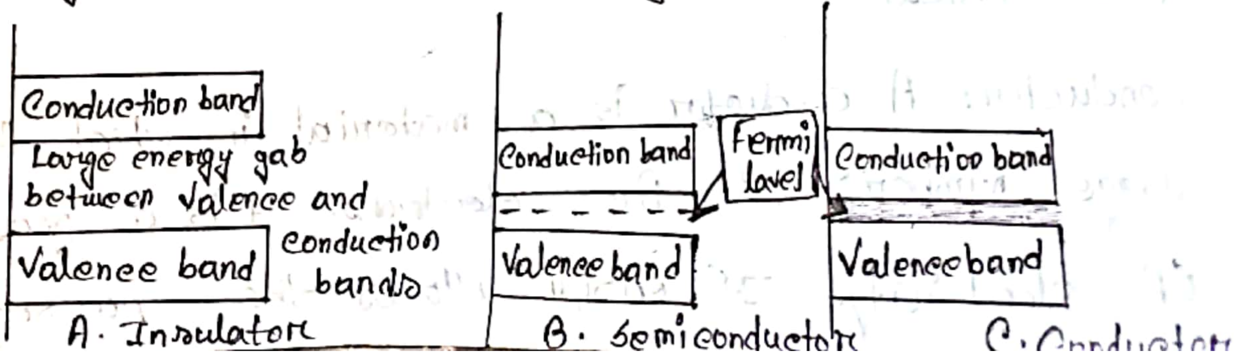
# Fundamentals of semiconductor devices

**Introduction:** An electronic device is a device in which the conduction takes place by movement of electrons through vacuum, gas or semi-conductor. Electronics is branch of science and engineering which deals with electron devices and their utilization. All electronic circuits contain a few basic components such as resistors, capacitors, inductors, tube devices and semi-conductor devices. 1st three were called passive components and the remaining were active components.

Certain substances like Germanium, Silicon, Carbon etc. Are neither conductors like copper nor insulators like glass or wood.

**Valence Band:** The range of energies possessed by valence electrons is known as valence band. In an normal atom, valence band has the electrons of highest energy. This valence maybe completed or partially filled



**Conduction band:** The range of energies possessed by conduction electrons is known as conduction band. At ordinary temparature some of the loosely attached valence electrons may becomes free electrons which are called conduction electrons and they are responsible for flow of current. All electron in the conduction band are free electron.

The energy gap between valence band and conduction band is very large ($\approx 15$ eV) in the case of insulator.

In the case of semiconductor it is relatively very small ($\approx 1$ eV).

In the case of conductor valence and conduction bands overlap each other.

**Forbidden gap:** The seperation between conduction band and valence band on the energy level diagram is known as forbidden energy gap.

**Insulator:** Insulator is a material which has no free electrons. It is a bad conductor of electricity. It does not allows the passage of electric current through. (Glass, Mica)

**Conductor:** A conductor is a material in which there are large numbers of free electrons. It is a good conductor of electricity. It easily allows the passage of electric current through (copper, Alluminum).

Semiconductor: Semiconductor is a material which has very few electrons at room temperatures. It's conducting properties lies between conductors and insulators, hence they are called as semiconductors. e.g. silicon, Germanium, Carbon.

Semiconductor: There are some materials, which have neither good conductivity nor bad conductivity of electricity. They have a moderate range of electrical conductivity. The examples of such materials are germanium, silicon, carbon etc. As the conductivity of thus materials lies between good conductors and insulators and these materials are called semiconductors.

A semiconductor is a ~~material~~ substance which has resistivity ($10^{-4}$ to $0.5\ \Omega m$) in between conductors and insulators e.g. germanium, silicon, selenium, carbon etc. Germanium and silicon are two typical & example of semiconductor.

Properties:

① The resistivity of a semiconductor is less than an insulator but more than a conductor.

② Semiconductors have negative temperature coefficient of resistance.

③ The number of valence electrons is four.

④ The energy gap is very narrow.

⑤ Sensitivity to light, either producing a photo voltage or change of resistance.

⑥ Example: Silicon, Germanium etc.

- Germanium is actually an insulator at low temperatures but it becomes a good conductor at high temperatures.

- The two most quently used materials are germenium (Ge) and silicon(Si). It is because the energy required to break their covalent bonds is very small, being about 0.7eV for germenium and about 1.1 eV for silicon.

## Types of Semiconductor:

- Semiconductors
  - Intrinsic or Pure semiconductor
  - Extrinsic or Impure Semiconductor
    - P-type (Positive)
    - N-type (Negative)

**Intrinsic semiconductor:** Extremely pure form of semiconductor is called Intrinsic semiconductor.

- The number of conduction electrons is equal to number of holes.
- The total current inside the semiconductor is the sum of currents due to free electrons and holes.

Extrinsic Semiconductor: When pure semiconductor added with some suitable impurity or doping agent or dopant then it is called extrinsic semiconductor.

① Pentavalent atoms – five Valence electrons –
Donor atom → Arsenic, Antimony, phosphorus.

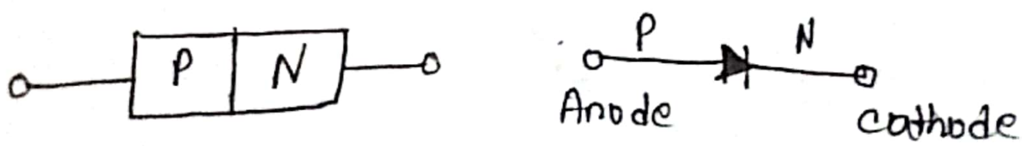
② Trivalent atoms – Three Valence electrons –
acceptor – Gallium, Indium, Aluminium.

P-n junction: When p-type and n-type semiconductors are fabricated on a single crystal by special techniques, a new semiconductor is formward. It is known as p-n junction or semi conductor diode.

→ P-n junction is able to ~~cor~~ current in one direction only.

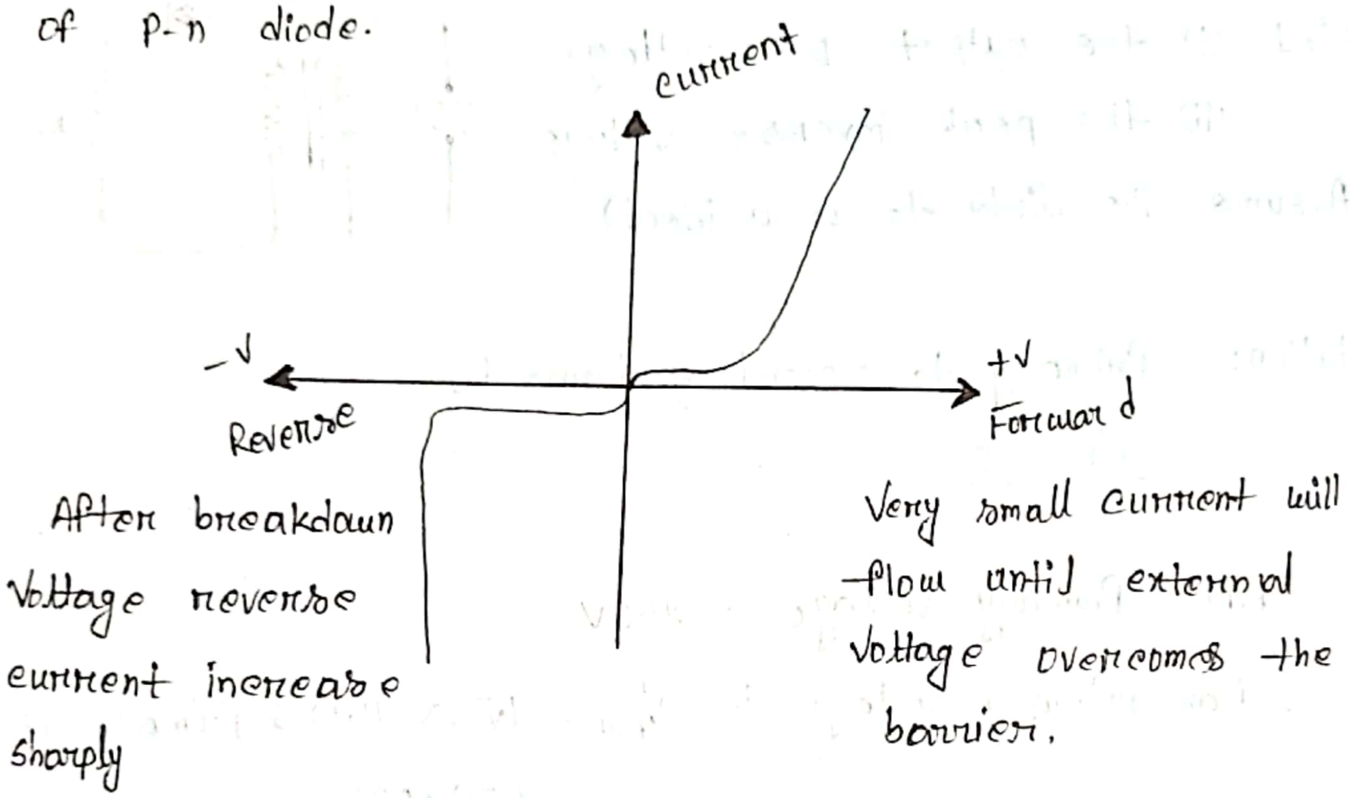
→ It offers low resistance in one direction and very high resistance in other direction almost as insalator.

→ Diodes are used in rectifiers.



V-I characteristics of a P-N junction :

The graph between the voltage applied across the terminals of p-n junction and resultant current passing through it, is called V-I characteristics of p-n diode.



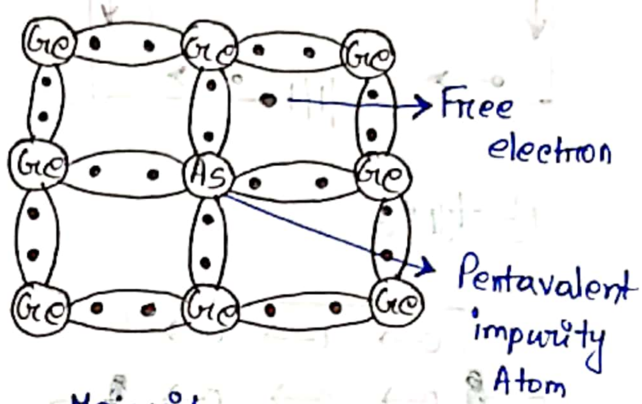

Zener diode: A properly doped crystal diode which has a sharp breakdown voltage is known as zener diode.

→ Always reverse biased

→ it's a silicon p-n junction diode.

## N-type semiconductor:

When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n-type semiconductor.

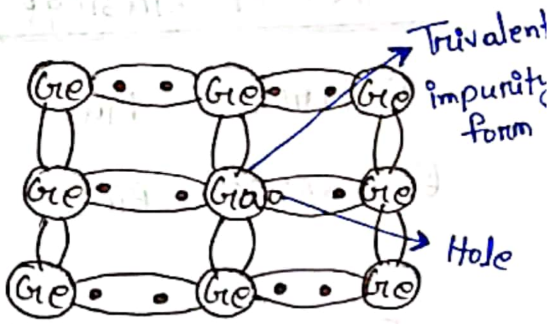



Majority carriers → Hole

Minority carries → electron

## P-type semiconductor:

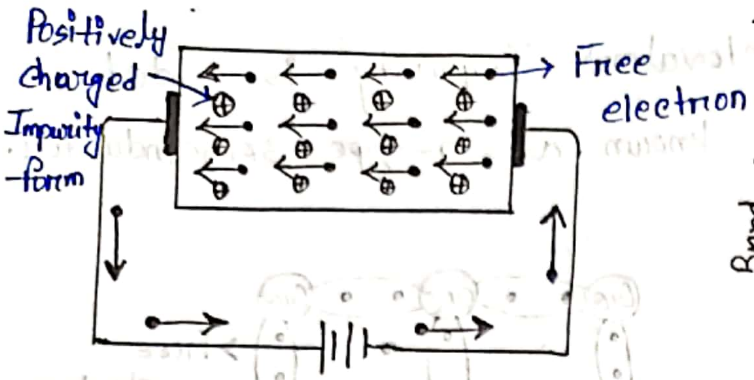
When a small amount of trivalent impurity is added to a pure semiconductor it is called p-type semiconductor.

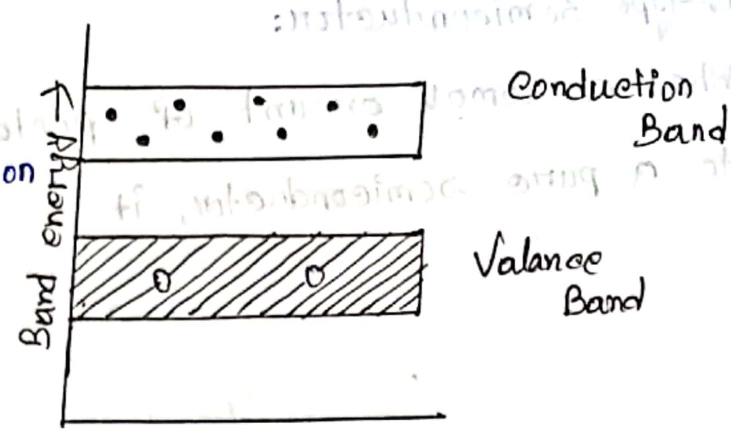



Majority carriers → electron

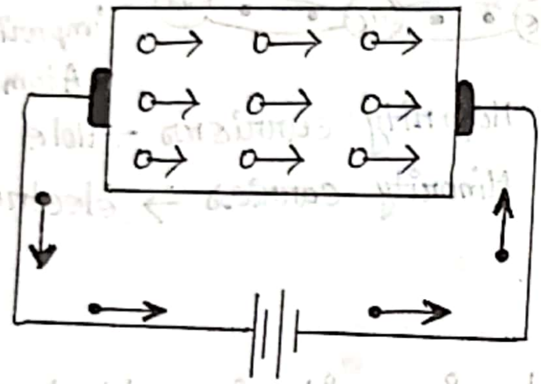
Minority carriers → Hole

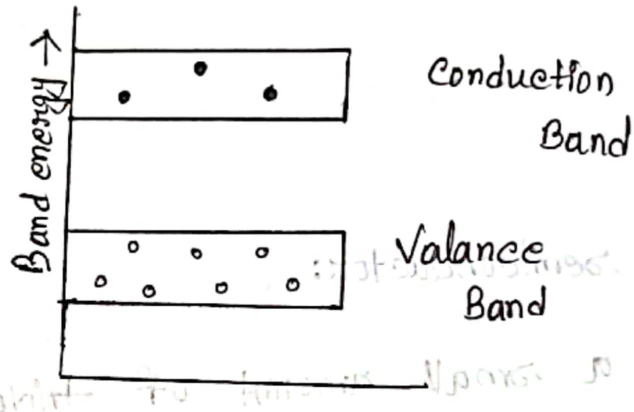
## N-type:




## P-type:

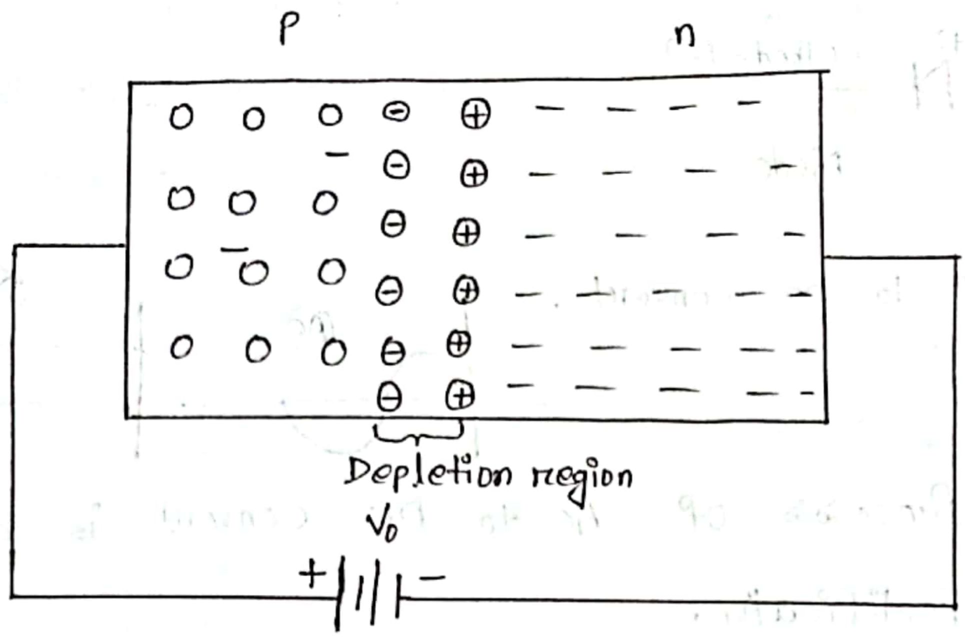





## Types of biasing:

1. Forward Bias
2. Reversed Bias

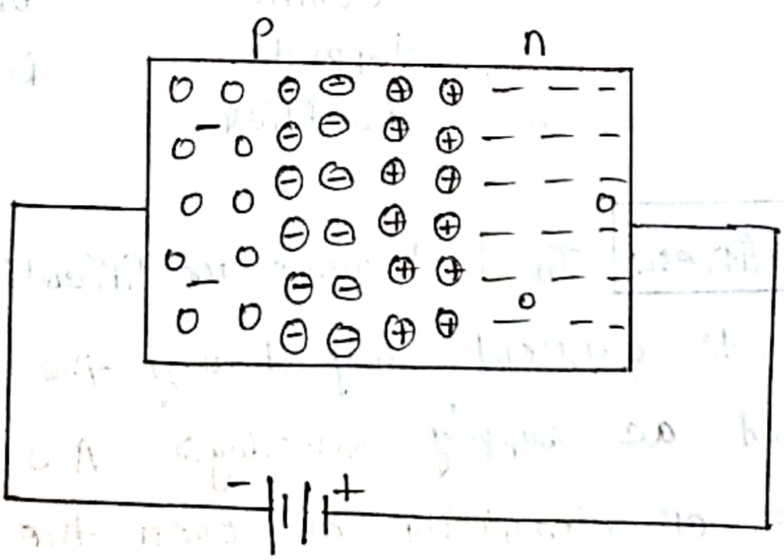
**Forward bias:** When external d.c voltage applied to the junction is in such a direction that it cancels the potential barrier thus permitting current flow, it is called forward bias.

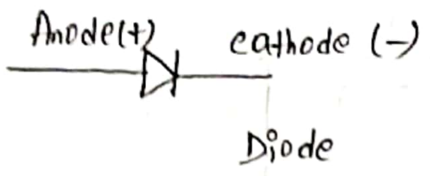



Forward bias p-n junction

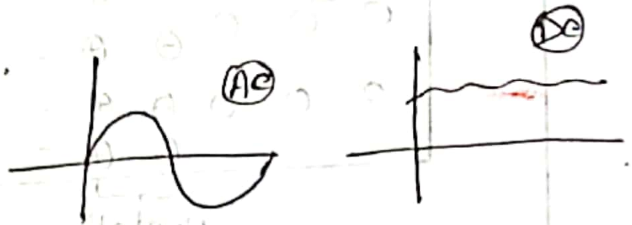
② Reversed Bias p-n junction:

When the external d.c voltage applied to the junction is in such a direction that potential barrier is increased, it is called reverse biasing.






**Diode:** Ac to Dc convert.



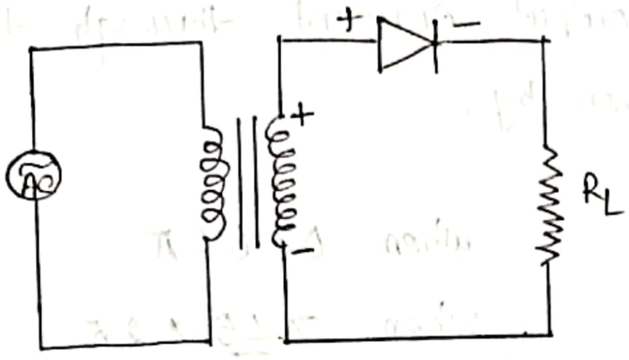

**Rectifine:** Process of Ac to Dc convert is called Rectification.

**Types of Rectifier:**

- Rectifier
  - Half wave
  - Full wave
    - Centre tapped Rectifier
    - Bridge Rectifier

**Half wave Rectifier:** In half wave rectification, the rectifier conducts current only during the positive half-cycles of input ac supply. Nowadays A.C is employed as a source of electricity all over the world because of its easy and economical production and distribution.

- A rectifier circuit designed with a single-diode which provides an output, only for half-cycle of A.C. (only for positive half-cycle) is called a half wave rectifier.

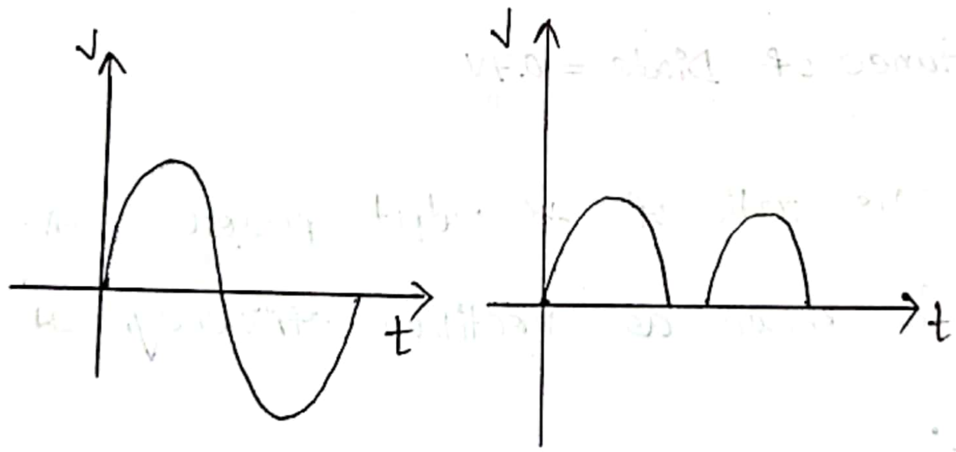



Every step এর জন্য Transformer এর polarity change হয়, তখন ⊖ হয়ে যায় ⊕, আর ⊕ হয়ে যায় ⊖।

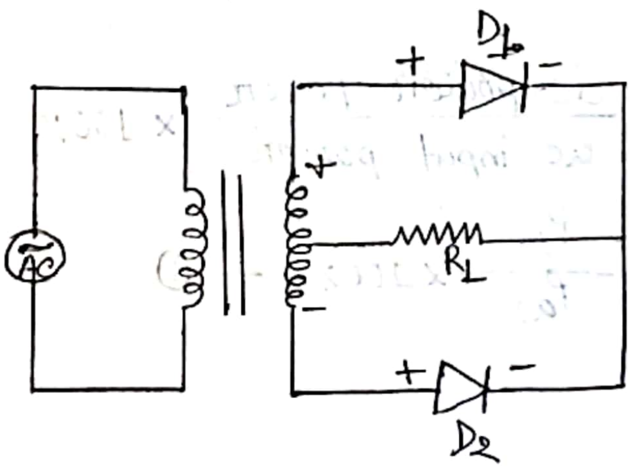
⇒ (+,+) হলো Reverse Bias

⇒ (−,+) (+,−) হলো Forward bias

⇒ Half wave শুধুমাত্র Positive cycle কে Rectification করতে পারে।




centre tapped:



Mathmatical analysis:

The input Voltage applied in the diode is given by

$$V_I = V_m \sin\theta$$

Then, the instantaneous output current through the load resistance $R_L$ is given by,

$$I = I_m \sin\theta \qquad \text{when } 0 \le \theta \le \pi$$

$$\text{and } I = 0 \qquad \text{when } \pi \le \theta \le 2\pi$$

$$\therefore I_m = \frac{V_m}{R_L + r_d}$$

$I_m$ = Peak Value of the current

$r_d$ = Dynamic forward resistance of the diode.

⇒ $r_d$ হলো Diode এর Internal resistance.

Internal resistance of Diode = 0.7V

Efficiency : The ratio of dc output power to the ac input power is known as rectifier efficiency. It is denoted by $\eta$.

$$\eta = \frac{\text{dc output power}}{\text{ac input power}} \times 100\%$$

$$= \frac{P_{dc}}{P_{ac}} \times 100\% \quad \text{--- (1)}$$

Dc output power: $P_{dc} = (I_{dc})^2 \times R_L$

where, $r_d$ = internal resistance of diode

$R_L$ = load resistance

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

$I_m$ = maximum value of load current

Dc average value of output current:

$$I_{avg} = I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} I d\theta$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\theta d\theta + \int_0^{\pi} (0 \times d\theta)\right]$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\theta\, d\theta\right]$$

[where $I_m = \frac{V_m}{r_d + R_L}$]

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

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

$$= \frac{I_m}{2\pi}\left[-\cos\pi - (-\cos 0^\circ)\right]$$

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

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

So, $P_{dc} = (I_{dc})^2 \times R_L$

$$= \left(\frac{I_m}{\pi}\right)^2 \times R_L$$

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

We know that, $P_{ac} = (I_{rms})^2 \times (R_L + r_d)$ —②

RMS Value of output current:

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} I^2 d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi} (I_m \sin\theta)^2 d\theta}$$

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

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

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

$$= \sqrt{\frac{I_m^2}{4\pi}\int_0^{\pi} (1-\cos 2\theta) d\theta}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[\int_0^{\pi} d\theta - \int_0^{\pi} \cos 2\theta \, d\theta\right]}$$

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

$$= \sqrt{\frac{I_m^2}{4\pi}\left\{(\pi - 0) - \left(\frac{\sin 2\pi}{2} - \frac{\sin 2\cdot 0}{2}\right)\right\}}$$

$$= \sqrt{\frac{I_m^2}{4\pi}(\pi - 0)}$$

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

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

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

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A.C power input:

Putting the value of $I_{r.m.s}$ in equation ②

$$P_{ac} = I_{r.m.s}^2 \times (r_d + R_L)$$

$$= \left(\frac{I_m}{2}\right)^2 \times (r_d + R_L)$$

$$= \frac{I_m^2}{4} (r_d + R_L)$$

Putting the above values in equation ① we have,

$$\text{Efficiency, } \eta = \frac{P_{dc}}{P_{ac}} \times 100\%$$

$$= \frac{\frac{I_m^2 \times R_L}{\pi^2}}{\frac{I_m^2 (R_L + r_d)}{4}} \times 100\%$$

$$= \frac{I_m^2 \times R_L}{\pi^2} \times \frac{4}{I_m^2 (R_L + r_d)} \times 100\%$$

$$= \frac{4 R_L}{\pi^2 (R_L + r_d)} \times 100\%$$

$$= \frac{0.406}{1 + \frac{r_d}{R_L}} \times 100\%$$

$$= 40.6\%$$

∴ The efficiency will be maximum if $r_d$ is negligible as compared to $R_L$

∴ Maximum rectifier efficiency is 40.6%. This shows that in half wave rectification, a maximum of 40.6% ac power is converted into dc power.

**Ripple factor** : The ripple factor is the ratio of r.m.s value of A.c. component to the D.c component ~~out~~ in the rectifier out i.e,

$$\gamma = \frac{\text{r.m.s value of A.c component of output voltage}}{\text{D.c component of output voltage}}$$

$$\gamma = \frac{V_{ac}}{I_{dc}} = \frac{I_{ac}}{I_{dc}}$$

The effective (r.m.s) value of total load current is given by

$$I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$$

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

$$\Rightarrow \frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}} \sqrt{I_{dc}^2 + I_{ac}^2}$$

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

For a half wave rectifier,

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

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

$$\gamma = \sqrt{\frac{\pi^2}{4} - 1} = 1.21$$

$$\therefore \gamma = 1.21$$

This indicates that the amount of A.c component Present in the output of a half wave rectifier is 121% of D.c output Voltage. the half wave rectifier is therefore a poor converter of ac into dc.

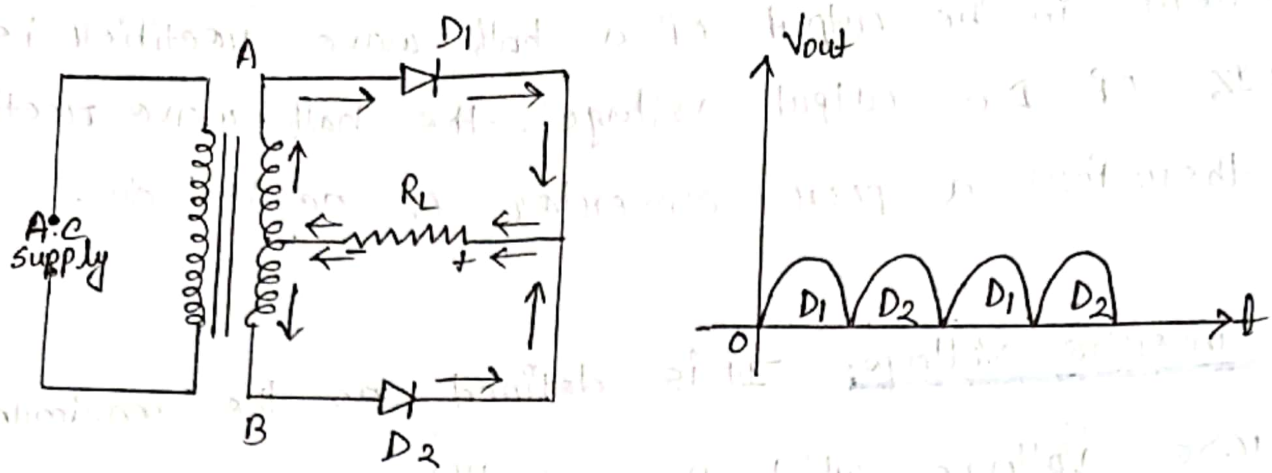
Peak inverse Voltage: It is defined as the maximum reverse Voltage which the rectifier has to withstand during the non-conducting period.

$$\boxed{PIV = V_m}$$

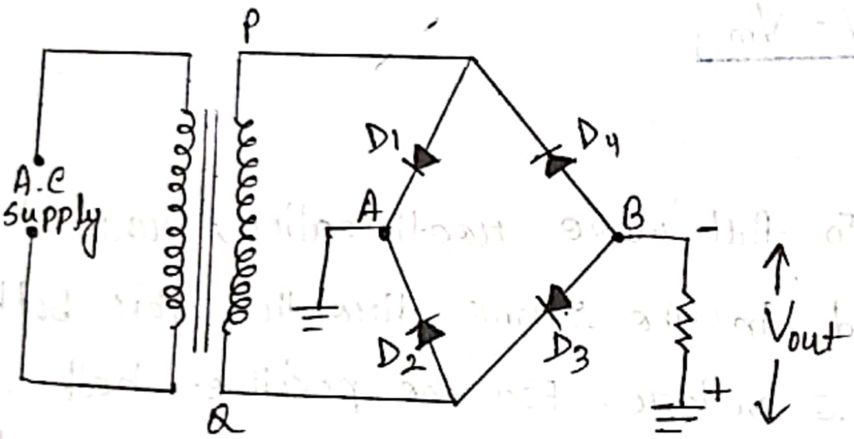
**Full wave Rectifier:** In full wave rectification, current flows through the load in the same direction for both half-cycles of input a.c Voltage. For the positive half-cycle of input Voltage, One diode supplies current to the load and for the negative half-cycle ~~of~~, the other diode does so. Therefore a full-wave rectifier utilises both half-cycles of input a.c Voltage to produce the d.c output.

(I) Centre full wave rectifier

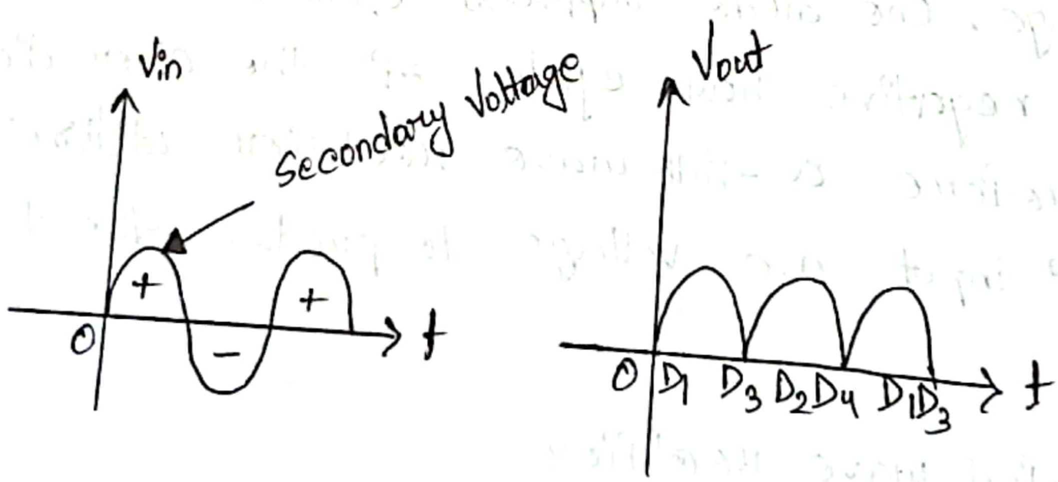
(II) Full wave bridge rectifier




Full wave bridge rectifier:




Here, $D_2$, $D_4$ Forward Bias. $D_1$, $D_3$ reversed Bias.



## Efficiency of full wave rectifier:

The ratio of dc output power to the ac input power is known as rectifier efficiency. It is denoted by $\eta$.

$$\eta = \frac{\text{dc output power}}{\text{ac input power}} \times 100\%$$

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

$$i = I_m \sin\theta$$

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

Dc output power: $P_{dc} = I_{dc}^2 \times R_L$

$$I_{dc} = I_{avg} = \frac{1}{2\pi} \times 2 \int_0^{\pi} I \, d\theta$$

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

$$= \frac{I_m}{\pi} \int_0^{\pi} \sin\theta \, d\theta$$

$$= \frac{I_m}{\pi} \left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{I_m}{\pi} \left[-\cos\pi - (\cos 0)\right]$$

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

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

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

$$= \left(\frac{2I_m}{\pi}\right)^2 \times R_L$$

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

AC input power: $P_{ac} = I_{r.m.s}^2 \times (R_L + r_d)$

R.M.S Value of current is,

$$I_{r.m.s} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (I)^2 d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (I_m \sin\theta)^2 d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (I_m^2 \sin^2\theta)\, d\theta}$$

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

$$= \sqrt{\frac{I_m^2}{2\pi}\cdot\frac{1}{2}\int_0^{2\pi} 2\sin^2\theta \cdot d\theta} = \sqrt{\frac{I_m^2}{2\pi}\cdot\frac{1}{2}\int_0^{2\pi} (1-\cos 2\theta)d\theta}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left[\int_0^{2\pi} d\theta - \int_0^{2\pi} \cos 2\theta\, d\theta\right]}$$

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

$$= \sqrt{\frac{I_m^2}{4\pi} \times (2\pi - 0) - 0}$$

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

$$\therefore P_{ac} = (I_{r.m.s})^2 \times (R_L + r_d)$$

$$= \left(\frac{I_m}{\sqrt{2}}\right)^2 \times (R_L + r_d)$$

$$= \frac{I_m^2}{2} \times (R_L + r_d)$$

$$\therefore \text{Efficiency, } \eta = \frac{P_{dc}}{P_{ac}} \times 100\%$$

$$= \frac{\frac{4I_m^2 \times R_L}{\pi^2}}{\frac{I_m^2 \times (R_L + r_d)}{2}} \times 100\%$$

$$= \frac{4I_m^2 \times R_L}{\pi^2} \times \frac{2}{I_m^2 \times (R_L + r_d)} \times 100\%$$

$$= \frac{8R_L}{\pi^2 (R_L + r_d)} \times 100\%$$

$$= \frac{0.812}{1 + \frac{r_d}{R_L}} \times 100\%$$

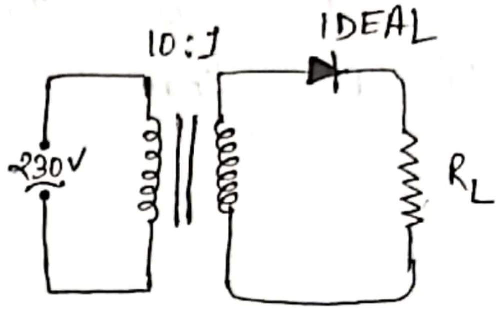
$$= 81.2\%$$

6.13 An a.c supply of 230 V is applied to a half wave rectifier circuit through a transformer of turn ~~into~~ ratio 10:1.

Find (i) the output D.C voltage

(ii) the peak inverse voltage

(Assume the diode to be a ideal)




Solution: Primary to secondary turns is

$$\frac{N_1}{N_2} = \frac{10}{1}$$

R.M.S Primary Voltage = 230V

∴ Max primary voltage is $V_{pm} = (\sqrt{2}) \times$ r.m.s Primary Voltag

$$= (\sqrt{2}) \times 230$$

$$= 325.3 \text{ V}$$

Max secondary Voltage is,

$$V_{sm} = V_{pm} \times \frac{N_2}{N_1}$$

$$= 325.3 \times \frac{1}{10}$$

$$= 32.53 \text{ V}$$

(i) $I_{d.c} = \frac{I_m}{\pi}$

$$\cancel{V_{dc} = \frac{I_m}{\pi} \times R_L}$$

$$V_{dc} = I_{dc} \times R_L$$

$$= \frac{I_m}{\pi} \times R_L$$

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

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

$$= \frac{32.53}{\pi}$$

$$= 10.36 \text{ V}$$

(ii) During the negative half-cycle of a.c supply, the diode is reverse biased and hence conducts no current. Therefore the maximum secondary voltage appears across the diode.

$\therefore$ Peak inverse voltage $= 32.53$ V.

6.17 A crystal diode having internal resistance, $r_f = 20\Omega$ is used for half wave rectification. If the applied voltage $V = 50 \sin\omega t$ and load resistance $R_L = 800\Omega$. find (i) $I_m$, $I_{dc}$, $I_{rms}$

(ii) a.c power input and d.c power input

(iii) d.c output voltage

(iv) efficiency of rectification

Solution: $V = 50 \sin \omega t$

$\therefore$ Maximum Voltage, $V_m = 50V$

(i) $I_m = \dfrac{V_m}{r_f + R_L}$

$= \dfrac{50}{20+800}$

$= 0.061 A$

$= 61 mA$

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

$= \dfrac{61}{\pi}$

$= 19.4 mA$

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

$= \dfrac{61}{2}$

$= 30.5 mA$

(ii) a.c power input, $= (I_{rms})^2 \times (r_f + R_L)$

$= \left(\frac{30.5}{1000}\right)^2 \times (20+800)$

$= 0.763$ Watt

d.c power input $= I_{dc}^2 \times R_L$

$= \left(\frac{19.4}{1000}\right)^2 \times 800$

$= 0.301$ Watt

(iii) d.c output Voltage $= I_{dc} R_L$

$= 19.4\ mA \times 800\Omega$

$= 15.52$ Volts

(iv) Efficiency of rectification $= \frac{\text{dc power input}}{\text{ac power input}} \times 100$

$= \frac{0.301}{0.763} \times 100$

$= 39.5\%$

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6.15 A half-wave rectifier is used to supply 50V d.c to a resistive load of 800Ω. The diode has a resistance of 25Ω. caculate a.c voltage required.

Solution: Output d.c Voltage, $V_{dc} = 50V$

Diode resistance, $r_f = 25\Omega$

Load resistance, $R_L = 800\Omega$

Let, $V_m$ be the maximum value of a.c voltage required,

$$V_{dc} = I_{dc} \times R_L$$

$$= \frac{I_m}{\pi} \times R_L$$

$$= \frac{V_m}{\pi(r_f + R_L)} \times R_L \qquad \left[I_m = \frac{V_m}{r_f + R_L}\right]$$

$$\Rightarrow 50 = \frac{\cancel{\pi} V_m}{\pi(25+800)} \times 800$$

$$\Rightarrow V_m = \frac{\pi \times 825 \times \cancel{800}50}{800}$$

$$= 162V$$

∴ a.c voltage of maximum value 162V is required.

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6.16 A full wave rectifier uses two diodes. The internal resistance of each diode may be assumed constant at $20\Omega$. The transformer r.m.s secondary voltage from centre tap to each end of secondary is 50 V and load resistance is $980\Omega$.

Find (i) the mean load current

(ii) the r.m.s value of load current.

Solution: $r_f = 20\Omega$; $R_L = 980\Omega$

Max a.c voltage, $V_m = 50\times\sqrt{2} = 70.7V$

Max load current, $I_m = \frac{V_m}{r_f + R_L}$

$= \frac{70.7V}{(20+980)\Omega}$

$= 70.7 mA$

(i) Mean load current, $I_{dc} = \frac{2I_m}{\pi}$

$= \frac{2\times 70.7}{\pi}$

$= 45 mA$

(ii) R.M.S value of load current is

$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{70.7}{\sqrt{2}}$

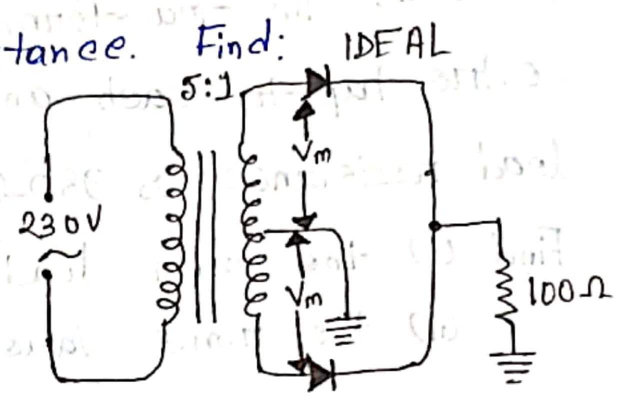
$= 50 mA.$

6.17 In the centre-tap circuit shown in Fig 6.31, the diodes are assumed to be ideal i.e. having zero internal resistance. Find:

(i) d.c output voltage

(ii) Peak inverse voltage

(iii) rectification efficiency




Solution: Primary to secondary turns, $N_1/N_2 = 5$

R.M.S Primary Voltage $= 230\,V$

R.M.S Secondary Voltage $= 230 \times \left(\frac{1}{5}\right)$

$= 46\,V$

Maximum Voltage across secondary

$= 46 \times \sqrt{2}$

$= 65\,V$

Maximum Voltage across half secondary winding is, $V_m = \frac{65}{2} = 32.5\,V$

(i) Average current, $I_{dc} = \frac{2V_m}{\pi R_L}$

$= \frac{2 \times 32.5}{\pi \times 100}$

$= 0.207\,A$

∴ dc output voltage, $V_{dc} = I_{dc} \times R_L$

$= 0.207 \times 100$

$= 20.7\,V$

(ii) The peak inverse voltage is equal to the maximum secondary voltage, i.e.

$$PIV = 65V$$

(iii) Rectification efficiency $= \dfrac{0.812}{1+\frac{r_f}{R_L}}$

Since, $r_f = 0$

$\therefore$ Rectification efficiency $= 81.2\%$

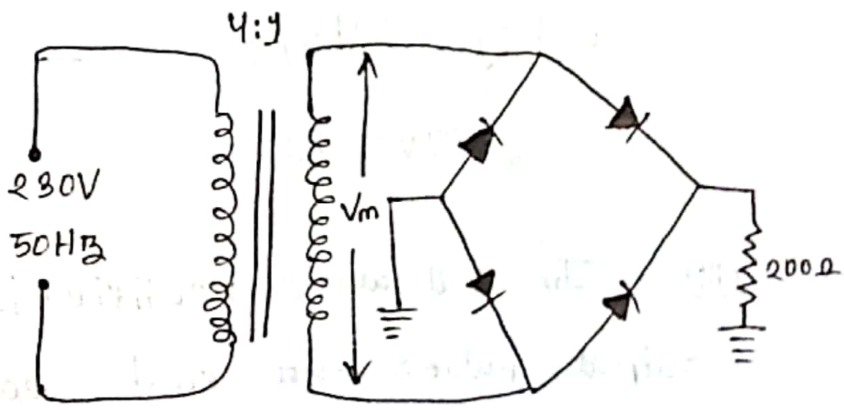
6.18 In the bridge type circuit shown in Fig 6.32 the diodes are assumed to be ideal. Find

(i) dc output voltage

(ii) Peak inverse voltage

(iii) output frequency.

Assume primary to secondary turns to be 4.



**Solution:** Primary / secondary turns, $N_1 / N_2 = 4$

R.M.S Primary voltage $= 230V$

R.M.S secondary voltage $= 230 \, (N_2/N_1)$

$$= 230 \left(\frac{1}{4}\right)$$

$$= 57.5 \, V$$

Maximum voltage across secondary is

$$V_m = 57.5 \times \sqrt{2}$$

$$= 81.3 \, V$$

(i) Average current, $I_{dc} = \dfrac{2V_m}{\pi R_L}$

$$= \frac{2 \times 81.3}{\pi \times 200}$$

$$= 0.26 A$$

$\therefore$ d.c output voltage, $V_{dc} = I_{dc} \times R_L$

$$= 0.26 \times 200$$

$$= 52 V$$

(ii) The peak inverse voltage is equal to the maximum secondary voltage

$$PIV = 81.3 \, V$$

(iii) In full wave rectification, there are two output pulses for each complete cycle of the input a.c voltage.

Therefore, the output frequency is twice that of the a.c supply frequency.

$$f_{out} = 2 \times f_{in}$$
$$= 2 \times 50$$
$$= 100 \text{ Hz}.$$

**6.19** Fig 6.33 (i) and Fig 6.33 (ii) show the centre-tap and bridge type circuits having the same load resistance and transformer turn ratio. The primary of each is connected to 230 V, 50 Hz supply.

(i) Find the d.c voltage in each case.

(ii) PIV for each case for the same d.c output.

Assume the diodes to be ideal.

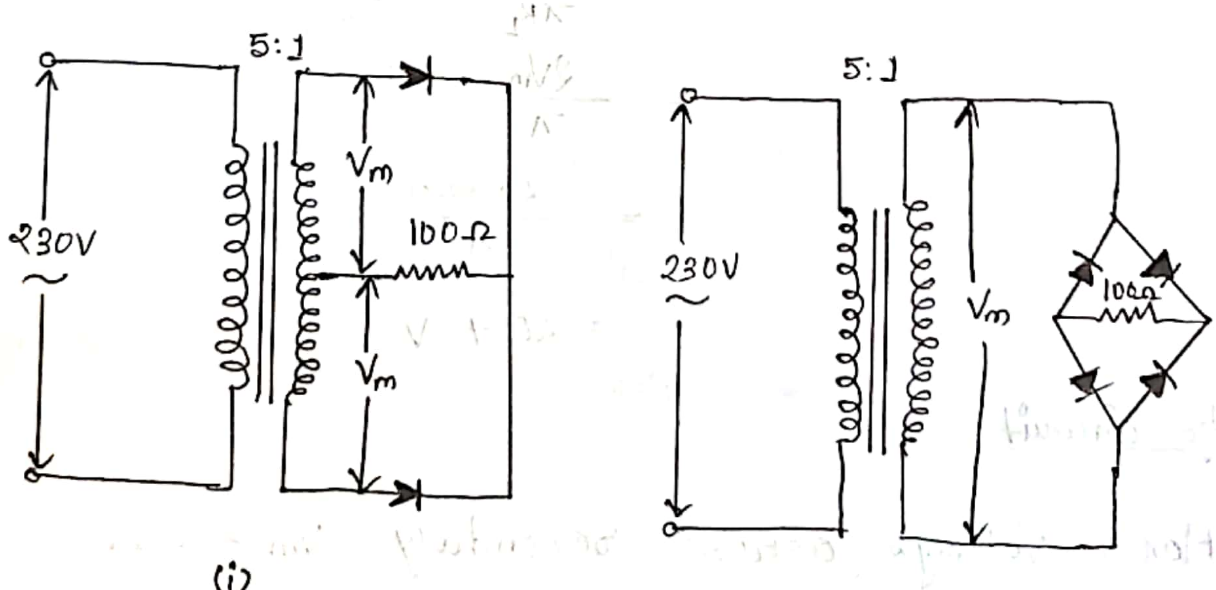



Fig: 6.33

Solution: (i) D.C output Voltage

centre tap circuit.

R.M.S secondary Voltage $= 230 \times \frac{1}{5}$

$= 46 V$

Max voltage across secondary $= 46 \times \sqrt{2}$

$= 65 V$

Max. Voltage appearing across half secondary winding is, $V_m = \frac{65}{2}$

$= 32.5 V$

Average current, $I_{dc} = \frac{2V_m}{\pi R_L}$

D.C output Voltage, $V_{dc} = I_{dc} \times R_L$

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

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

$= \frac{2 \times 32.5}{\pi}$

$= 20.7 V$

Bridge circuit.

Max. Voltage across secondary, $V_m = 65 V$

D.C output voltage, $V_{dc} = I_{dc} R_L$

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

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

$$= \frac{2 \times 65}{\pi}$$

$$= 41.4\,V$$

This shows that for the same secondary voltage, the d.c output voltage, the d.c output voltage of bridge circuit is twice that of the centre tap circuit.

(ii) PIV for same d.c output voltage

The d.c output voltage of the two circuits will be the same if $V_m$ (i.e. max voltage utilised by each circuit for conversion into d.c) is the same.

Centre tap circuit

R.M.S secondary voltage $= 230 \times \frac{1}{5}$

$= 46\,V$

Max voltage across secondary $= 46 \times \sqrt{2}$

$= 65\,V$

Max voltage across half secondary winding is

$$V_m = \frac{65}{2} = 32.5\,V.$$

$\therefore$ PIV $= 2V_m$

$= 2 \times 32.5$

$= 65V$

Bridge type circuit

R.M.S secondary voltage $= 230 \times \frac{1}{10}$

$= 23V$

Max. Voltage across secondary, $V_m = 23 \times \sqrt{2}$

$= 32.5 V$

$$PIV = V_m = 32.5V$$

This shows that for the same d.c output voltage. PIV of bridge circuit is half that of centre-tap circuit. This is a distinct advantage of bridge circuit,

6.20 The four diodes used in a bridge rectifier circuit have forward resistance which may be considered constant at $1\Omega$ and infinite reverse resistance. The alternating supply voltage is 240 V r.m.s. and load resistance is $480\Omega$. Caculate (i) mean load current and.

(ii) Power dissipated in each diode.

Solution: Max a.c Voltage $V_m = 240 \times \sqrt{2}$ V

(i) At any instant in the bridge rectifier, two diodes in series are conducting. Therefore, total circuit resistance, $= 2r_f + R_L$

Max load current, $I_m = \dfrac{V_m}{2r_f + R_L}$

$$= \frac{240 \times \sqrt{2}}{2 \times 1 + 480}$$

$$= 0.7 \text{ A}$$

Mean load current, $I_{dc} = \dfrac{2I_m}{\pi}$

$$= \frac{2 \times 0.7}{\pi}$$

$$= 0.45 \text{A}$$

(ii) Since each diode conducts only half a cycle diode r.m.s current is,

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

$$= \frac{0.7}{2}$$

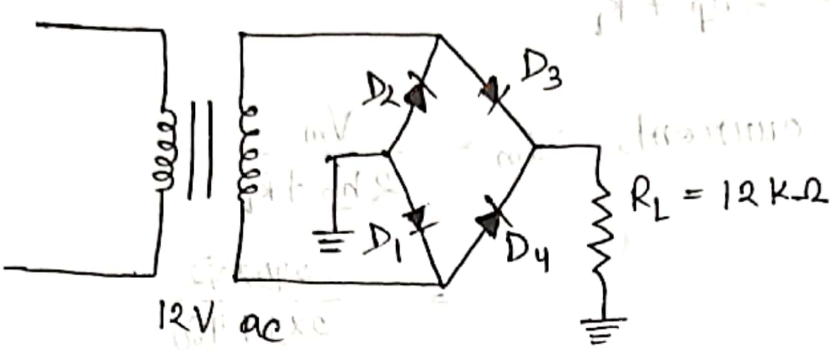
$$= 0.35 \text{ A}$$

Power dissipated in each diode $= I_{rms}^2 \times r_f$

$$= (0.35)^2 \times 1$$

$$= 0.123 \text{ W}$$

6.21 The bridge rectifier shown in Fig 6.35 uses silicon diodes. Find (i) d.c output voltage (ii) d.c output current. Use simplified model for the diodes.




Solution: The conditions of the problem suggest that the a.c voltage across transformer secondary is 12V r.m.s.

∴ Peak secondary voltage is

$$V_{S(PK)} = 12 \times \sqrt{2}$$
$$= 16.97\,V$$

(i) At any instant in the bridge rectifier, two diodes in series are conducting.

∴ Peak output voltage is $V_{out(PK)} = 16.97 - 2(0.7)$
$$= 15.57\,V$$

∴ Average (or d.c) output voltage is

$$V_{av} = V_{dc} = \frac{2 V_{out(PK)}}{\pi}$$
$$= \frac{2 \times 15.57}{\pi}$$
$$= 9.91\,V$$

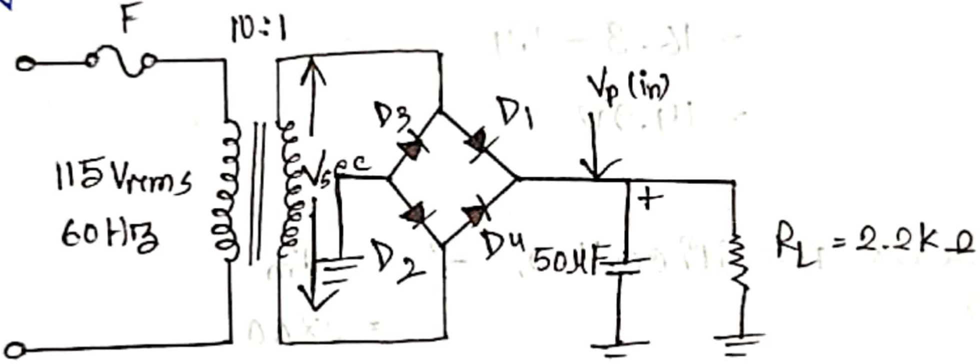
(ii) Average (or d.c) output current is

$$I_{av} = \frac{V_{av}}{R_L}$$

$$= \frac{9.91\ V}{12\ K\Omega}$$

$$= 825.8\ \mu A$$

6.23 For the circuit shown in Fig 6.44, Find the output d.c Voltage.




Solution: It can be proved that output d.c voltage is given by:

$$V_{dc} = V_{p(in)} \left(1 - \frac{1}{2 f R_L C}\right)$$

Here, $V_{p(in)}$ = Peak rectified full-wave voltage applied to the filter.

$f$ = output frequency

Peak Primary Voltage, $V_{P(Prim)} = \sqrt{2} \times 115$
$= 163\ V$

Peak secondary Voltage, $V_{P(sec)} = \left(\frac{1}{10}\right) \times 163$
$= 16.3\ V$

Peak full-wave rectified Voltage at the filter input is,

$$V_{P(in)} = V_{P(sec)} - 2 \times 0.7$$
$$= 16.3 - 1.4$$
$$= 14.9V$$

For full-wave rectification, $f = 2f_m$
$= 2 \times 60$
$= 120\ Hz$

Now, $$\frac{1}{2fR_LC} = \frac{1}{2 \times 120 \times (2.2 \times 10^3) \times (50 \times 10^{-6})}$$
$$= 0.038$$

$$\therefore V_{dc} = V_{P(in)} \times \left(1 - \frac{1}{2fR_LC}\right)$$
$$= 14.9\ (1 - 0.038)$$
$$= 14.3\ V.$$

**6.24** The choke of Fig. 6.45 has a d.c resistance of 25 Ω. What is the d.c Voltage if the full-wave signal into the choke has a peak Value of 25.7 V?

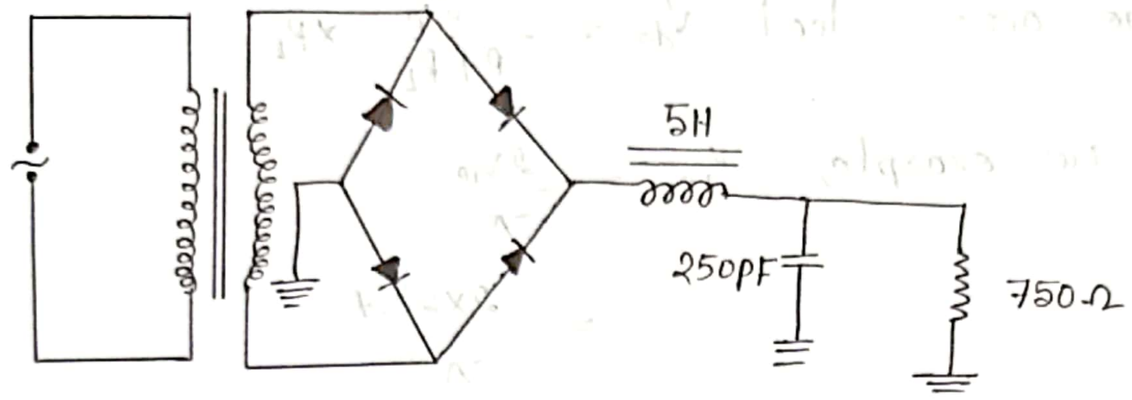



Fig: 6.45

**Solution:** The output of a full-wave rectifier has a d.c component and an a.c component. Due to the presence of a.c component, the rectifier output has a pulsating character as shown in Fig. 6.46. The maximum Value of the Pulsating output is $V_m$ and d.c component is $V'_{dc} = 2V_m/\pi$

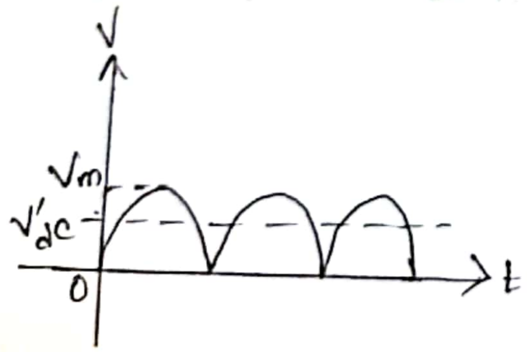



Fig: 6.46

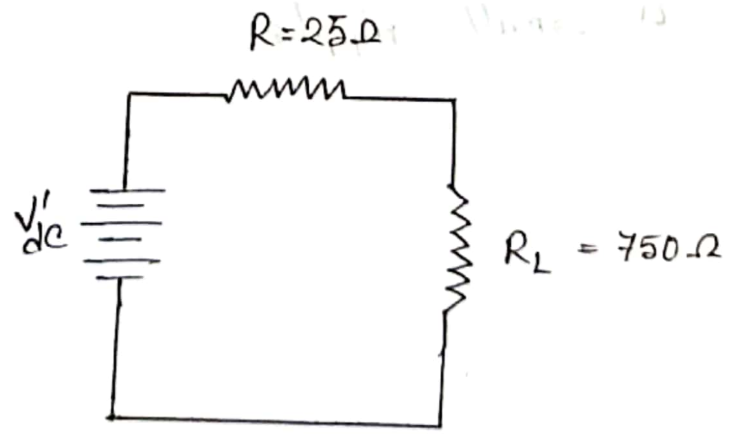



Fig: 6.47

For d.c component $V'_{dc}$, the choke resistance is in series with the load as shown in Fig. 6.47.

$\therefore$ Voltage across load, $V_{dc} = \dfrac{V'_{dc}}{R+R_L} \times R_L$

In our example, $V'_{dc} = \dfrac{2V_m}{\pi}$

$$= \frac{2\times 25.7}{\pi}$$

$$= 16.4V$$

$\therefore$ Voltage across load, $V_{dc} = \dfrac{V'_{dc}}{R+R_L} \times R_L$

$$= \frac{16.4}{25+750} \times 750$$

$$= 15.9V$$

$\therefore$ The voltage across the load is 15.9 V dc plus a small ripple.