* BASICS OF ELECTROSTATICS *

* Properties of semiconductors:

- the resistivity of semiconductor is less than insulator but more than conductors.
- semiconductors have negative temperature coefficient of resistance i.e. $\uparrow$ in temp. $\Rightarrow$ $\downarrow$ ~~increase~~ decrease in resistance
- when suitable impurities are added to semiconductor its current conducting properties changes.

* Intrinsic semiconductors

- semiconductor in an extremely pure form is known as intrinsic SC.

* Extrinsic Semiconductor

- to be useful in electronic devices the pure semiconductor must be changed so as to increase its conducting properties. this is achieved by adding small amount of suitable impurities to a semiconductor.

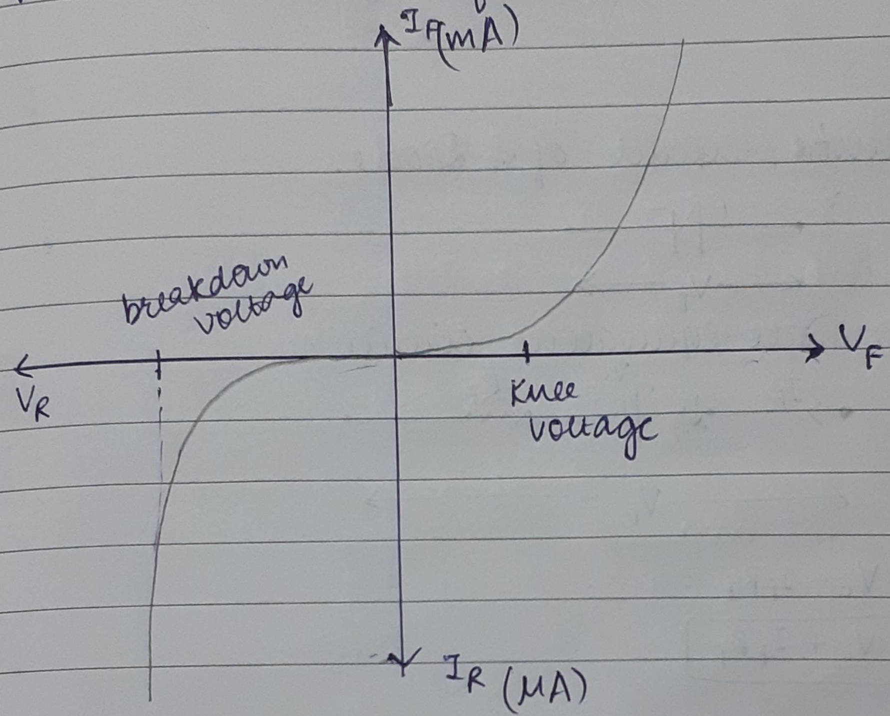
→ The process of adding impurities to the semiconductor is known as Doping.

* Forward Bias

when external voltage applied to the junction is in such a direction that it cancels the potential barrier and allows the current to flow is known as forward bias.

* Reverse Bias:
when the external voltage applied to the junction is in such a direction that potential barrier is increased is known as reverse bias.

* V-I characteristics of PN junction diode.



* Knee voltage: It is the forward voltage at which current through the junction start to increase rapidly

* breakdown voltage: It is the reverse voltage at which PN junction breaks down with sudden rise in reverse current

Imp. * Limitations in the operating conditions of PN junction:
- the PN junction will give satisfactory performance if it is operated within limiting values.

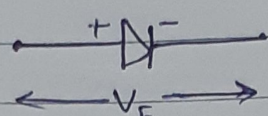
(i) maximum forward current: it is the highest forward current that a PN junction can conduct without damaging the junction.

(ii) Peak inverse voltage (PIV).
it is the maximum reverse voltage that can be applied to PN junction without damaging the junction.

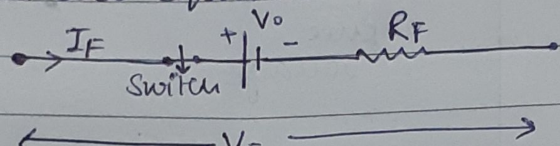
(iii) Max Power rating
It is the maximum power that can be decipitated at the junction without damaging the junction.

Imp

Equivalents circuit of a Diode.



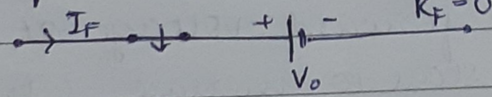
1) approximate equivalent circuit.



$V_F - V_0 - I_F R_F = 0$

$\boxed{V_F = V_0 + I_F R_F}$

2) Simplified equivalent ~~circuit~~ model.



$\boxed{V_F = V_0}$

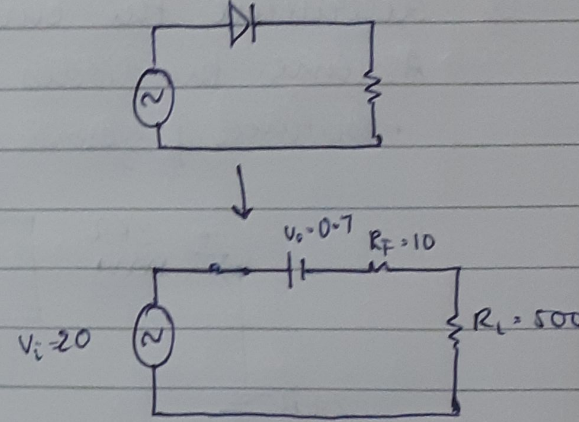
the internal resistance (R_F) of the diode can be ignored in comparision to other elements in equivalent circuit. So in simplified equivalent circuit consider $R_F = 0$.

3) Ideal diode Model
• an ideal diode behaves as perfect conductor in forward bias and perfect insulator in reverse bias. So, $R_F = 0$. and V_0 is considered negligible the ideal diode is never found in practice.

$\boxed{R_F = 0, \ V_0 = 0}$

Q. An AC voltage of peak value of 20 volt is connected in series with silicon diode and load $R = 500\Omega$. If forward resistance of diode is 10Ω find
(i) peak current through diode.
(ii) peak output voltage
(iii) What will be these values if the diode is ~~reversed~~ assume to be ideal.

ans: $R_F = 10\ \Omega$
$R_L = 500\ \Omega$ $\quad$ $V_0 = 0.7$ volt (silicon
$V_i = 20$ volt
~~$V_0 = V_F - I_F R_F$~~

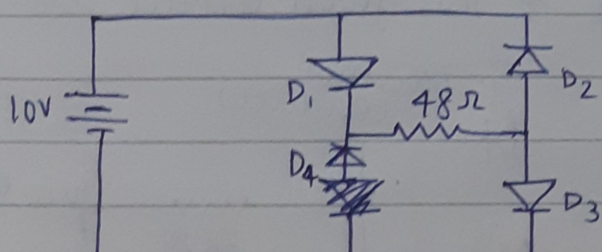


thus,
$V_i = V_0 + I_F(R_F + R_L)$
$\frac{20 - 0.7}{510} = I_F = \boxed{37.8\ mA}$

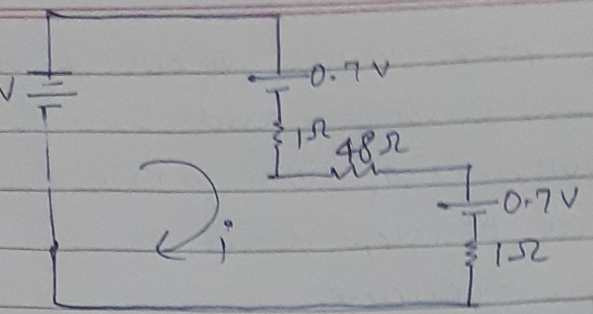
Q (ii)
$V_{out} = I_F \times R_L$
$= 37.8 \times 500 \times 10^{-3} = 18.9$ volt

(iii) $R_F = 0$
thus $I_F = \frac{\cancel{19.3}\ 20}{500} = \cancel{39.4\ mA}\ 40\ mA$

$V_{out} = 20$ volt

Q. 

Calculate current through 48Ω resistor in the given circuit. Assume the diode to ~~the~~ be of silicon and forward resistance each of 1Ω.

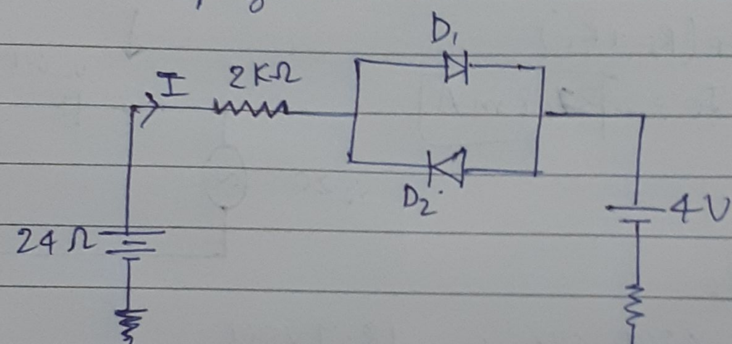


$10 - 0.7 - i - 48i - 0.7 - i = 0$

$$i = \frac{10 - 0.7 - 0.7}{1 + 48 + 1}$$

$= 0.172\ A = 172\ mA$

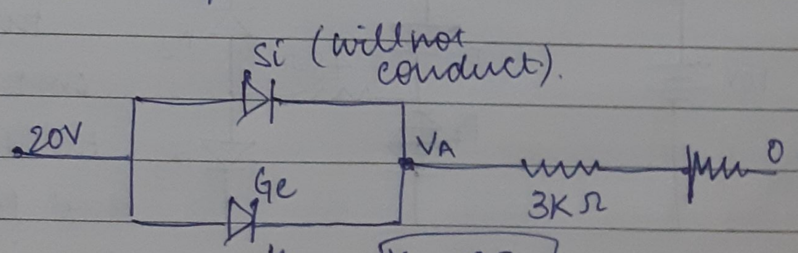
Q. determine the current I for the given circuit. Assume the diodes to be of silicon and forward resistance of zero



Only D_1 is conducting as current is flowing from 24V battery and not 4V battery

$$I = \frac{V}{R} = \frac{24 - 4 - 0.7}{2 \times 1000} = 9.65\ mA$$

Q. find the voltage V_a for the given circuit use simplified model



thus $\boxed{V_A = 19.7}$

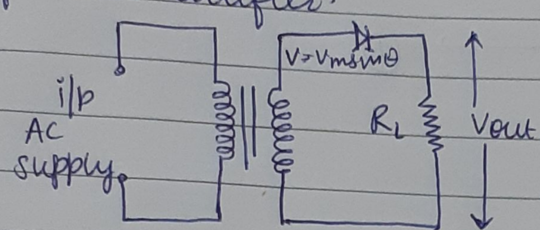
~~rectifiers~~

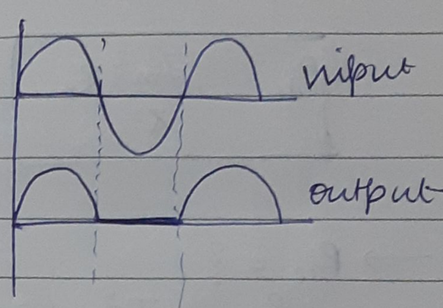
* RECTIFIERS :

(i) Half wave rectifier

(ii) full wave → centre loop / → bridge

(i) Half wave rectifier:





disadvantage

- the output of half wave rectifier is pulsating DC. so filtering is required to produce pure DC

- the AC supply deliver the power only half of the time. so output is low.

* Efficiency of halfwave rectifier.

$$\eta = \frac{\text{output DC power}}{\text{input AC power}} = \frac{P_{dc}}{P_{AC}}$$

$$P_{dc} = I_{dc}^2 \times R_L$$

I_{dc}

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} I \, d\theta \qquad \text{here } I = \frac{V_m \sin\theta}{R_L + R_F}$$

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} \frac{V_m \sin\theta \, d\theta}{R_L + R_F}$$

$$= \frac{V_m}{2\pi(R_L+R_F)}\int_0^{\pi} \sin\theta \, d\theta = \frac{V_m}{2\pi(R_L+R_F)}\left[-\cos\theta\right]_0^{\pi}$$

I_{dc}

$$I_{dc} = \left(\frac{V_m}{R_L + R_F}\right) \cdot \frac{1}{\pi}$$

$$I_{dc} = \frac{I_m}{\pi}$$ here I_m = max current

$$I_m = \frac{V_m}{R_L + R_F}.$$

$$P_{dc} = (I_{dc})^2 R_L$$

$$\boxed{P_{dc} = \frac{I_m^2}{\pi^2} R_L} \longrightarrow (1)$$

→ $P_{ac} = ?$

$$P_{ac} = I_{rms}^2 (R_F + R_L)$$

$$I_{rms} = \sqrt{(\text{mean of } i)^2}.$$

$$i = \frac{V_m \sin\theta}{(R_F + R_L)}$$

$$i = I_m \sin\theta.$$

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2\theta \, d\theta}.$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi}\left(\frac{1-\cos 2\theta}{2}\right) d\theta}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\frac{\theta}{2} - \frac{\sin 2\theta}{4}\right]_0^{\pi}}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \times \frac{\pi}{2}} = \sqrt{\frac{I_m^2}{4}} = \boxed{\frac{I_m}{2}}$$

$P_{ac} = I^2_{rms}(r_F + R_L)$

$$\boxed{P_{ac} = \frac{I_m^2}{4} \times (R_F + R_L)} \longrightarrow (2)$$

from (1) and (2)

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{4}{\pi^2} \times R_L}{R_F + R_L} = \frac{0.406}{\frac{R_F}{R_L} + 1}$$

$R_F <<< R_L$

thus $\frac{R_F}{R_L} = 0$

$$\boxed{\eta = 40.6\%}$$

Q Crystal diode having internal resistance $R_F = 20\Omega$ is used for half wave rectification if the applied voltage is $V = 50 \sin\omega t$ and the load resistance $R_L = 800\Omega$ find

(i) I_m. (ii) I_{dc} (iii) I_{rms}.

(iv) AC input power

(v) DC output power

(vi) DC output voltage

(vii) efficiency of rectification.

ans. $I_m = \frac{50}{820} = \frac{5}{82} = 0.00609\ A$

$I_{dc} = \frac{0.00609 \times \cancel{1000}}{3.14} = 19.39\ mA$

$I_{rms} = \frac{0.00609}{2} = 0.00305\ A$

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$P_{ac} = \frac{(61.9)^2 \times 10^{-6} \times 820}{4}$

$= 785480.05 \times 10^{-6}$

$= 0.78$ watt

$P_{dc} = \frac{61.9 \times 6.19 \times 10^{-6} \times 80\cancel{0}}{\cancel{2} \times 1\cancel{0}}$

$= 0.306$ watt

$V_0 = I_{dc} \times R_c$

$= 15.512$ volt

$\eta = \frac{P_{dc}}{P_{ac}} = \frac{0.306}{0.78} = 39.4\%$

$P_{AC} = 930.25 \times 10^{-6} \times 820$
$= \underline{0.76\ W}$

$V_{DC} = I_{DC} R_L = 19.42 \times 10^{-3} \times 800$
$= \underline{15.5\ V}$

$\eta = \cancel{\frac{0.76}{0.30}} = \cancel{2.53}$ $\frac{0.30}{0.76} = \underline{0.39}$

→ ~~A Full wave Rectifier:~~

Q: A halfwave rectifier is used to supply 50 V DC to a resistance load of 800 Ω. The diode has resistores of 25 Ω. Calculate AC voltage req:

$V_{DC} = 50\ V$
$R_L = 800\ \Omega$
$r_f = 25\ \Omega$

$\frac{V_{out}}{R_L} = I_{DC}$

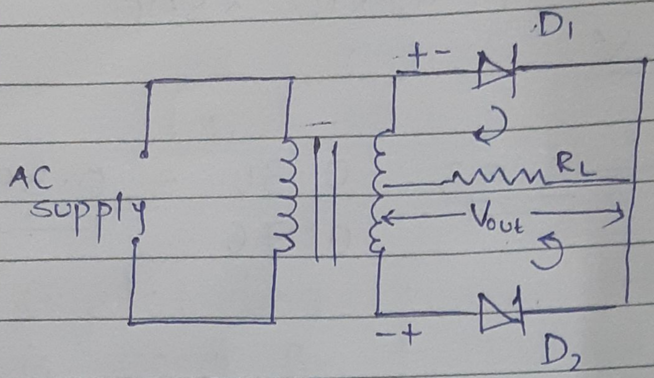
$\therefore I_{DC} = \frac{50}{80} = \boxed{0.0625\ A}$

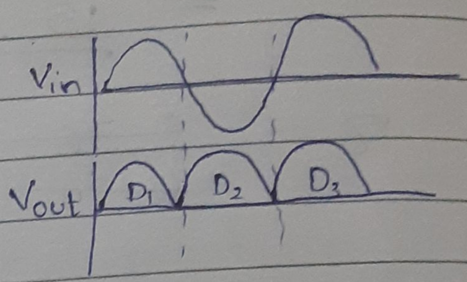
$I_m = 0.0625\ \pi$
$\boxed{I_m = 0.1963\ A}$

$V_m = I_m (R_L + r_f)$
$V_m = 0.1963 \times 825$
$\therefore \boxed{V_m = 162\ V}$

* FULL-WAVE RECTIFIER:

→ Centre-tap full-wave rectifier:





→ Disadvantages:

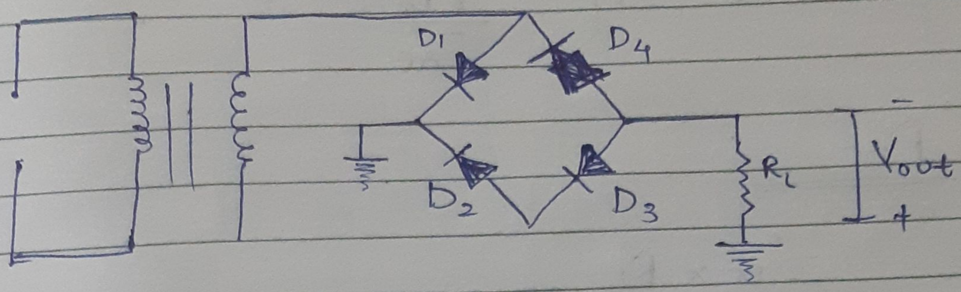
- It is difficult to locate centre-tap on the secondary winding.
- The DC output is small as each diode uses only half of the transformer secondary voltage.

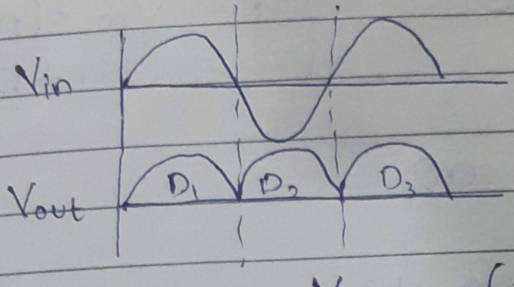
PIV of centre tap full-wave rectifier can be given as:

$PIV = V_m + V_m$ ($\because$ for both halfs, max. voltage is V_m)

$\therefore \boxed{PIV = 2V_m}$

* Full-wave bridge rectifier :





For +ve half D_1 & D_3 are in action while in -ve half D_2 & D_4 are in action

$PIV = V_m$ ($\because$ all diodes are in parallel connectⁿ)

→ Advantages:

- The need for centre-tap transformer is eleminated
- Output is twice that of centre-tap circuit for the same secondary voltage.
- The PIV is one-half that of centre-tap circuit.

→ Disadvantages:

- It requires 4 diodes.
- Voltage drop in internal resistance of rectifying unit will be twice compared to centre-tap circuit.

→ Efficiency of full-wave rectifier :

We know that, $\eta = \dfrac{P_{DC}}{P_{AC}}$

(I) P_{DC} :

$$P_{DC} = I_{DC}^2 \times R_L$$

where $I_{DC} = \dfrac{1}{2\pi}\int_0^{2\pi} i\,d\theta$ $\left(i = \dfrac{V_m \sin\theta}{R_L + r_f} \right)$

$$\therefore I_{DC} = \frac{1}{2\pi}\int_0^{2\pi} \frac{V_m \sin\theta}{R_L + r_f}\, d\theta$$

$$= \frac{V_m}{2\pi(R_L + r_f)} \int_0^{2\pi} \sin\theta\, d\theta$$

$$= \frac{V_m \cancel{(2)}}{\cancel{2}\pi(R_L + R_f)} \int_0^{\pi} \sin\theta\, d\theta$$

$$= \frac{V_m \cdot 2}{\pi(R_L + r_f)}$$

$$\boxed{I_{DC} = \frac{2 I_m}{\pi}} \quad \left(\because I_m = \frac{V_m}{R_L + r_f} \right)$$

$$\therefore \boxed{P_{DC} = 4\left(\frac{I_m}{\pi}\right)^2 . R_L} \quad \text{——— (1)}$$

(II) P_{AC} :

$$P_{AC} = (I_{rms})^2 (R_F + R_L)$$

where $I_{rms} = \sqrt{(\text{mean of } i)^2}$

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but $i = \dfrac{V_m \sin\theta}{R_L + r_f}$

i.e $i = I_m \sin\theta$

$\therefore (I_{rms})^2 = \dfrac{1}{2\pi}\displaystyle\int_0^{2\pi} I_m^2 \sin^2\theta \, d\theta$

$= \dfrac{I_m^2 \cdot \cancel{2}}{2\pi}\displaystyle\int_0^{\pi} \sin^2\theta \, d\theta$

$= \dfrac{I_m^2}{\pi}\displaystyle\int_0^{\pi} \dfrac{1-\cos 2\theta}{2}$

$= \dfrac{I_m^2}{2\pi}[(\pi - 0) - 0]$

$= \dfrac{I_m^2}{2}$

$\therefore \boxed{I_{rms} = \dfrac{I_m}{\sqrt{2}}}$

$\therefore \boxed{P_{AC} = \dfrac{I_m^2 (R_L + r_f)}{2}}$ —— 2

From above 2 eqⁿ's :

$\eta = \dfrac{P_{DC}}{P_{AC}} = \dfrac{\left(\dfrac{2I_m}{\pi}\right)^2 R_L}{\left(\dfrac{I_m}{\sqrt{2}}\right)^2 (R_L + r_f)}$

$\therefore \eta = \dfrac{4/\pi^2 \cdot R_L}{(1/2)(R_L + r_f)} = \dfrac{0.812}{\dfrac{r_f}{R_L} + 1}$

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$$\therefore \boxed{\eta = \frac{0.812}{\frac{r_f}{R_L} + 1}}$$

if $r_f <<< R_L$

$$\boxed{\eta = 81.2\%}$$

Q: Full-wave rectifier uses 2 diodes and internal resistance of each diode is 20 Ω. The transformer (rms) secondary voltage from the centre tap to each end of secondary is 50 V (rms value) and load resistance is 980 Ω.

Find 1) Mean load current
2) Rms value of load current.

$r_f = 20\ \Omega$, $R_L = 980\ \Omega$ $V_{rms} = 50\ V$

$\therefore V_m = V_{rms} \sqrt{2}$

$V_m = 50 \times 1.43$

$\therefore V_m = 70.7\ V$

1) $I_{dc} = \frac{2I_m}{\pi} = 45\ mA$

2) $I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{0.0707}{\sqrt{2}} = 0.050\ A$

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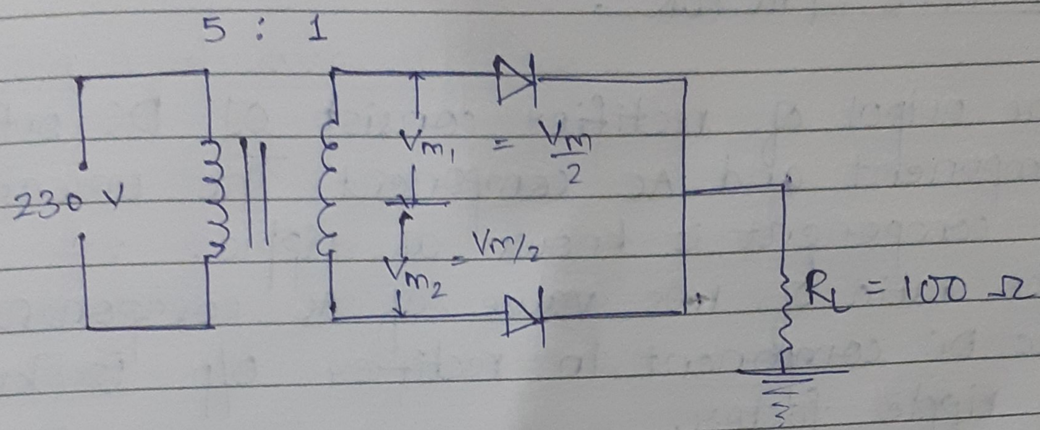
Q: For the given centre-tap circuit, the diodes are assumed to be ideal i.e 0 internal resistance.
Find : 1) DC O/P voltage
2) PIV
3) Rectification Efficiency



5 : 1 is ratio of $N_1 : N_2$

$V_{rms} = 230\ V$ (primary voltage)

V_m ~~Vrms2~~ $= V_{rms}\sqrt{2} = 322\ V$

$V_m = 322/5 \approx 65\ V$ ($\because$ 5 : 1 ratio)

$\therefore V_{m_1} = V_{m_2} = 65/2 = 32.5\ V$

$I_{DC} = \frac{2 I_m}{\pi}$ (here, $I_m = \frac{V_m/2}{R_L + r_f}$)

$I_m = \frac{65/2}{(100+0)} = \frac{0.65}{200}$

$I_m = 0.207\ A$

(1) $V_{out} = I_{DC} \times R_L = 0.207 \times R_L$

$\boxed{V_{out} = 20.7\ V}$

(2) $PIV = V_{m_1} + V_{m_2}$

$= 32.5 + 32.5$

$\boxed{PIV = 65\ V}$

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$$\eta = \frac{0.812}{r_f/R_L + 1}$$

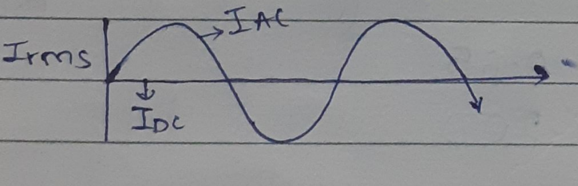
$$\boxed{\eta = 81.2\,\%} \qquad (\because r_f = 0)$$

Ripple Factor :

The output of rectifier consist of DC output component and AC component. The unwanted AC component is known as ripple.
The ratio of rms value of AC component through the DC component in rectifier o/p is known as ripple factor.

$$\therefore \text{Ripple factor} = \frac{I_{ac}}{I_{dc}} \text{ or } \frac{V_{ac}}{V_{dc}}$$

The effectiveness of rectifier depends on magnitude of AC component in o/p. Smaller the ripple factor, more effective is the rectifier.



$$I_{rms} = \sqrt{I_{AC}^2 + I_{DC}^2}$$

now dividing by I_{DC} :

$$\therefore \frac{I_{rms}}{I_{DC}} = \frac{\sqrt{I_{AC}^2 + I_{DC}^2}}{I_{DC}}$$

$$\therefore \frac{I_{rms}}{I_{DC}} = \sqrt{\frac{I_{AC}^2}{I_{DC}^2} + 1}$$

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$$\therefore \boxed{\frac{I_{AC}}{I_{DC}} = \sqrt{\frac{I_{rms}^2}{I_{DC}^2} - 1}} \longrightarrow (1)$$

This is the expression to calculate the ripple factor for halfwave and fullwave rectifier.

For halfwave rectifier:

$I_{rms} = I_m/2$

$I_{DC} = I_m/\pi$

substituting value in eq^n 1,

$$\frac{I_{AC}}{I_{DC}} = \sqrt{\frac{(I_m/2)^2}{(I_m/\pi)^2} - 1}$$

$$= \underline{\underline{1.21}}$$

For fullwave rectifier;

$I_{rms} = I_m/\sqrt{2}$

$I_{DC} = 2I_m/\pi$

substituting value in eq^n 1,

$$\frac{I_{AC}}{I_{DC}} = \sqrt{\frac{(I_m/\sqrt{2})^2}{(2I_m/\pi)^2} - 1}$$

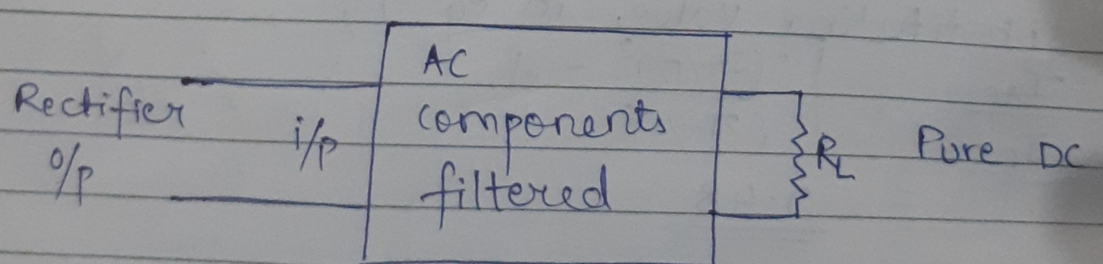
$$= \underline{\underline{0.48}}$$

eg: Power supply A delivers 10 V DC with ripple of 0.5 V rms while the power supply B delivers 25 V DC with a ripple of 1 mV. Which is better power supply?

A	B
$V_{DC} = 10$	$V_{DC} = 25$
$V_{AC} = 0.5$	$V_{AC} = 10^{-3}$
ripple factor $= \frac{V_{ac}}{V_{DC}}$	ripple factor $= \frac{10^{-3}}{25}$
$= \frac{0.5}{10}$	$= 4 \times 10^{-5}$.
$= 0.05$	
i.e 5%	i.e. 0.004 %.

∴ Power supply B is better than power supply A.

Filter Circuit :



Filter Circuit.

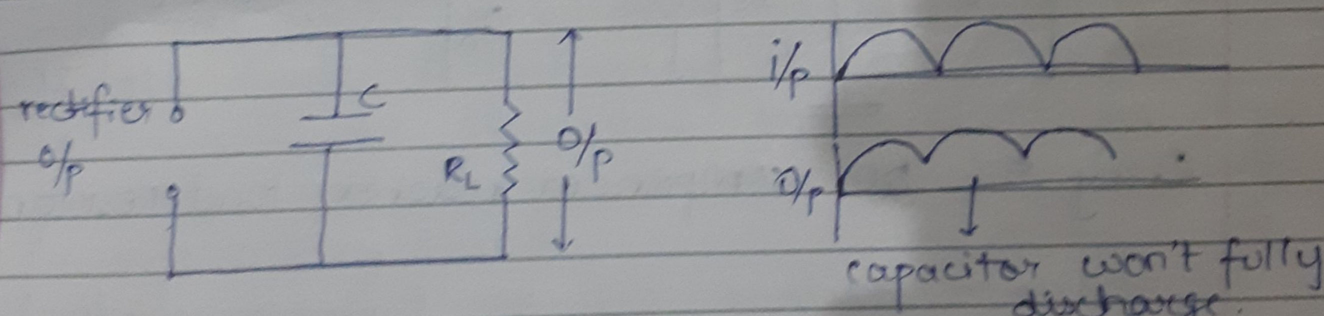
A filter circuit is a device which removes AC components of rectifier o/p but allows the DC components to reach the load (R_L).

- Filter circuit is combination of inductor and capacitor.
- Capacitor passes the AC component & blocks to the DC component whereas the inductor passes DC component & opposes AC component.

* Types of Filter Circuit :

1) Capacitor Filter
2) Choke i/p filter
3) Capacitor o/p filter / π filter

○ Capacitor Filter :

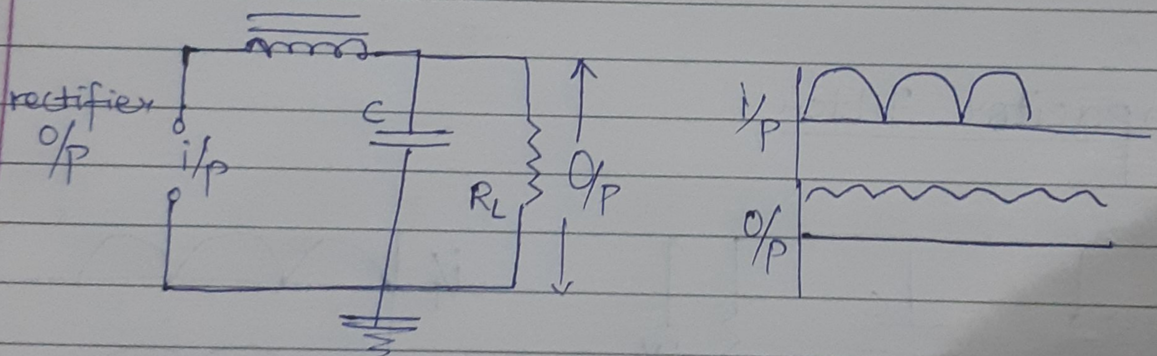


- Circuit consists of capacitor C placed across rectifier o/p in parallel with load resistance (R_L).
- As the rectifier voltage increases, it charges the capacitor. The capacitor is charged to peak value (V_m) of rectifier voltage.
- Now the rectifier voltage starts to decrease so capacitor discharges to load resistance (R_L).

The capacitor does not discharge fully because immediately the next voltage peak comes & recharge the capacitor. This process is repeated again and again which gives the o/p of filter circuit.

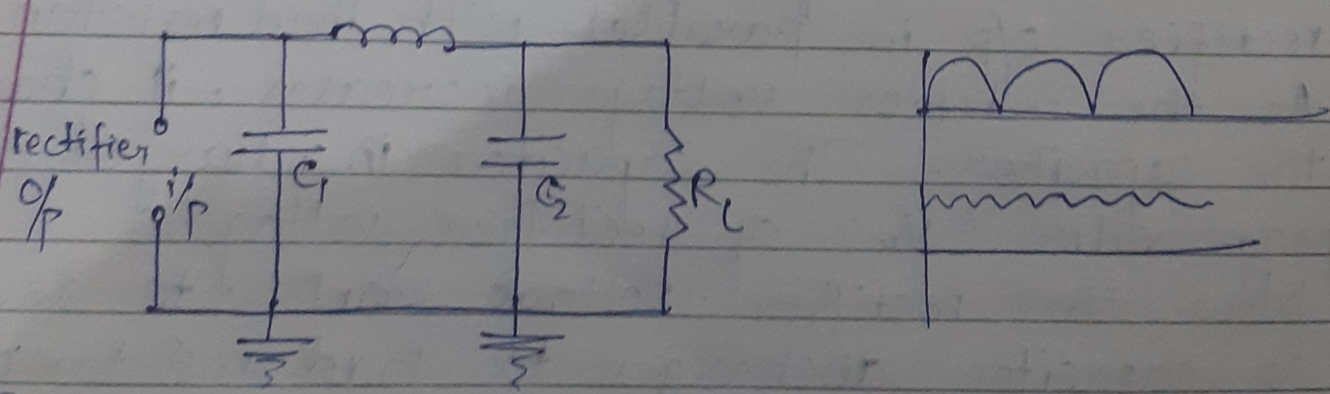
- The capacitor filter is extremely popular because of low cost, small size & good characteristics. It is commonly used in transistor, radio, battery, eliminator.

○ CHOKE INPUT FILTER :



Only 5% DC component reaches load resistance.

○ CAPACITOR INPUT FILTER:



Only 0.001% DC component reached R_L.

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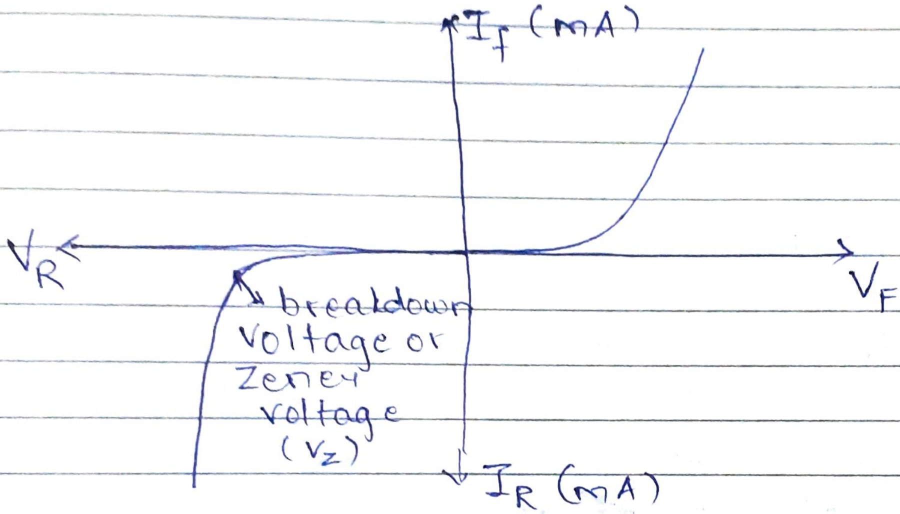
* ZENER DIODE :

Properly doped diode which has sharp breakdown voltage is known as Zener diode.

→ V-I characteristics of Zener Diode :



- The breakdown voltage / zener voltage (V_Z) depends upon the amount of doping.
- If the diode is heavily doped, depletion layer will be thin and breakdown of the junction will occur at low reverse voltage.
On the other hand,
- Lightly doped diode has higher breakdown voltage.

1) Zener diode is always connected in reverse bias

2) Zener diode has sharp breakdown voltage.

3) When it is connected in forward bias, its characteristics is similar to ordinary diode.

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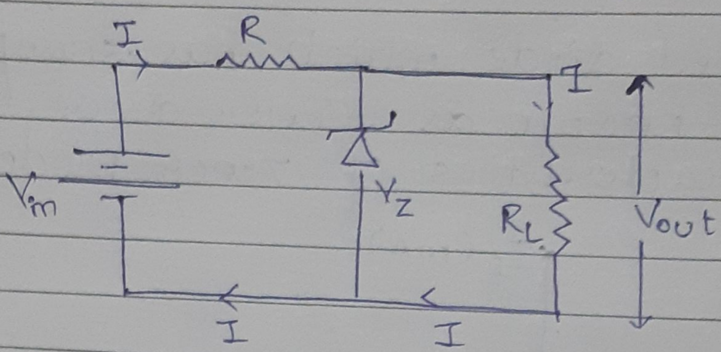
→ Zener Diode as Voltage Regulator :



V_{in} - line voltage
R_L - load resistance.

→ (1) Line Regulation :

- Suppose input voltage increases, it is clear from the circuit diagram that $V_{out} = V_Z$
- The excess voltage is dropped across series resistance R.
- This will cause an increase in current i, the increase in current i comes from increase in I_Z while the value of I_L remains constant.
- So, output voltage remains constant irrespective of changes in input voltage.

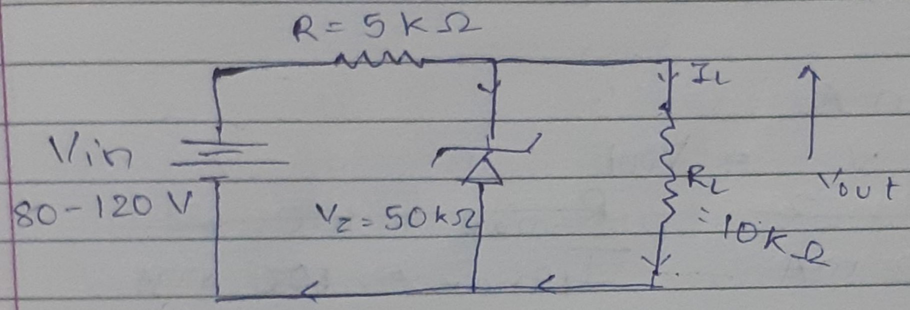
→ (2) Load Regulation :

- Suppose that input voltage is constant but R_L decreases, this will increase I_L. So the output voltage remains constant.

$$\boxed{R = \frac{V_{in} - V_{out}}{I_Z + I_L}}$$

- Examples:

(1) For the given circuit find the maximum & minimum value of Zener diode current.



$V_Z = V_{out} = 50$ V

$\cancel{R = \frac{V_{in} - V_{out}}{I_Z + I_L}}$

$I = \frac{80 - 50}{5} = 6$ mA (min)

$I = \frac{120 - 50}{5} = 14$ mA (max)

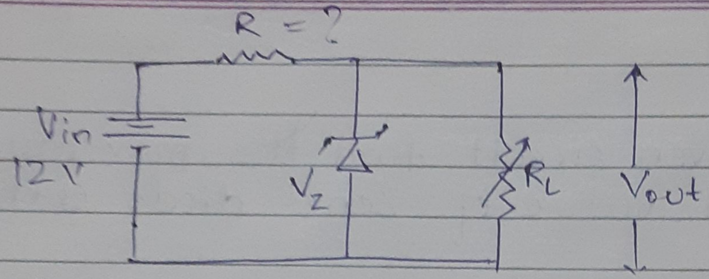
$I_L = \frac{V_{out}}{R_L} = \frac{50}{10 \times 1000} = 5$ mA

$\therefore I_Z = I - I_L = 6 - 5 = 1$ mA $\rightarrow$ min

$I_Z = I - I_L = 14 - 5 = 9$ mA $\rightarrow$ max

(2) 7.2 V Zener is used in given circuit and load current varies from 12 to 100 mA. Find value of series resistance R to maintain a voltage of 7.2 V across the load. Vin is constant at 12 V.

$I_{Z_{min}} = 10$ mA.



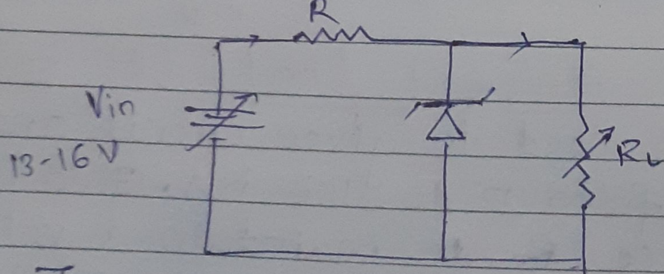
$I_{Z min} = 10$ mA
$V_Z = 7.2$ V $= V_{out}$
~~$R_{Z min} = 12\ \Omega$~~ ~~$R_{Z max} = 100\ \Omega$~~
$I_{L min} = 12$ mA $I_{L max} = 100$ mA

$$R = \frac{12 - 7.2}{\underset{\text{min}}{10} + \underset{\text{max}}{100}} \times 10^{-3}$$

$\therefore R = 43.5\ \Omega$

(4)

(3) 10 V Zener diode is used to regulate voltage across variable load resistor. The input voltage varies b/w 13 V and 16 V and load current changes b/w 10 mA - 85 mA. The value of I_Z (min) is 15 mA. Calculate : i) series resistance R ?



$I_Z = 15$ mA
$V_Z = 10$ V $= V_{out}$

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$$R = \frac{V_{in} - V_{out}}{I_z + I_L}$$

$$= \frac{13 - 10}{15 + 85 \times 10^{-3}}$$

$$= 30\ \Omega$$

(4) $V_z = 18$ V, Voltage across load remains 18 V as long as I_z is maintained b/w 200 mA - 2 A. Find value of R so that Vout remains 18 V while Vin is free to varig b/w 22 V to 28 V

$R_L = 18\ \Omega$

$I_L = \frac{18}{18} = 1$

$$R = \frac{22 - 18}{0.2 + 1}$$

$$R = 3.33\ \Omega$$

4/10/18

8. Basics of Electronics

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TRANSISTORS

Definition : When the third doped element is added to a diode in such a way that 2 P-N junctions are formed, the resulting device is known as transistor.

- Transistor is capable of achieving amplification of weak signals.

- Types : 1) NPN
  2) PNP

- Origin of name - Transistor :

Transistor had 2 PN junctions, one junctn is forward bias and other is reverse bias. The forward bias junction has low resistance path whereas reverse bias junction has high resistance path.
The weak input signal is applied to low resistance path and output is taken from high resistance path.
So, a transistor transfers a signal from low resistance path to high resistance path.
That is why it is named Transistor.
Transistor = Transfer + ~~Register~~ Resistor.

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Transistor Terminals:

Transistor has 3 terminals:

1) Emitter : The section which supplies charge carriers is known as emitter. It is always forward bias wrt base so that it can supply large number of majority charge carriers.

2) Collector : Collector collects the charge carriers. It is always connected in reverse bias.

3) Base : The middle section which forms 2 P-N junctions between Emitter and Collector is known as base.
Base - Emitter junction is forward bias.
Base - Collector junction is reverse bias.

* Facts about Transistor:

1) Transistor has 3 regions - E, B and C.
The base is much thinner than emitter while collector is wider than both emitter and base.

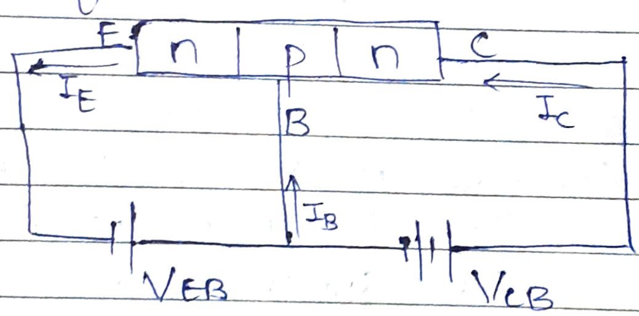
2) The emitter is heavily doped so that it can supply large number of charge carriers to base. The base is lightly doped and passes

most of emitter supplied charged carrier to collector. The collector is moderately doped.

3) The emitter is always forward bias and collector is always reverse bias.

4) During transistor operation, much amount of heat is produced at collector junction. To dissipate this heat, collector is made wider.

* Working of n-p-n transistor :



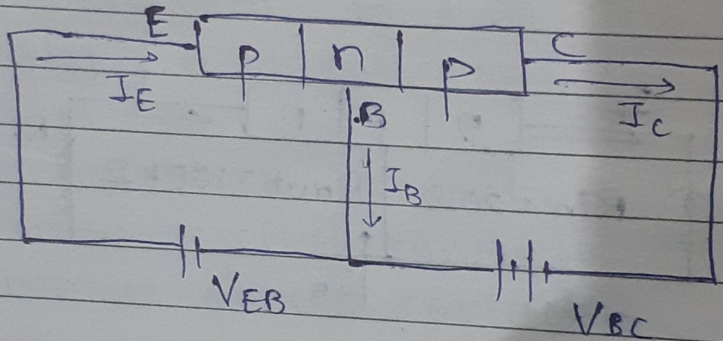
- The emitter-base junct^n is forward bias. The forward bias causes the electrons in n-type of emitter to move towards base.
- This movement of electrons causes current I_E to flow.
- Base is lightly doped. So, only few free charge carriers present in base can combine with emitter supplied charge carrier.
- This electron-hole combination occuring in base region causes current I_B to flow.
- Rest of the electron from the base will more

towards collector. This movement of electrons causes current I_C to flow.

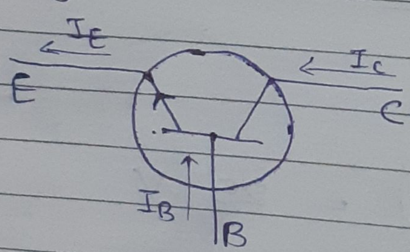
- Current in circuit is given by:

$$I_E = I_B + I_C$$

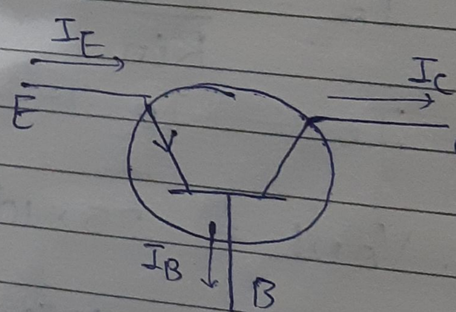
* PNP configuration:



⟹ Symbols:



NPN transistor



PNP transistor

Unit of I_E and I_C is mA and unit of I_B is μA.

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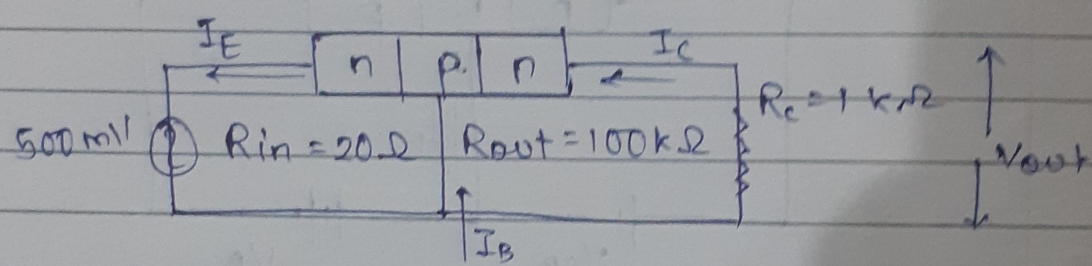
Q: A common base transistor amplifier has input resistance of 20 Ω and output resistance of 100 kΩ. ~~bt~~ The collector load is 1 kΩ. If a signal of 500 mV is applied between emitter and base, find the voltage amplification.



$V_{out} = I_C \times R_C$

$I_E = \dfrac{V_{in}}{R_{in}} = \dfrac{500 \times 10^{-3}}{20} = 25 \times 10^{-3}$ A

$I_C \simeq I_E = 25$ mA

$\therefore V_{out} = 25 \times 10^{-3} \times 10^{3} = 25$ V

Voltage amplificatn $(A_v) = \dfrac{V_{out}}{V_{in}}$

$= \dfrac{25}{500 \times 10^{-3}}$

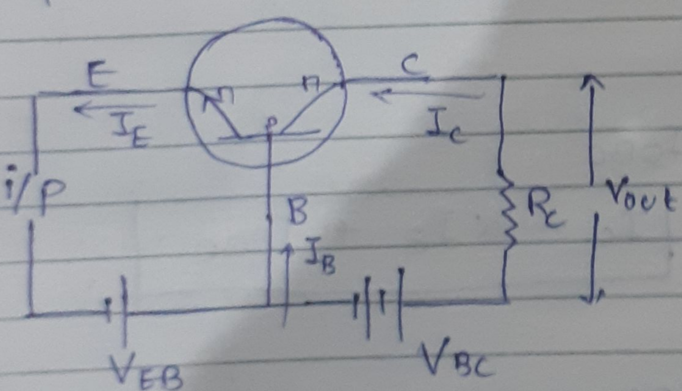
$= \underline{\underline{50}}$

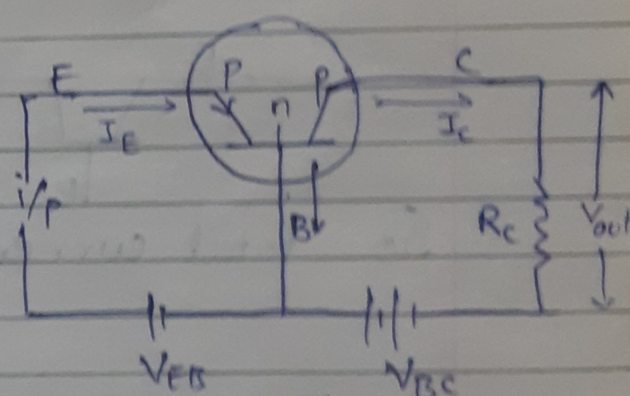
* Transistor Connection :

When a transistor is to be connected in a circuit, we require 4 terminals. 2 for input and 2 for output.
This difficulty is overcome by making one terminal common to both input and output.
Accordingly, a transistor can be connected in 3 ways :

1) Common base connection EBC
2) Common emitter connection BEC
3) Common collector connection ECB

⟹ Common base connection/(CB)





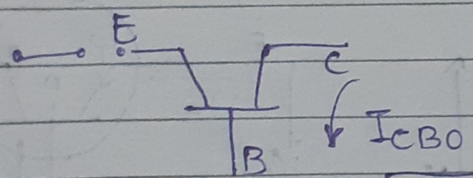
- Current Amplification factor $\alpha = \frac{\Delta I_C}{\Delta I_E}$
(at constant V_{CB})

- Expression for Output current (I_C) :
when ~~am~~ emitter is connected,
$I_C = \alpha I_E$ — (1)
when emitter is not connected;
I_{CBO} (leakage current) flows

∴ Total output current :
$I_C = \alpha I_E + I_{CBO}$
CBO is collector base open emitter

- The entire emitter current does not reach to collector because of electron-hole combination occuring in base region. So, the emitter current which ~~is to co~~ reaches to collector is :
$I_C = \alpha I_E$ —— (1)

- Collector-base juncⁿ is reverse bias so some leakage current flows due to movement of minority charge charriers. This current is known as $I_{Leakage}$ or I_{CBO}.



So total current $\boxed{I_C = \alpha I_E + I_{CBO}}$.

$I_C = \alpha I_E + I_{CBO}$
now replacing I_E by $I_B + I_C$
$(1-\alpha) I_C = \alpha I_B + I_{CBO}$

$$\therefore \boxed{I_C = \frac{\alpha I_B + I_{CBO}}{1-\alpha}}$$

* Examples :

(1) In CB connectⁿ, current amp. factor is 0.9. If $I_E = 1$ mA, determine value of I_B.

$\alpha = 0.9$

$I_C = 0.9$ mA

$\therefore I_B = 1 - 0.9 = \underline{0.1 \text{ mA}}$

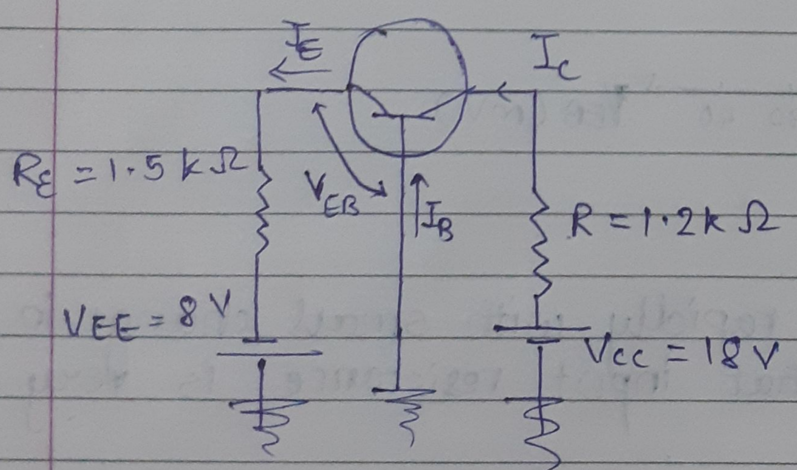
(2) In CB connectⁿ, $I_E = 1$ mA, if emitter circuit is open, $I_{CBO} = 50$ µA. Find total I_C for $\alpha = 0.92$.

$I_C = 0.92 \times 10^{-3} + 50 \times 10^{-6}$

$\underline{I_C = 0.97 \times 10^{-3} \text{ A}}$

(3) For the given ~~to~~ CB circuit, determine I_C and V_{CB}. Assume transistor to be of silicon (i.e $V = 0.7$ V).

$V_{EB} = 0.7$



$V_{EE} = I_E R_E + V_{EB}$

$V_{CC} = I_C R_C + V_{CB}$

From eq^n 1,

$8 = I_E 1500 + 0.7$

$I_E = \frac{7.3}{1500} = 4.86 \times 10^{-3}$ A

$V_{CC} = 4.86 \times 1200 \times 10^{-3} + V_{CB}$

$18 - 5.832 = V_{CB}$

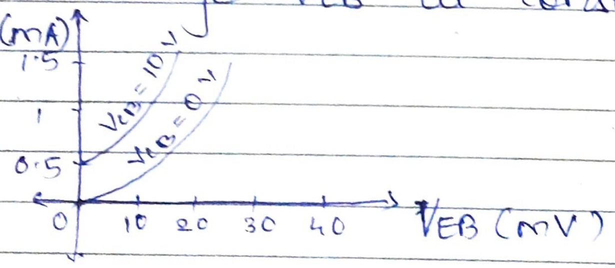
$\therefore V_{CB} = 12.168$ V

* Characteristics of CB Connection:

Complete behaviour of transistor can be described by giving the relation of various current & voltages.

(a) Input Characteristics:

It is the curve between i/p current I_E and input voltage V_{EB} at constant V_{CB}.



Observation:

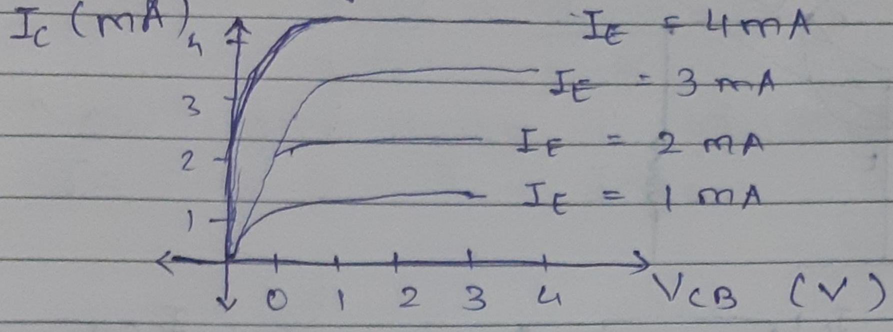
1) I_E increases rapidly with small change in V_{EB}. It means that input resistance is very small.

2) I_E is almost independent of V_{CB}.

Input resistance $r_i = \frac{\Delta V_{BE}}{\Delta I_E}$ at const. V_{CB}

(b) Output Characteristic :

It is a curve between O/p current I_C and output voltage V_{CB} at constant I_B.

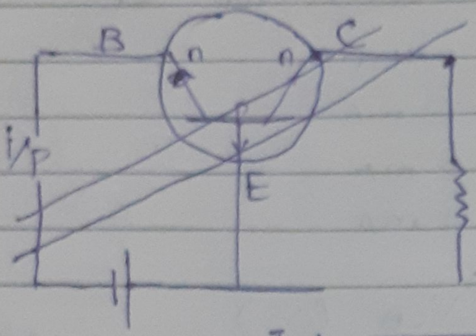


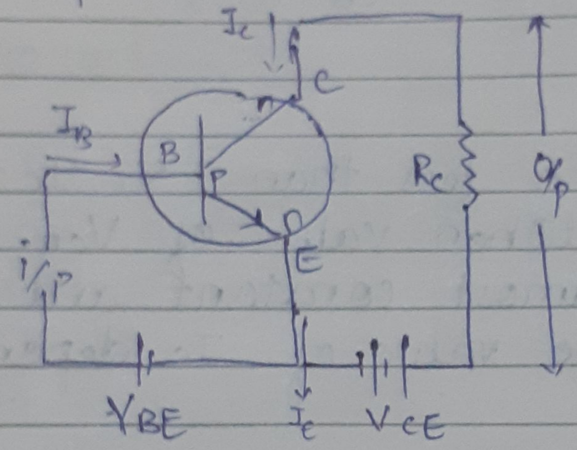
Observation :

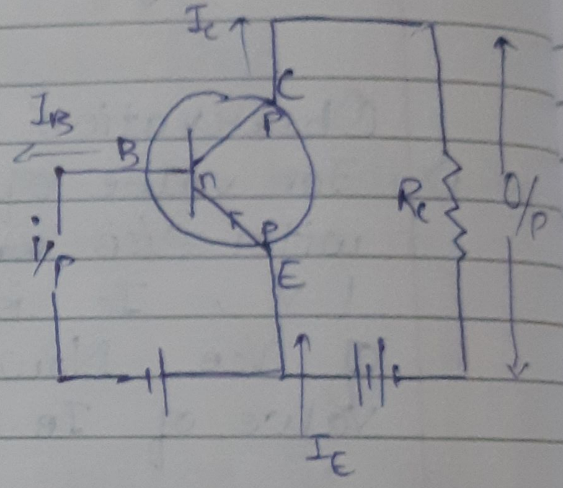
1) For value of V_{CB} less than 1 V, I_C changes with V_{CB}. ~~On~~ When value of V_{CB} is above 1 V, I_C is almost constant and independent of V_{CB}. Now the value of I_C depends on value of I_B.

Output resistance $r_o = \frac{\Delta V_{CB}}{\Delta I_C}$ at const. I_E

⟹ [Common Emitter Connection (CE)]







Current amplication factor $\boxed{(\beta) = \frac{\Delta I_c}{\Delta I_B}}$

$$I_E = I_B + I_c \quad \text{—— (1)}$$

$$\alpha = \frac{\Delta I_c}{\Delta I_E} \quad \text{and} \quad \beta = \frac{\Delta I_c}{\Delta I_B}$$

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

(Dividing eqⁿ 1 by ΔI_c & substituting values)

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

$$\therefore \boxed{\alpha = \frac{\beta}{1+\beta}} \quad \text{and} \quad \boxed{\beta = \frac{\alpha}{1-\alpha}}$$

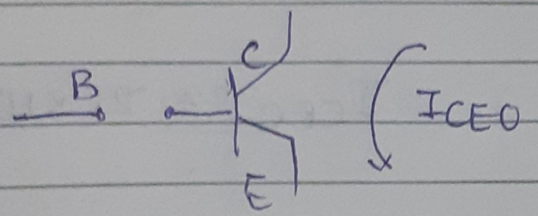
→ Expression for o/p current (I_C) :

$$I_C = \alpha I_E + I_{CBO}$$

$$I_C = \frac{\alpha I_B}{1-\alpha} + \frac{I_{CBO}}{1-\alpha} \quad \text{——— (i)}$$

Now when base is disconnected,

$I_B = 0$, $I_C = I_{CEO}$



Now substituting $I_B = 0$ & $I_C = I_{CEO}$

$$\boxed{I_{CEO} = \frac{I_{CBO}}{1-\alpha}}$$

Now $I_C = \frac{\alpha}{1-\alpha} I_B + I_{CEO}$

$$\therefore \boxed{I_C = \beta I_B + I_{CEO}} \quad \left(\because \beta = \frac{\alpha}{1-\alpha}\right)$$

Examples :

1) Calculate I_E ~~when~~ in transistor for which $\beta = 50$ and $I_B = 20\ \mu A$.

$$\beta = \frac{I_C}{I_B} \qquad \therefore 50 = \frac{I_C}{20\ \mu A}$$

$\therefore I_C = 1000\ \mu A$

$\therefore I_E = I_B + I_C$

$= 1000\ \mu A + 20\ \mu A$

$= 1020\ \mu A$

(2) An NPN transistor at room temperature has its emittor disconnected. Voltage of 5 V is applied between collector & base. With collector +ve current of 0.2 μA flows when base is disconnected & same voltage is applied between collector & emittor, the current is found to be 20 μA. Find α, I_E and I_B when $I_C = 1$ mA.

$I_{CBO} = 0.2 \times 10^{-6}$ A $\qquad I_{CEO} = 20 \times 10^{-6}$ A

$V_{CB} = 5$ V

$\cancel{10^{-3} = \alpha I_E + 0.20 \times 10^{-6}}$

$$I_{CEO} = \frac{I_{CBO}}{1-\alpha}$$

$$\therefore 1-\alpha = \frac{0.2}{20} = \frac{2}{200} = 0.1$$

$$\therefore \boxed{\alpha = 0.99}$$

$$\alpha = \frac{I_C}{I_E} \Rightarrow I_E = \frac{10^{-3}}{0.99}$$

$$\boxed{I_E = 1.01 \text{ mA}}$$

$$1.01 = 1 + I_B$$

$$\therefore \boxed{I_B = 0.01 \text{ mA}}$$

(3) Transistor is connected in common emitter config in which $V_{CC} = 8$ V & voltage drop across R_C connected in collector circuit is 0.5 V ($V_{CE} = 0.5$ V). The value of $R_C = 800\ \Omega$ and $\alpha = 0.96$. Determine:
1) V_{CE}
2) I_B

$$V_{CC} = V_{CE} + I_C R_L$$

$$I_C = \frac{0.5}{800} = 0.625 \text{ mA}$$

$$\cancel{V_{CE} = 8 - 0.625 \times 10^{-3} \times 800}$$

$$V_{CE} = 8 - 0.5 = 7.5 \text{ V}$$

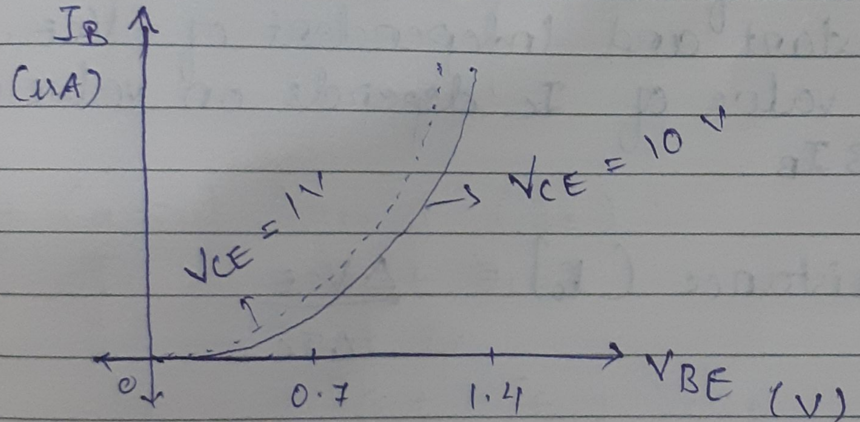
$$\therefore \beta = \frac{I_C}{I_B} \qquad \beta = 24$$

$$I_B = \frac{0.625}{24} = 0.026 \text{ mA}$$

* Characteristic of Common Emitter Connectⁿ :

(1) Input Characteristics :

It is a curve between I_B and V_{BE} i.e input current & input voltage respectively at constant V_{CE}.

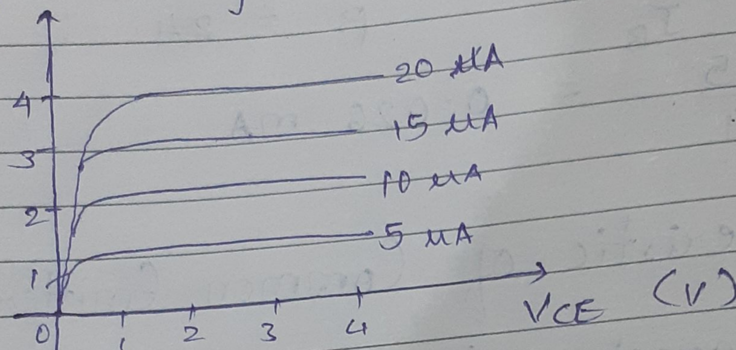


(1) Characteristic is similar to forward bias P-N junction diode.

(2) As compared to CB, I_B increases less rapidly with V_{BE}. It means input resistance of CE is higher than that of common base (CB).

Input resistance $(r_i) = \frac{\Delta V_{BE}}{\Delta I_B}$
(at constant V_{CE})

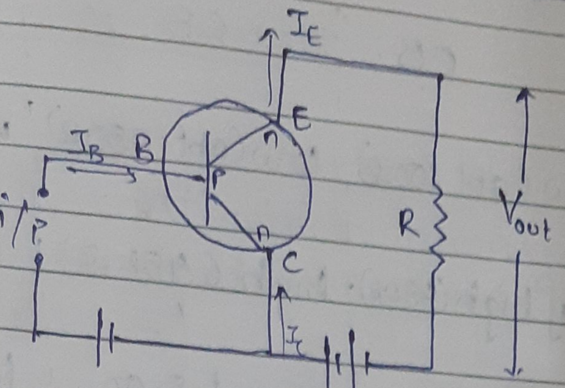
(2) **Output Characteristics :**
It is the curve between output current I_c & output voltage (V_c) at constant I_B.

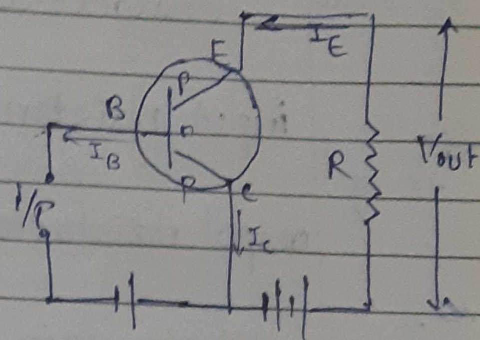


1) When value of V_{CE} is less than 1 V, I_c changes with V_{CE}.
2) When value of V_{CE} is above 1 V, I_c becomes almost constant and independent of V_{CE}.
3) Now the value of I_c depends on value of I_B.
$I_c \simeq \beta I_B$

Output resistance $(r_o) = \frac{\Delta V_{CE}}{\Delta I_C}$

Common Collection Connection : CC





Current Amplificatⁿ factor (γ) $= \dfrac{\Delta I_E}{\Delta I_B}$

→ Relation b/w α, β and γ :

$\alpha = \dfrac{I_C}{I_E}$, $\gamma = \dfrac{I_E}{I_B}$

$\dfrac{I_E}{I_B} = \dfrac{I_B}{I_B} + \dfrac{I_C}{I_B}$

$\therefore \boxed{\gamma = 1+\beta}$ | $||^{ly}$ $\gamma = 1 + \dfrac{\alpha}{1-\alpha}$

$\therefore \boxed{\gamma = \dfrac{1}{1-\alpha}}$

→ Output Current (I_E) :

$I_C = \alpha I_E + I_{CBO}$

$I_E = I_B + I_C$

$\therefore I_E = I_B + \alpha I_E + I_{CBO}$

$\therefore I_E = \dfrac{I_B}{1-\alpha} + \dfrac{I_{CBO}}{1-\alpha}$

$\therefore I_E = \gamma I_B + \dfrac{I_{CBO}}{1-\alpha}$

$\therefore \boxed{I_E = \gamma I_B + \cancel{I_{CBO}}\ I_{CEO}}$

Imp for Practical

* Comparison of transistor connections

Characteristics	CB	CE	CC
input resistance	low (abt 100 Ω)	low (abt 750 Ω)	very high (750 kΩ)
output resistance	very high (450k)	high (45k Ω)	low (50 Ω)
voltage gain	about 150 Ω	about 500	less than 1
applications	for high freq. applications	for audio freq. applicatn	for independently matching