are in the positive area.

② Cut-off Region — Emitted current value is less than zero.

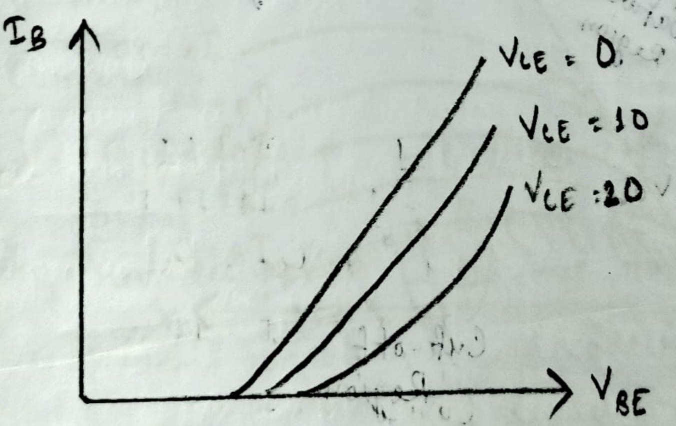
③ Saturation Region — Negative area side of V_{CB}. Here, both the junctions are forward-biased.

H.W ⑬

② Common Emitter Configuration :-



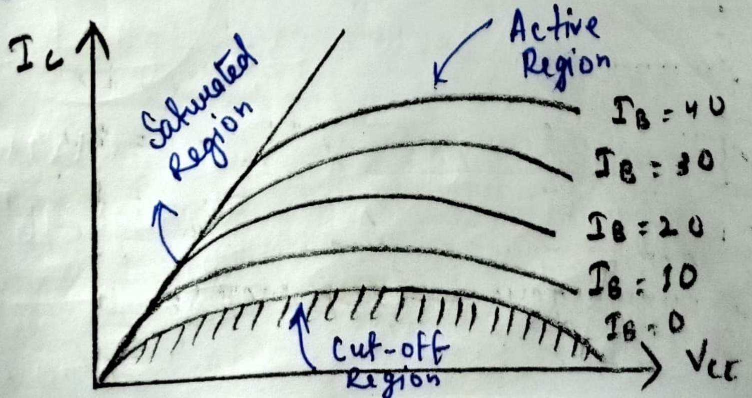
Input Characteristics :-



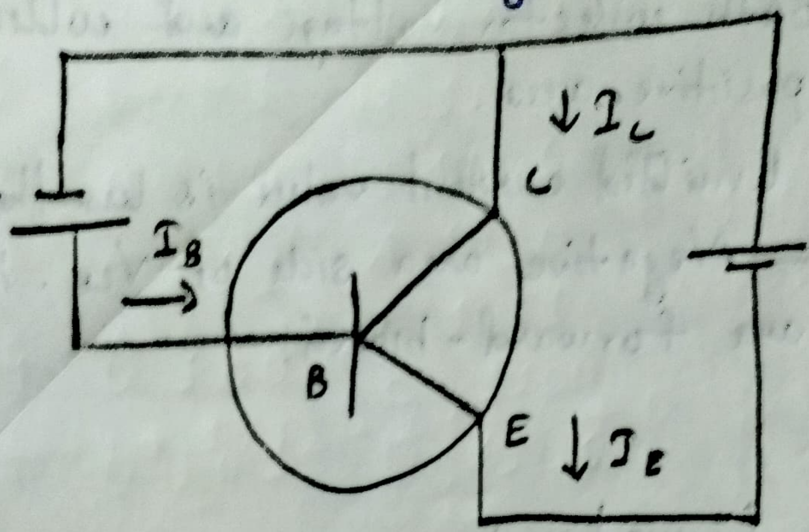
→ A graph of I_B v/s V_{BE} for various EB values

→ V_{CE} is increased, I_B increases steeply.

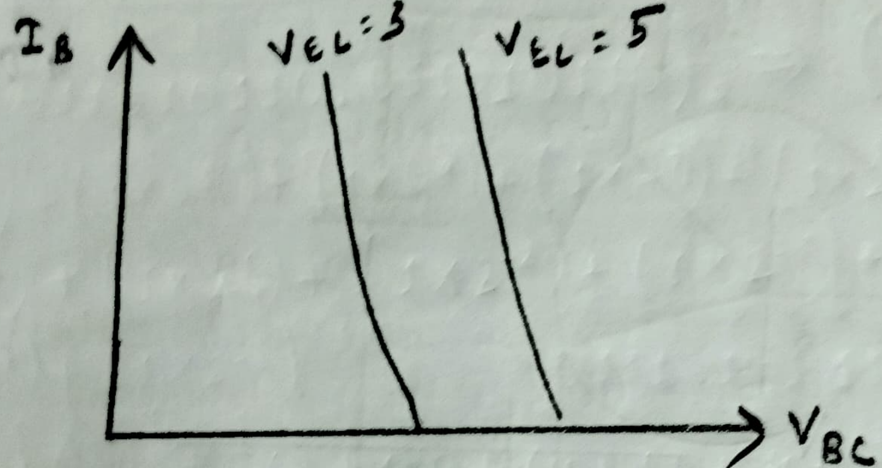
Output Characteristics :-



③ Common Collector Configuration :-



Input Characteristic :-



Output Characteristic :-