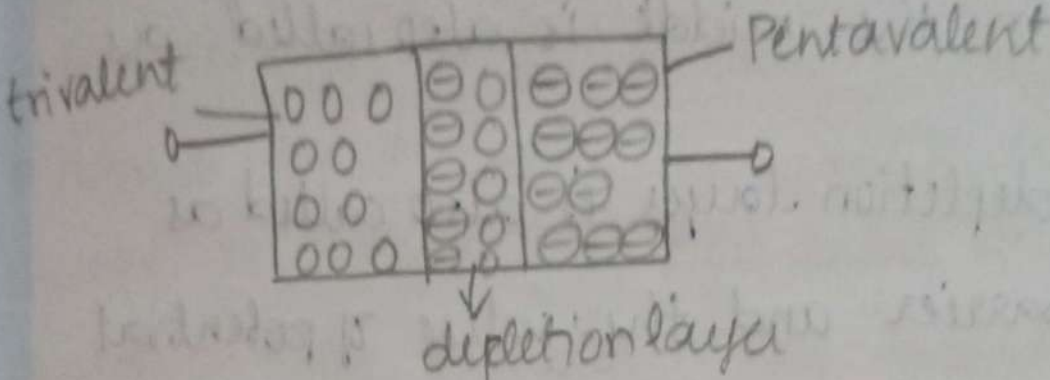
UNIT-IV

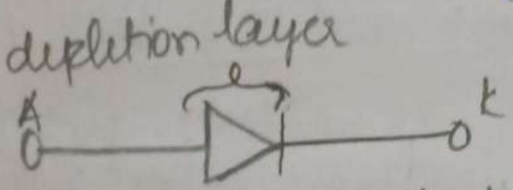
Diode and its characteristics

P-N Junction diode:



Potential barrier – Si – 0.7 V

Ge – 0.3 V



Diode symbol.

→ unidirectional device
→ conduction starts from Anode to cathode in forward bias

→ When a p-type semiconductor is sandwiched with n-type materials (trivalent impurities is added to pentavalent impurities) where p-type material consists of holes as majority carriers and electrons as minority carriers. Where as in n-type materials electrons are majority carriers & holes are minority charge carriers.

→ Whenever, it is joined to together minority carriers in p-type element moves away from the holes towards the junction & holes from n-type elements moves towards junction & thereby these holes & electrons from depletion region or layer in the middle is also called as junction.

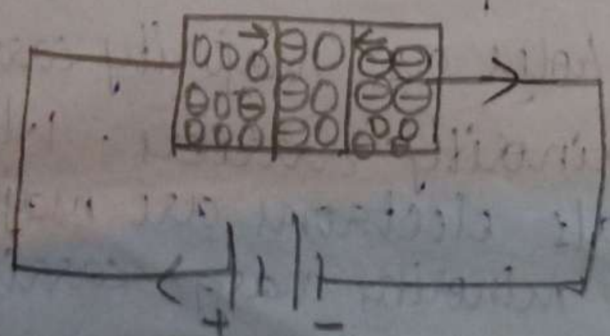
→ Where, depletion layer is also called as potential barrier and the value of potential barrier for silicon is 0·7V & germanium is 0·3V

Diode:

→ P-n junction diode is a two terminal device which allows electric current in only one direction while blocks current in opposite direction.

Working of P-N junction diode:

1. Forward biased mode: forward blocking mode.



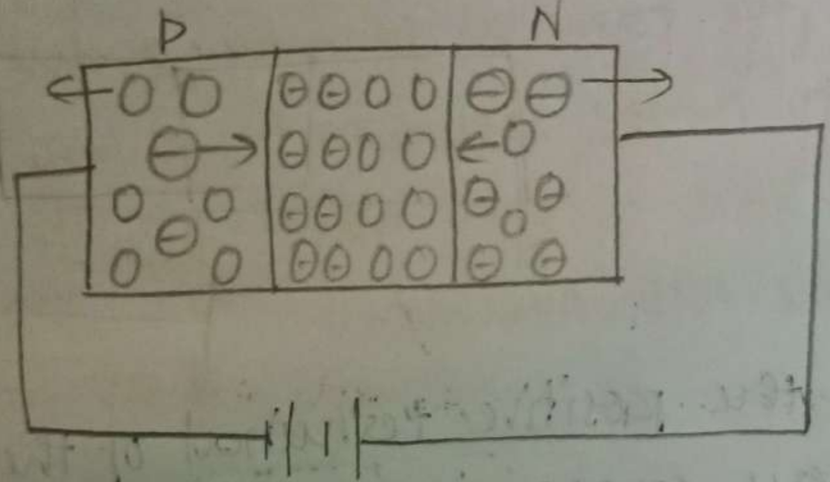
ready to conduct

→ Excitation is called biasing
→ Insulation & resistance is reduced in forward bias
→ Depletion layer becomes thin in forward bias.
→ Whenever a +ve terminal is connected to p-type & -ve terminal to n-type & due to +ve charge to p-type repulsion takes b/w positive charge & holes so holes moves toward's junction & combine with electrons.
→ When the positive terminal of the supply or battery source is connected to p-type (Anode) and negative terminal is connected to n-type (cathode side) of the diode is known as forward bias.
→ In forward bias mode the p-side holes repulse due to charge carriers of positive terminal & in ~~the~~ n-side electron repulse due to charge carriers ~~to~~ of -ve terminal.
→ Due to this the width of depletion layer will be reduced at some forward voltage depletion layer will break known as

Breakdown voltage   Current due to minority charge carriers in F.B is called leakage current

→ In forward biased condition p-n junction diode acts as on switch due to very low resistance of depletion layer.

Reverse biased mode:

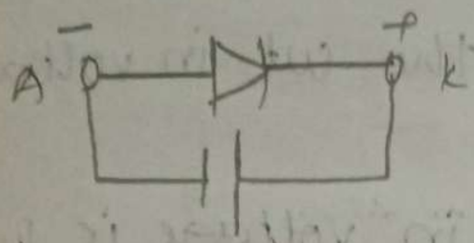


→ The supply or battery when positive terminal is connected to n-side & -ve terminal of battery connected to p-side. This mode is known as reverse biased mode.

→ In the reverse biased condition holes are attracted by the -ve terminal & vice versa

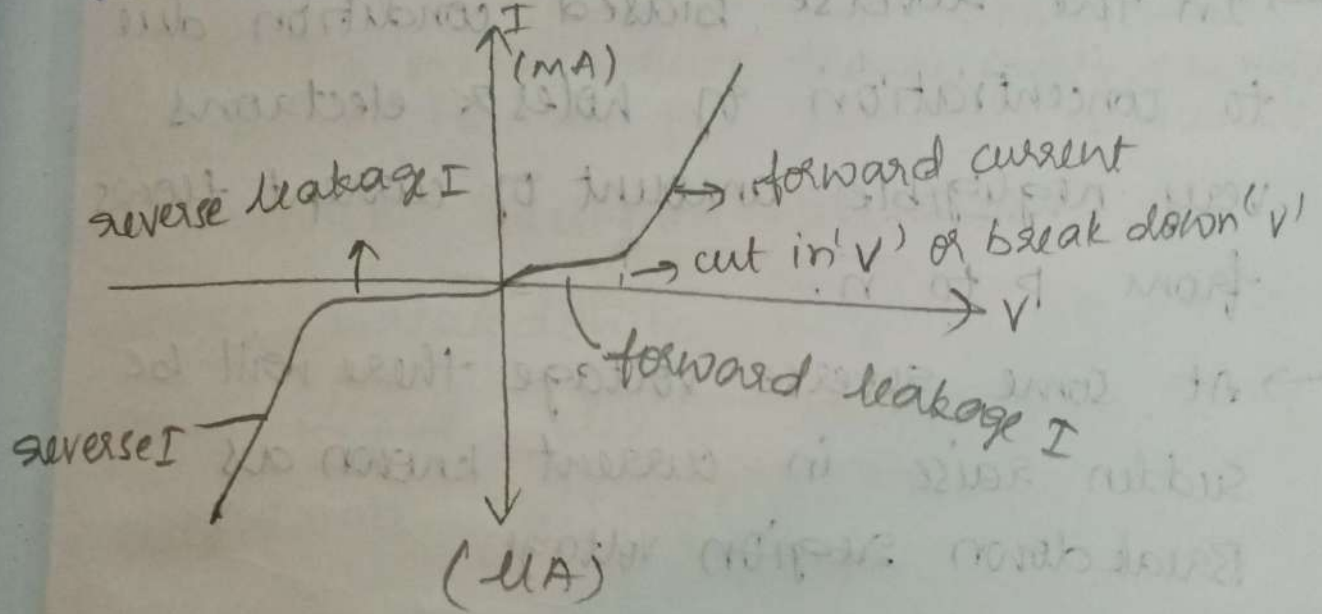
→ Due to this the depletion layer width ↑ses & then there is no conduction from p to n

→ At this instant, p-n junction diode acts as off switch due to very high resistance of depletion layer.



f. conduction gate

V-I characteristics:



In forward conduction state when the voltage is rised the diode conducts.

Cut-in V → Si − 0.7V
Ge − 0.3V

In the forward biased mode a small amount or negligible amount of current flows through the device in the range of micro Amperes to milli A

→ At some forward voltage the current instant-aneously raise known as cut in voltage or break down Voltage.

→ for Germanium the cut-in voltage is 0.3V

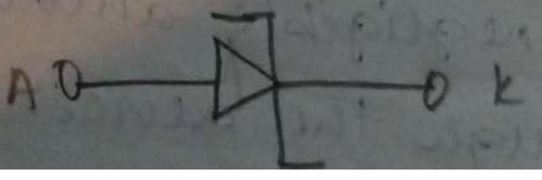
→ for Silicon the cut-in voltage is 0.7V

→ In the reverse biased condition due to concentration of holes & electrons very negligible amount of current flows from p to n.

→ At some reverse voltage there will be sudden raise in current known as Break down ~~region~~ voltage.

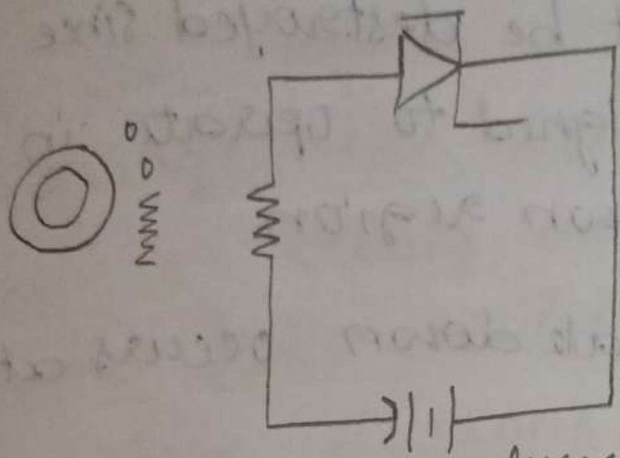
→ The sharp increase in current in reverse direction due to which some heat is produced which may damage the device

Zener diode: Properly or heavily doped compared to normal diode.



1) Avalanch break down mode. properly or
2) Zener break down. Heavily doped

1). Avalanche break down:



we connect resistance in series in order to provide protection as external resistance is applied current is reduced & heat reduces thereby safety is provided

Zener diode is a p-n junction semiconductor device designed to operate in reverse breakdown region. It is a highly doped diode which has sharp breakdown voltage.

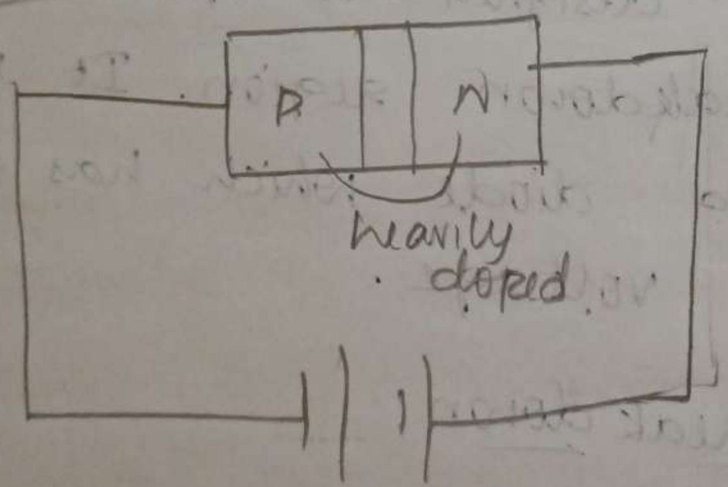
Avalanche break down:

This break down occurs in normal & zener diode at reverse voltage when high amount of reverse voltage is applied to p-n junction diode. free e⁻s gain large amount of energy as a result electric current in diode ↑ses rapidly.

This sudden increase in current may permanantly destroy normal diode however Zener diode may not be destroyed since it is carefully designed to operate in Avalanche break down region.

Avalanche break down occurs at greater than 6V.

2) Zener break down: Electrical intensity depends on width of depletion region

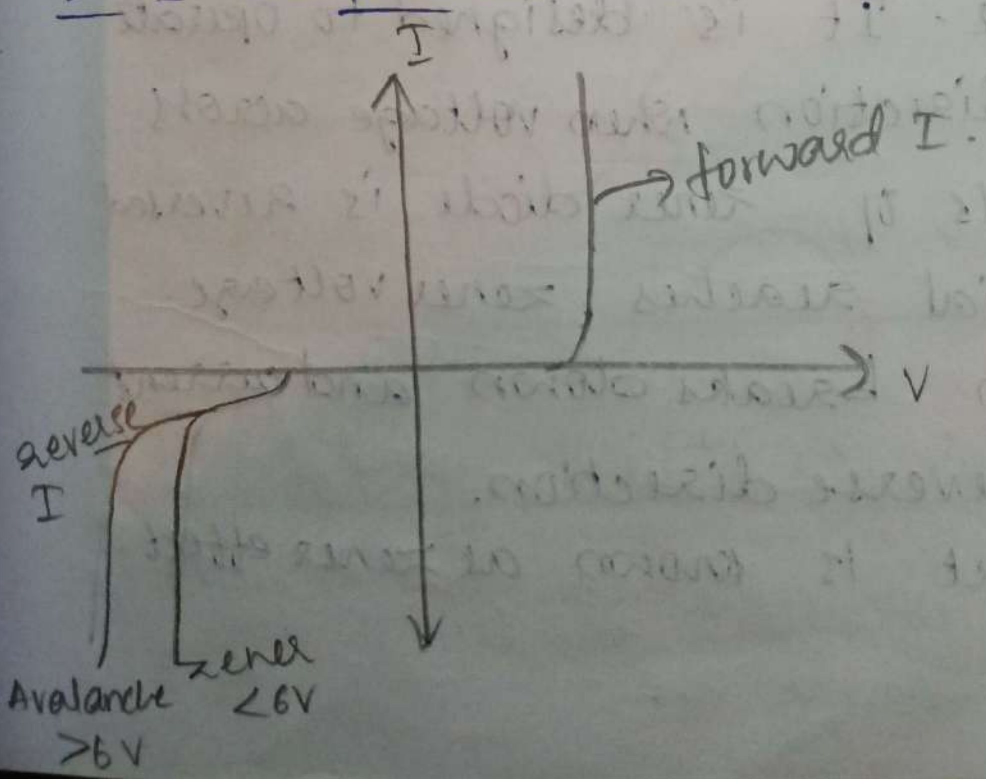


$$\boxed{E = \frac{V}{d}}$$

When high amount of voltage is given electrical field will be produced around the diode and due to the voltage the closely packed electrons with covalent bond in depletion region can be broken easily & electrons can be pulled out & depletion layer vanishes naturally.

When reverse biased voltage applied to diode the moment it reaches close to zener voltage the electric field in depletion layer is strong enough to pull the electrons from covalent bonds of depletion layer. As these electrons gains sufficient energy from electric field there by conduction starts & zener breakdown occurs at voltage less than 6V.

I-V characteristics:



Advantages:

1) Power dissipation capacity is very high.
2) High accuracy
3) Small in size (compact)
4) low cost

Applications:

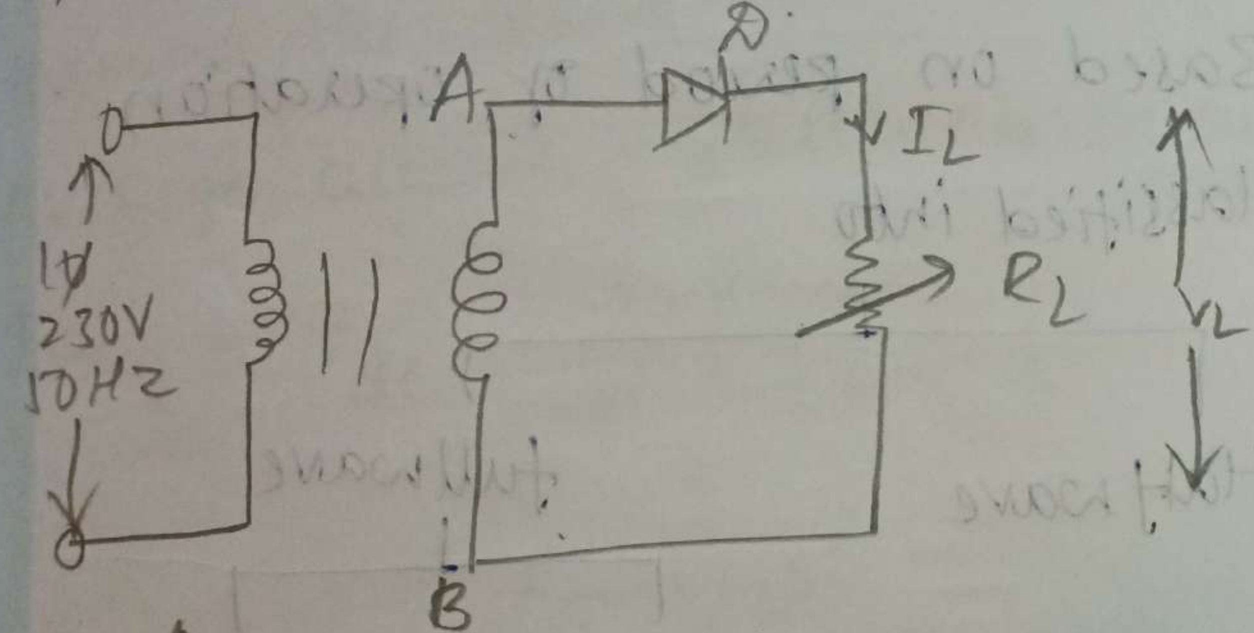
1) It is used in voltage stabilizers.
2) As voltage references
3) Used ~~at~~ in switching operations.
4) Used in various protection circuits.

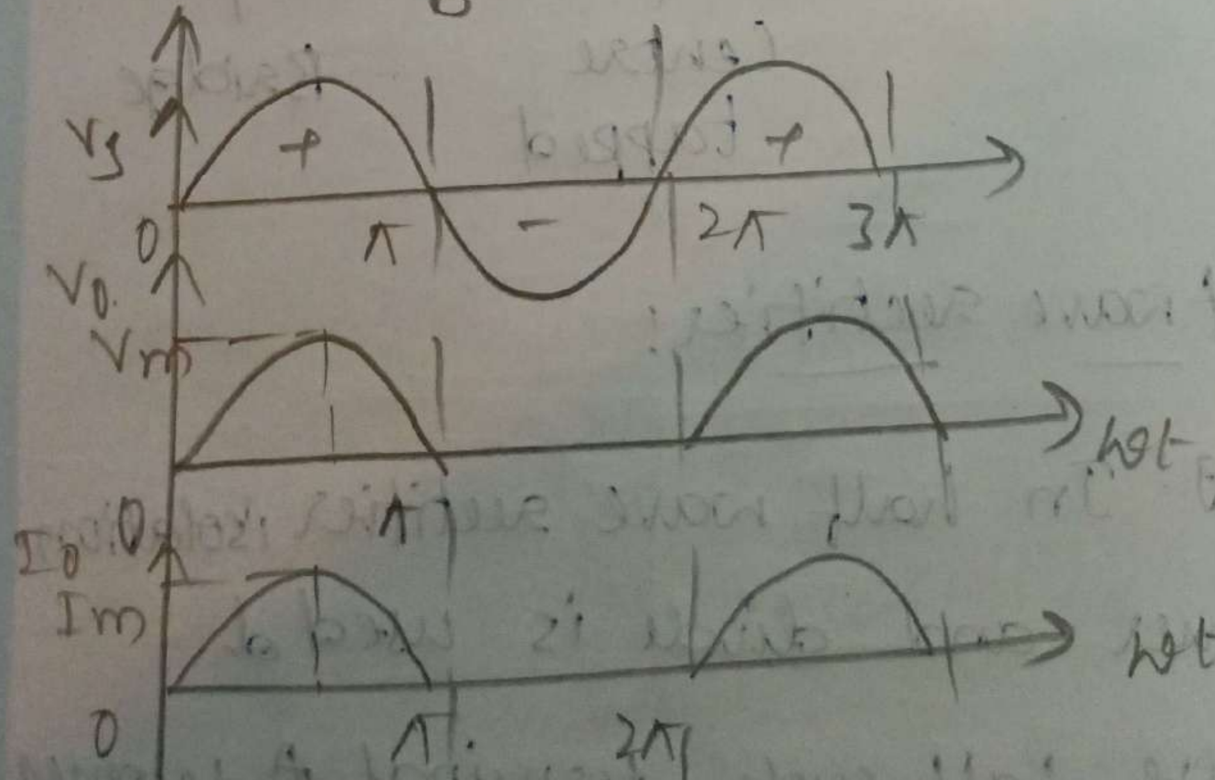
Zener effect:

The zener diode also known as break down diode. It is designed to operate in reverse direction when voltage across the terminals of zener diode is reversed and potential reaches zener voltage. The junction breaks down and current flows in reverse direction.

This effect is known as zener effect.

1ϕ Half wave rectifier :





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Rectifiers: Purpose of recitifier:

It is an electronic device which converts fixed AC to variable dc.

Rectifiers are classified into two types:

1) Based on no of ~~fae~~ phases 1ϕ, 3ϕ

- 1ϕ
- 3ϕ

2) Based on period of operation

Classified into

- Half wave
- fullwave
  - Centre tapped
  - Bridge

1ϕ Half wave rectifier:

Working: In half wave rectifier isolation transformer and diode is used ~~d~~

During +ve half cycle terminal A becomes +ve & B becomes -ve

Now diode is under forward biased mode and now current flows from anode to cathode and then to load.

During -ve half cycle: terminal A becomes -ve & B becomes +ve due to this diode comes into reverse biased mode. Due to which it doesnot allow the current flow through the load.

Average current expression (or) DC output current:

$$I_{oavg} = I_{dc} = \frac{1}{T}\int_0^T I(\omega t)\,d\omega t$$

$$I = I_m \sin\omega t$$

$$= \frac{1}{2\pi}\int_0^{\pi} I_m \sin\omega t\, d\omega t$$

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

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

$$= \frac{I_m}{2\pi}(-(-1)+1)$$

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

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

Average Voltage Expression (or) output dc voltage:

$$V_{oav} = V_{dc} = I_{dc} R_L$$

$$= \frac{I_m}{\pi} R_L \quad \left[\because I_m = \frac{V_m}{R_L}\right]$$

$$= \frac{V_m}{\cancel{R_L}\pi} \cancel{R_L}$$

$$\boxed{V_{oav} = \frac{V_m}{\pi}}$$

output power expression:

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

$$= \frac{I_m^2}{\pi^2} R_L$$

$$= \frac{V_m^2}{R_L^{\cancel{2}}\pi^2} \cancel{R_L}$$

$$\boxed{P_{dc} = \frac{V_m^2}{R_L \pi^2}}$$

Rms value of output current:

$$I_{orms} = I_{ac} = \left\{ \frac{1}{T} \int_0^T I^2(\omega t)\, d\omega t \right\}^{1/2}$$

$$I = I_m \sin \omega t$$

$$= \left\{ \frac{1}{2\pi} \int_0^{\pi} I_m^2 \sin^2 \omega t\, d\omega t \right\}^{1/2}$$

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

$$= \left\{ \frac{I_m^2}{4\pi} \left[(\omega t)_0^{\pi} - \left(\frac{\sin 2\omega t}{2} \right)_0^{\pi} \right] \right\}^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi} \left[\pi - 0 - \frac{1}{2} (\sin 2\pi - \sin 0) \right] \right]^{1/2}$$

$$= \left\{ \frac{I_m^2}{4} \right\}^{1/2}$$

$$\boxed{I_{orms} = \frac{I_m}{2} = I_{ac}}$$

$$V_{orms} = V_{ac} = I_{ac} R_L = \frac{I_m R_L}{2}$$

$$= \frac{V_m}{2 R_L} R_L$$

$$\boxed{V_{orms} = V_{ac} = \frac{V_m}{2}}$$

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$$P_{ac} = I_{ac}^2 R_L$$

$$= \frac{I_m^2}{4} R_L$$

$$= \frac{V_m^2}{4R_L^2} R_L$$

$$\boxed{P_{ac} = \frac{V_m^2}{4R_L}}$$

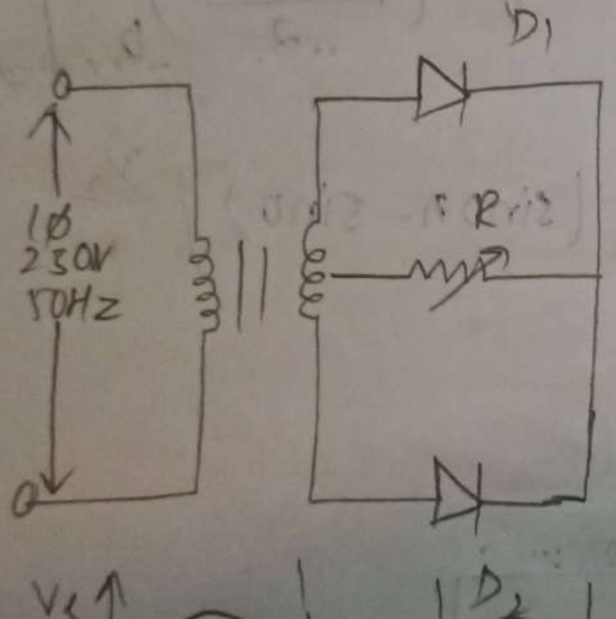
$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\frac{V_m^2}{R_L \pi^2}}{\frac{V_m^2}{R_L 4}} = \frac{4}{\pi^2} = 40.6\%$$

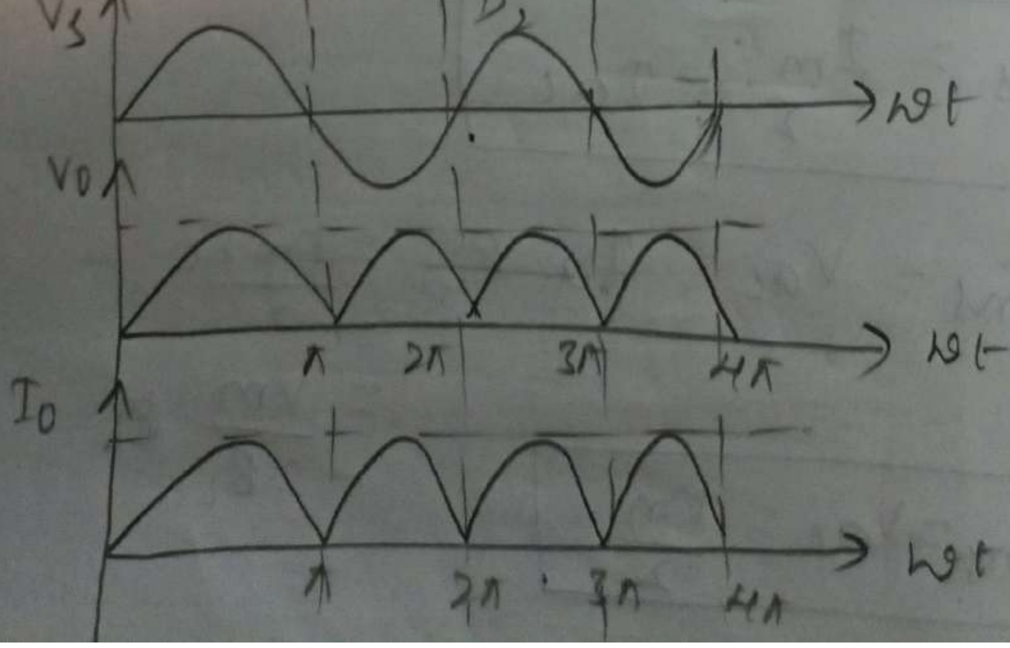
$P.I.V = V_m$

ripple factor $= \sqrt{\left(\frac{rms}{avg}\right)^2 - 1}$

ripple factor $= 1.21$.

full wave centre tapped rectifier:-

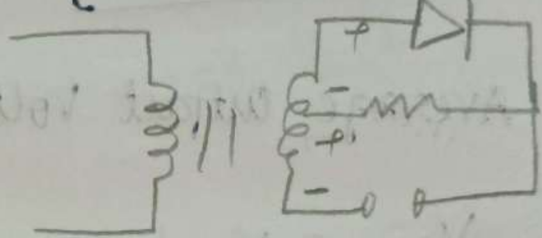




circuit consisting of two diodes D_1 & D_2
circuit will be operated during both +ve halfcycle as well as -ve half cycle

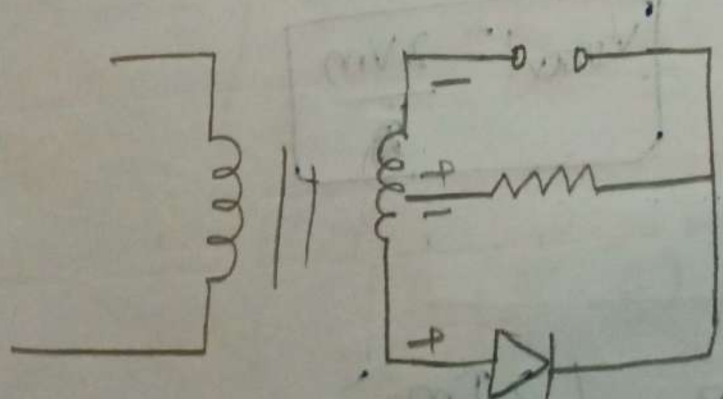
(i) Positive Halfcycle:

During +ve halfcycle diode D_1 gets forward biased and D_2 will be open circuited since it is reverse biased and now current flows through D_1 & then to load. And D_2 acts as open switch since it is reverse biased.



(ii) Negative halfcycle:

During -ve halfcycle diode D_2 conducts current through the load & D_1 remains open circuited since it is reverse biased.



Avg output current expression:

$$I_{oav} = I_{dc} = \frac{1}{T}\int_0^T I_m \sin\omega t \, d\omega t$$

$$= \frac{1}{\pi}\int_0^{\pi} I_m \sin wt \, dt$$

$$= \frac{1}{\pi} I_m \int_0^{\pi} \sin wt \, dt$$

$$= \frac{1}{\pi} I_m \left(-\cos wt\right)_0^{\pi}$$

$$= \frac{1}{\pi} I_m (2)$$

$$\boxed{I_{dc} = \frac{2 I_m}{\pi}}$$

Average output voltage (V_{oav}):

$$V_{oav} = V_{dc} = I_{dc} R_L = \frac{2 I_m}{\pi} R_L$$

$$= \frac{2V_m}{\pi \cancel{R_L}} \cancel{R_L}$$

$$\boxed{V_{oav} = \frac{2V_m}{\pi}}$$

output power

$$P_{dc} = I^2_{dc} R_L = \left(\frac{2 I_m}{\pi}\right)^2 R_L$$

$$= \frac{4 I^2_m}{\pi^2} R_L$$

$$= \frac{4V_m^2}{\pi^2 R_L^{\cancel{2}}} \cancel{R_L}$$

$$\boxed{P_{dc} = \frac{4V_m^2}{\pi^2 R_L}}$$

AC component (or) I_{rms} (or) I_{ac}:

$$I_{rms} = I_{ac} = \left\{ \frac{1}{T} \int_0^T I_m^2 \sin^2 \omega t \, d\omega t \right\}^{1/2}$$

$$= \left\{ \frac{1}{\pi} \int_0^\pi I_m^2 \sin^2 \omega t \, d\omega t \right\}^{1/2}$$

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

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

$$= \left[\frac{I_m^2}{2\cancel{\pi}} (\cancel{\pi} - 0) \right]^{1/2}$$

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}} = I_{ac}}$$

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$$V_{o\,rms} = V_{ac} = I_{ac} R_L$$

$$= \frac{I_m}{\sqrt{2}} R_L$$

$$= \frac{V_m}{\sqrt{2}\,\cancel{R_L}} \cancel{R_L}$$

$$\boxed{V_{o\,rms} = V_{ac} = \frac{V_m}{\sqrt{2}}}$$

$$P_{ac} = I_{ac}^2 R_L = \frac{I_m^2}{2} R_L = \frac{V_m^2}{2 R_L^{\cancel{2}}} \cancel{R_L}$$

$$\boxed{P_{ac} = \frac{V_m^2}{2R_L}}$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\dfrac{4V_m^2}{\pi^2 R_L}}{\dfrac{V_m^2}{2 R_L}} = \frac{8}{\pi^2} = 81.05\%$$

$$\boxed{\eta = 81.05\%}$$

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

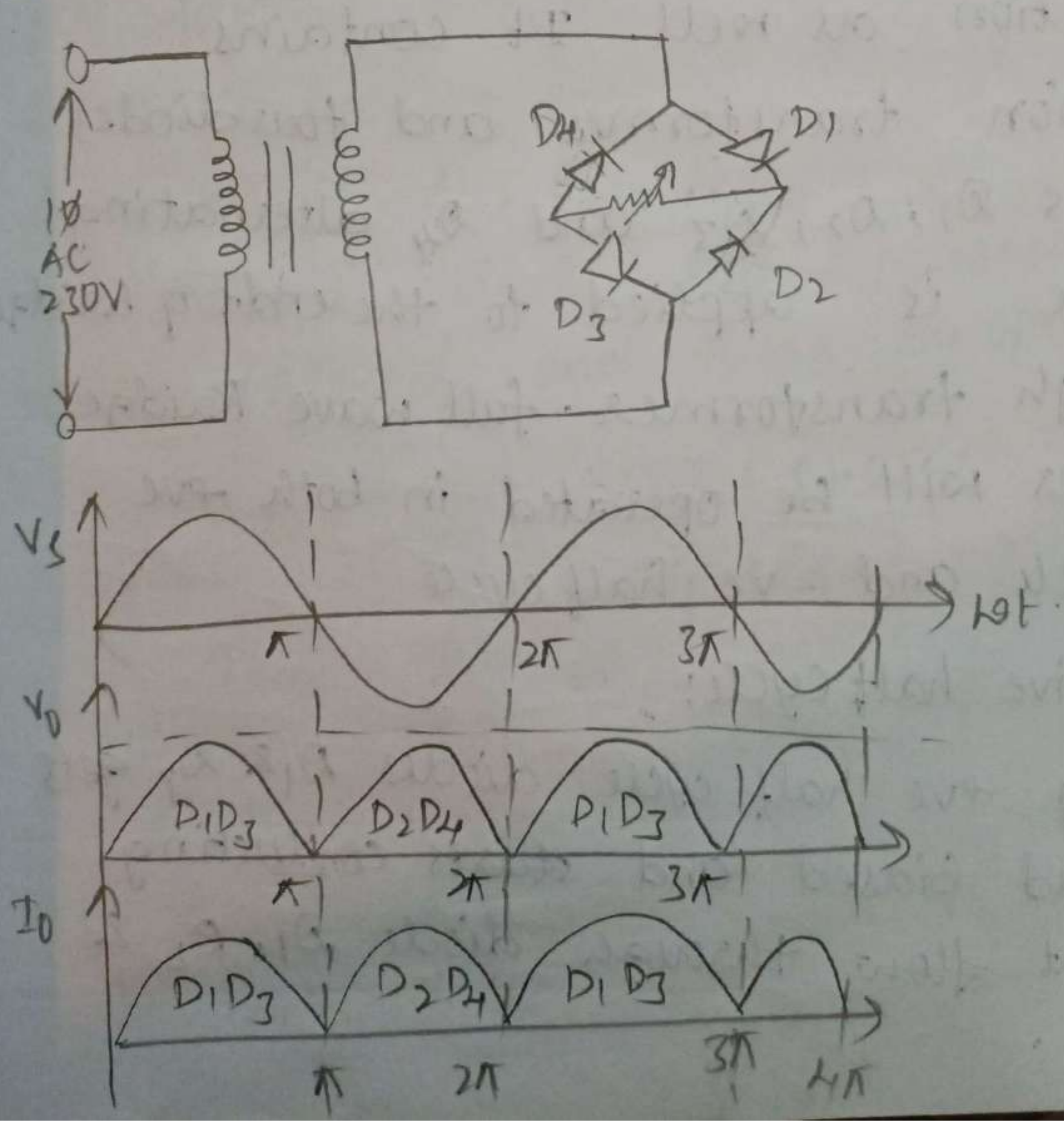
$$\boxed{\text{ripple factor} = \sqrt{\left(\frac{rms}{avg}\right)^2 - 1}}$$

Ripple factor:
The unwanted AC component present in desired output is known as ripple factor.

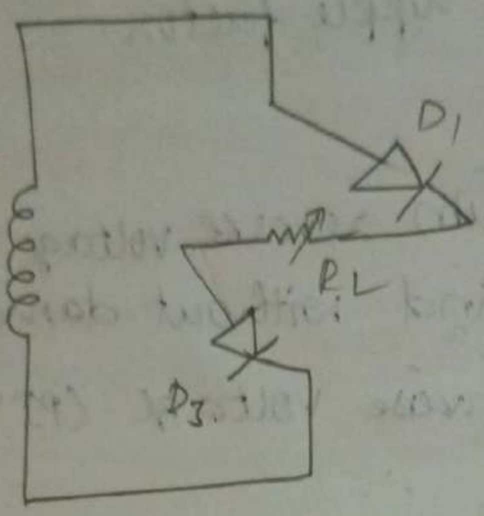
Peak inverse Voltage:
It is the maximum reverse voltage that diode can with stand without damage is known as Peak Inverse Voltage (PIV)

$\boxed{PIV = 2V_m}$

full wave Bridge rectifier:



Case(i) -ve:



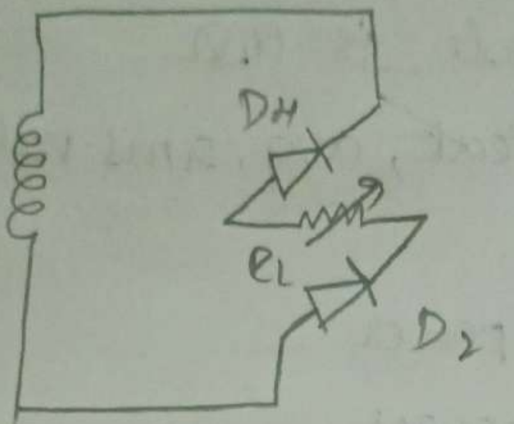
The full wave operation can be operation can be obtained without the bridge connection as well. It contains isolation transformer and four diodes that is D_1, D_2, D_3 and D_4 alternating voltage is applied to the ends of bridge through transformer. full wave Bridge rectifier will be operated in both +ve halfcycle and -ve half cycle

(i) Positive half cycle:

During +ve half cycle diodes D_1 & D_3 gets forward biased and starts conducting current flow through diode D_1, R_L & D_3.

Whereas D_2 & D_4 are reverse biased there by open circuited.

case(ii) Negative half cycle.



During -ve half cycle diodes D_2 & D_4 gets forward biased and there by it starts conducting current through load from diode D_2, R_L, D_4

Whereas diode D_1 & D_3 remains reverse biased and there by open circuited.

$$V_{oav} = \frac{2V_m}{\pi} \qquad \eta = 81.05\%$$

$$\text{ripple factor} = \sqrt{\left(\frac{rms}{avg}\right)^2 - 1}$$

$$I_{oav} = \frac{2I_m}{\pi}$$

$$\boxed{PIV = V_m}$$

$$P_{ac} = \frac{V_m^2}{2R_L} \qquad V_{orms} = \frac{V_m}{\sqrt{2}}$$

$$P_{dc} = \frac{4V_m^2}{\pi^2 R_L} \qquad I_{orms} = \frac{I_m}{\sqrt{2}}$$

Q) A sinusoidal voltage of peak amplitude of 20 volts is applied to a half wave reactifier using p.n junction diode the load resistance is 1000Ω. the forward resistance of diode is 10Ω

calculate (i) Peak, avg, rms values of load current.

(ii) Dc output power

(iii) Ac input power.

(iv) rectifier efficiency.

(V) PIV.

$V_m = 20V$, $R_L = 1000\Omega$, $R_f = 10\Omega$

$$I_m = \frac{V_m}{R_L + R_f} = \frac{20}{1000+10} = 0.0198$$

$$I_{orms} = \frac{I_m}{2} = \frac{0.0198}{2} = 9.5 \times 10^{-3}$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{0.019}{3.14} = 6.050 \times 10^{-3}$$

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

$$= (6.050 \times 10^{-3})^2 (1010)$$

$$= 0.0369 W$$

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

$$= (9.5 \times 10^{-3})^2 (1000+10)$$

$$= 0.091 W$$

$$\% \eta = \frac{P_{dc}}{P_{ac}} \times 100 = \frac{0.0369}{0.091} \times 100$$

$$= 40.6 \%$$

$PIV = V_m = 20V$

Q) A full wave rectifier uses load resistor of 1200 Ω a forward resistance of diode is 8Ω sinewave of peak voltage is 30V applied to each diode calculate

(i) Max, DC, rms load currents.

(ii) DC output power

(iii) AC input power

(iv) Rectifier efficiency

$R_L = 1200\,\Omega$. $R_f = 8\,\Omega$.

$V_m = \cancel{8\Omega}\ 30V$.

$I_{max} = \dfrac{V_{max}}{R_L + R_f}$

$= \dfrac{30}{1200+8}$

$= \dfrac{30}{1208}$

$I_{max} = 0.0248\ A$.

$I_{dc} = \dfrac{2 I_m}{\pi}$

$I_{dc} = \dfrac{2(0.0248)}{3.14}$

$= 0.0157$

$I_{rms} = \dfrac{I_m}{\sqrt{2}} = 0.0175\ A$

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

$$= (0.0157)^2 (1208)$$

$$P_{dc} = 0.2977 \, W$$

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

$$= (0.0175)^2 (1208)$$

$$P_{ac} = 0.36995 \, W$$

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100$$

$$= \frac{0.2977}{0.36995} \times 100$$

$$= 80.4\%$$

Q) A sinusoidal peak voltage is 14.4V which is applied to half wave rectifier with the load of 1000Ω & it has forward resistance of 10Ω determine (i) Peak, Rms, Avg values of current (ii) Dc & Ac power (iii) η of HWR

$V_m = 14.4V$ $R_L = 1000\Omega$ $R_f = 10\Omega$

(iv) Ripple factor.

(i) Peak current.

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

$$= \frac{14.4}{1010} = 0.0142 A.$$

$$I_{rms} = \frac{I_m}{2} = \cancel{0.071} = 7.1 \times 10^{-3}.$$

$$I_{avg} = \frac{I_m}{\pi} = \frac{0.0142}{3.14}.$$

$$I_{dc} = 4.522 \times 10^{-3}$$

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

$$= 4.522 \times 10^{-3} \times 4.522 \times 10^{-3} (1010)$$

$$= 0.0206 W$$

$P_{ai} = (7.1 \times 10^{-3})^2 (1010)$

$= 0.0509. \Rightarrow \eta = \frac{0.0206}{0.0509} \times 100$

$\eta = 40.4.$

$\text{Ripple factor} = \sqrt{\left(\frac{I_{rms}}{I_{avg}}\right)^2 - 1}.$

$= \sqrt{\left(\frac{0.007}{0.0044}\right)^2 - 1}$

Ripple factor $= 1.21$ $\quad = \sqrt{\left(\frac{7.1 \times 10^{-3}}{4.522 \times 10^{-3}}\right)^2 - 1}$

Q) A pure sinosoidal maximum voltage is 15.4V ~~which~~ is applied to a full wave rectifier with the load of $1.2 k\Omega$ & it has forward resistance of 14Ω determine

(i) max, rms, avg values of current.

(ii) DC & AC power.

(iii) η of FWR.

$V_m = 15.4V,$ $R_L = 1.2 \times 10^3 = \frac{12}{10} \times 10^3$

$= 1200$

$R_f = 14\,\Omega$

$$I_m = \frac{V_m}{R_L + R_f} = \frac{15.4}{1214} = 0.0126A$$

$$I_{dc} = \frac{2I_m}{\pi} = \frac{2 \times 0.0126}{3.14}$$

$$= 8.025 \times 10^{-3} A$$

$$I_{ac} = \frac{I_m}{\sqrt{2}} = 8.909 \times 10^{-3}$$

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

$$= (8.025 \times 10^{-3})^2 (1214)$$

$$= 0.078\ AW$$

$$P_{ac} = I_{ac}^2 (1214)$$

$$= 0.0963\ W$$

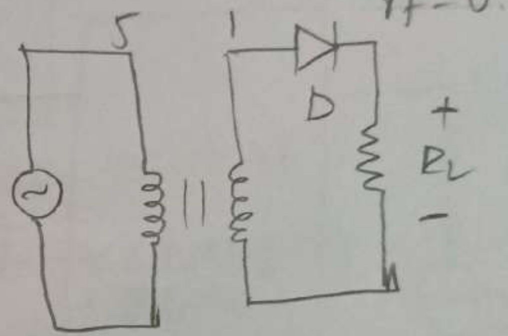
$$\eta = \frac{0.078}{0.096} = 0.812 \times 100$$

$$= 81.2\%$$

ripple factor = $\sqrt{\left(\frac{8.909\times10^{-3}}{8.025\times10^{-3}}\right)^2 - 1}$

$= 0.48$

8) An ac supply of 230V is applied to a half wave rectifier through a transformer find.



Vdc, η, PIV.

(i) DC output voltage.

(ii) Efficiency.

(iii) Peak inverse voltage.

$\boxed{1.110}$

$\boxed{\text{DC output voltage} = \sqrt{2}\, V_{ac}}$

$\boxed{1.2321 - 1}$

$= \sqrt{2} \times 230$

$= 325.267V.$

DC output voltage = 325.267V.

Im =

$R_f = 0.$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{dc}^2 (R_L + R_f)}{I_{ac}^2 (R_L + R_f)} = \frac{I_{dc}^2 (R_L + 0)}{I_{ac}^2 (R_L + 0)}$$

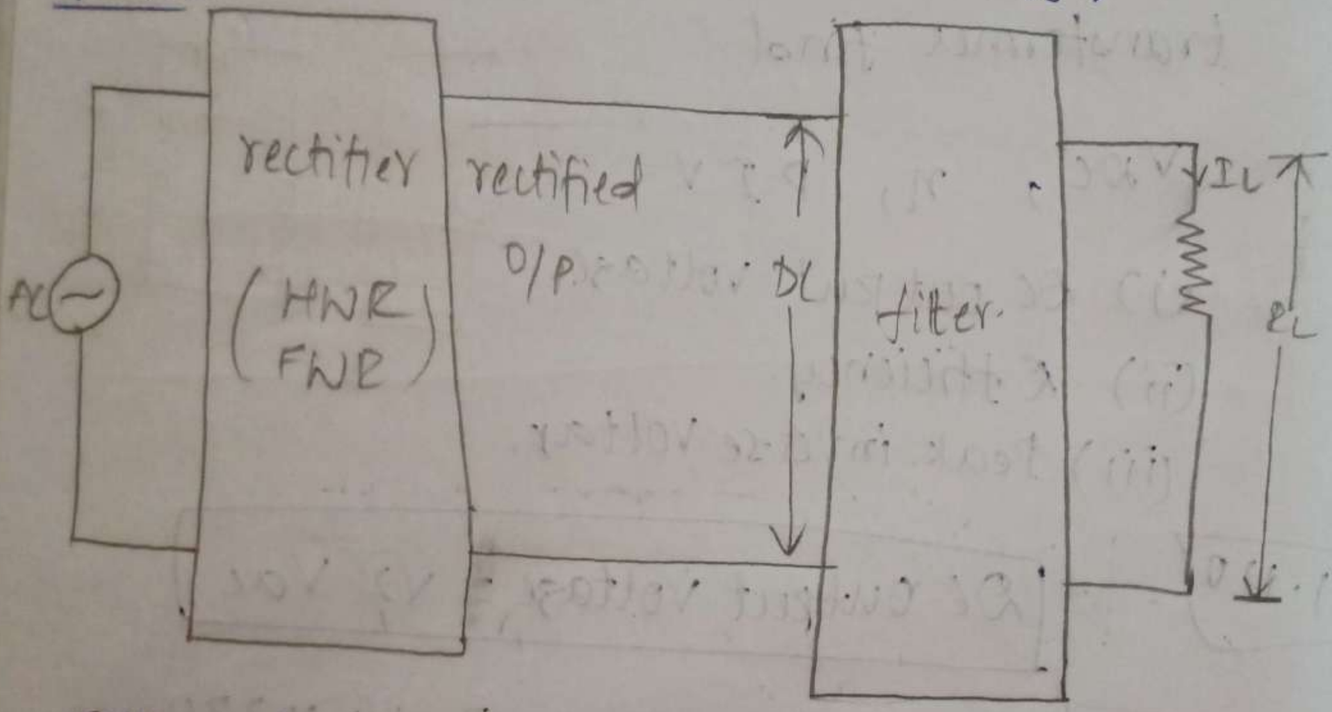
$$\therefore = \frac{I_{dc}^2 R_L}{I_{ac}^2 R_L} = \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{2}\right)^2 R_L} = \frac{\frac{V_m^2}{\pi^2 R_L^{\cancel{2}}} \cancel{R_L}}{\frac{V_m^2}{4 R_L^{\cancel{2}}} \cancel{R_L}} = \frac{4}{\pi^2} = 40.6\%$$

(iii) PIV = V_m

$$k \Rightarrow \frac{V_2}{V_1} = \frac{N_2}{N_1} \Rightarrow V_2 = V_1 \times \frac{N_2}{N_1} \Rightarrow 325.26 \times \frac{1}{5}$$

$$\therefore V_2 = 65.05\,V$$

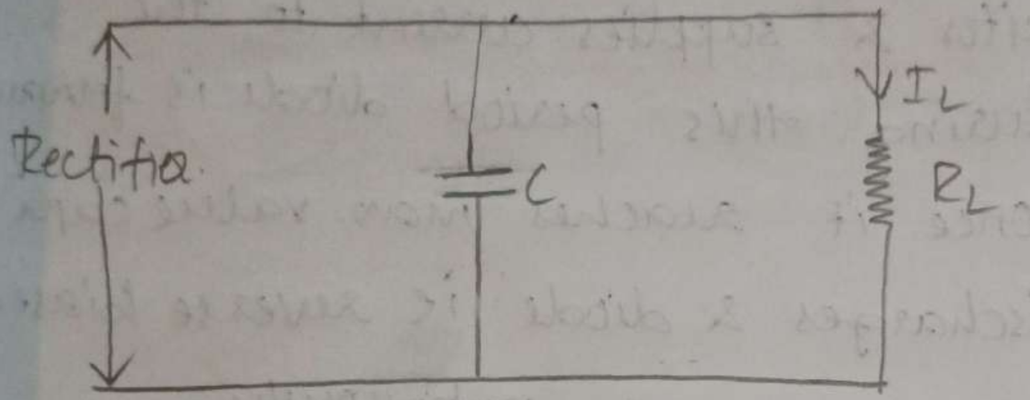
<u>filter:</u>



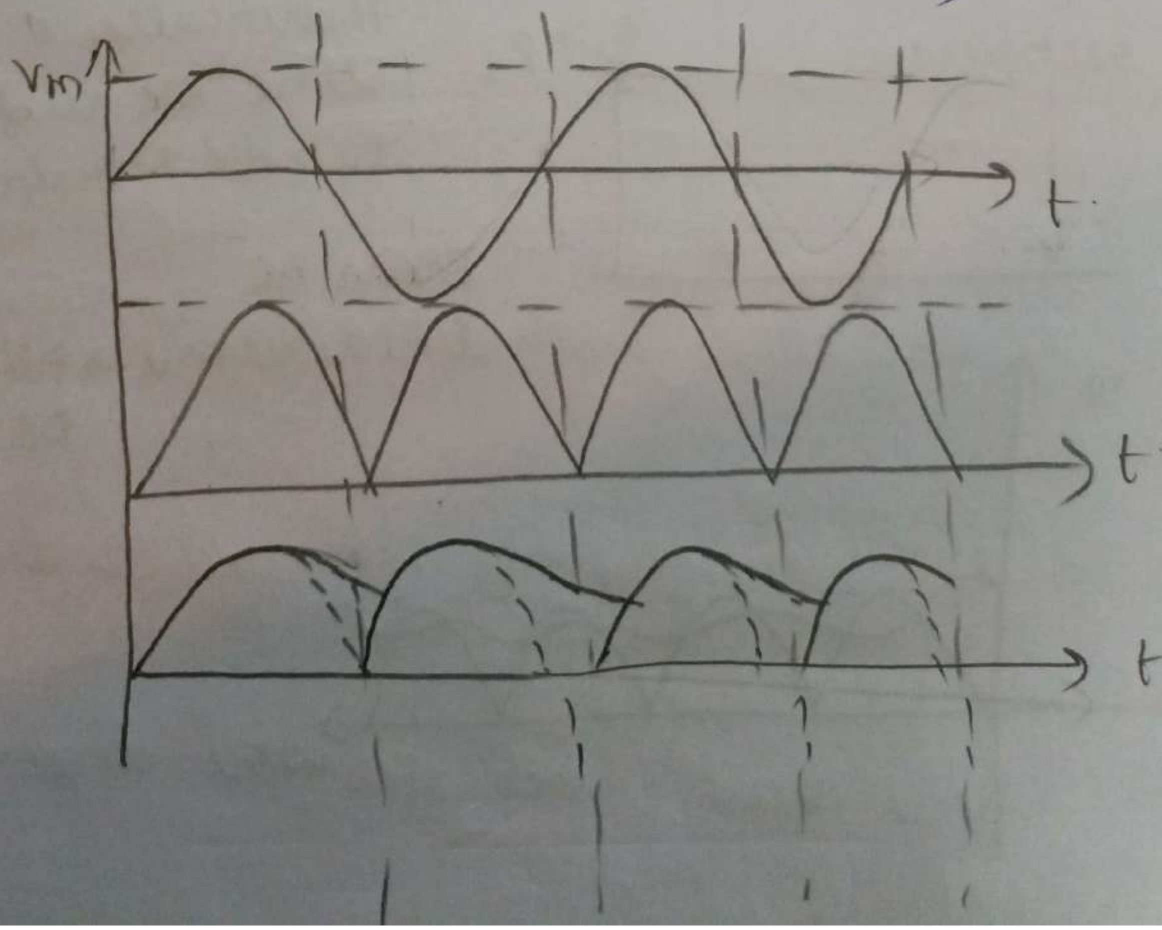
Filter is an electronic device which converts ripple content in rectifier output that is pulsating DC to pure DC it allows only DC component to reach the load. A filter circuit should be installed between rectifier & the load.

Filter circuit is classified into two types
(i) Capacitor filter
(ii) Inductor filter.

Capacitor filter: Blocks dc allows ac

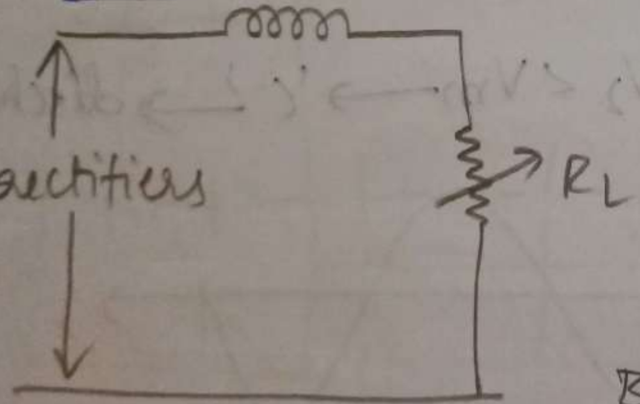


'D' → f.B → $V_2 > V_m$ → 'C' → charging
'D' → R.B → $V_2 < V_m$ → 'C' → discharging.



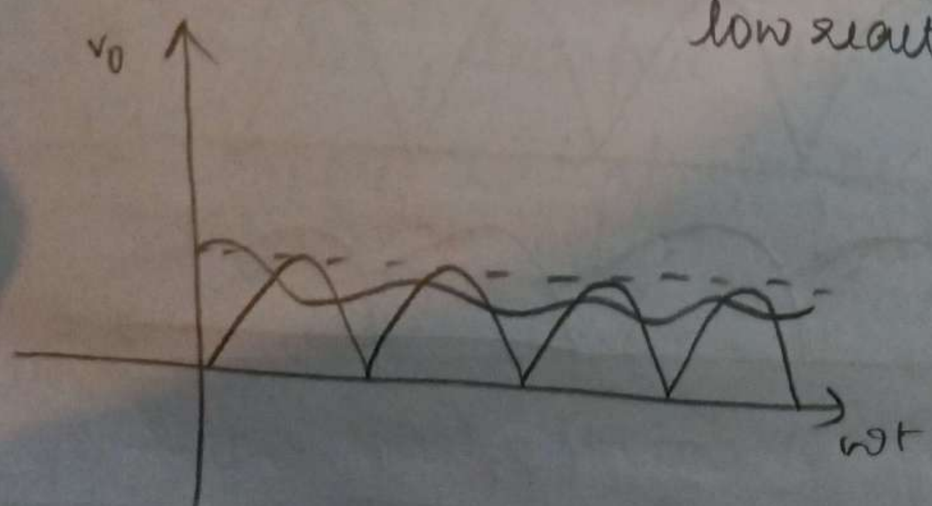
A capacitor filter consists of a capacitor placed across rectifier in parallel with load resistance the voltage of rectifier applied across rectifier as the input voltage rises to maximum voltage (Vm) it charges the capacitor & supplies current to the load during this period diode is forward biased once it reaches max. value capacitor discharges & diode is reverse biased & this process repeats continuously.

Inductor filter (choke) L → high resistance → Blocks AC



Inorder to get a theoretically st line we need to add regulator

Blocks AC
low reactance → Allows DC.



Inductor filter also known as choke filter it consists of an inductor which is inserted b/w rectifier & load resistance. When the output current passes through inductor it offers high reactance to AC component & low reactance to DC component which while reaching to load resistor.