Halfwave rectifier.

→ Half wave rectifying element conducts only during positive half cycle of input a.c. supply.

→ The negative half cycles of a.c supply are eliminated from the output.

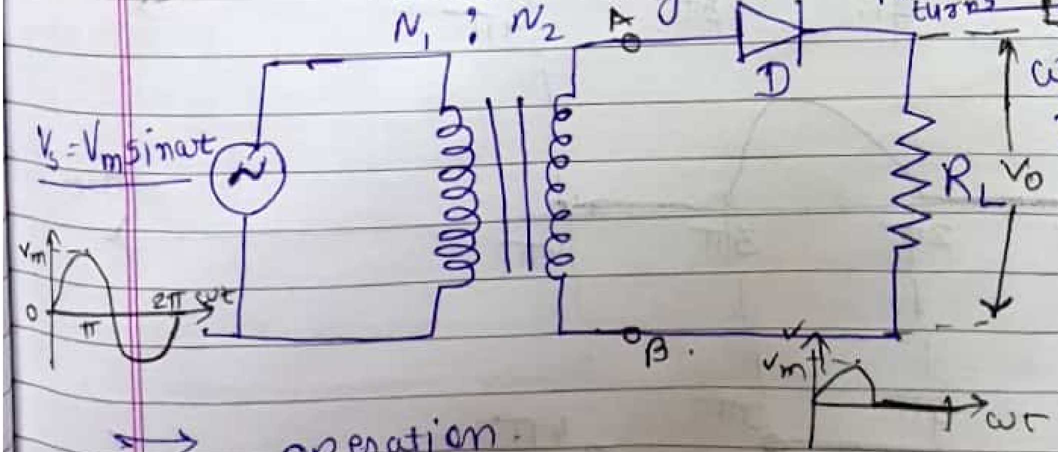
→ This rectifier circuit consits of
  → Resistive Load
  → P-N Junction diode.
  → Source of a-c voltage.

→ To obtain the desired d.c voltage across rectifier circuit using suitable step-up or step down transformer, mostly step-down one, with necessary turns ratio.

→ Circuit Diagram.

$$\boxed{\frac{N_2}{N_1} = \frac{E_{sm}}{E_{pm}}}$$

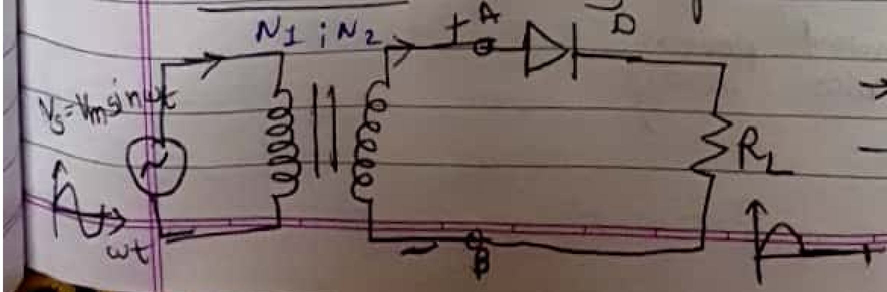
N_2 – secondary turns; N_1 – primary turns; E_{sm} – peak secondary voltage; E_{pm} – peak primary voltage Transformer



where
V_m = Peak value of a.c voltage
R_L = Resistive Load
D = Diode.
V_0 = Output voltage

→ operation.

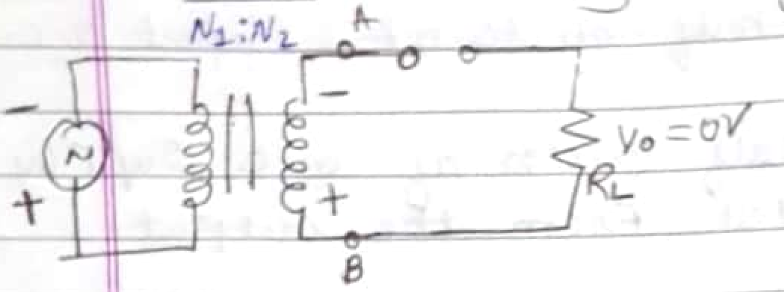
Case - 1 During positive half cycle.



→ $0 \le \omega t \le \pi$

→ Diode forward Bias. (conduct)

Case-2 : During Negative half cycle.



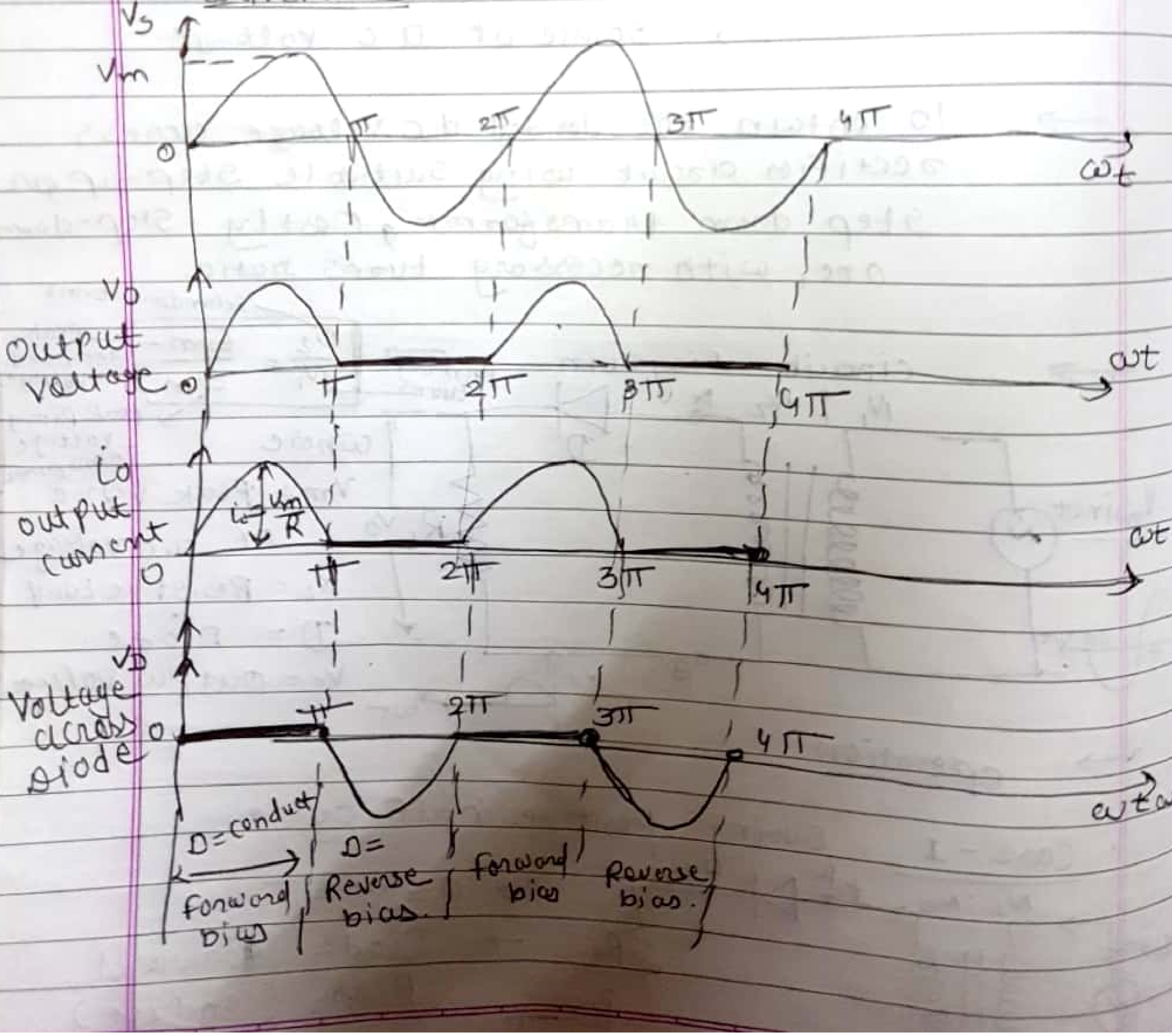
$\pi \le \omega t \le 2\pi$

output Voltage

$V_0 = 0V$.

A is Negative w.r.t to B. , Diode = Reverse bias

waveforms



Mathematically current waveform can be described as,

$$i_L = I_m \sin\omega t \quad \text{For } 0 \le \omega t \le \pi$$
$$i_L = 0 \quad \text{For } \pi \le \omega t \le 2\pi$$

where I_m = Peak value of Load current

* **Average current (I_{DC}) :-**

$i_L = I_m \sin\omega t$

$$I_{DC} = \frac{1}{2\pi}\int_0^{2\pi} I_m \sin\omega t \, d(\omega t).$$

NOTE
$\int \sin\omega t = -\cos\omega t$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t + \int_{\pi}^{2\pi} 0\right] d\omega t$$

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

$\cos\pi = -1$
$\cos 0 = 1$

$$= \frac{I_m}{2\pi}\left[-\cos\omega t\right]_0^{\pi} = \frac{I_m}{2\pi}\left[-\cos\omega t\pi - (-\cos 0)\right]$$

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

$$\boxed{I_{DC} = \frac{I_m}{\pi}}$$

$\left(\text{where } I_m = \frac{V_m}{R_f + R_L + R_s}\right)$ $\left(R_f = \text{Diode F.B resistance}\right.$
R_L = Resistive load.

* RMS current (I_{rms})

$i_L = I_m \sin\omega t$

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} i_L^2 \, d(\omega t)}$$

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

Half wave

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NOTE:- $\sin^2\omega t = \frac{1-\cos 2\omega t}{2}$

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

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

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

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\left[\frac{\omega t}{2}\right]_0^{\pi} - \left[\frac{\sin 2\omega t}{2\times 2}\right]_0^{\pi}\right]}$$

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

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

R_f = for

R_L = lo

R_s = se

$\Rightarrow$ DC power output (P_{DC})

The dc power output can be obtained as,

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

$$= (I_{DC} R_L) I_{DC}$$

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

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

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

R_f — Diode Forward Resistance

R_L — Load Resistance

R_s — secondary side transformer resistance

$$\boxed{P_{DC} = \frac{V_m^2}{\pi^2 \times (R_f + R_L + R_s)^2} \times R_L}$$

AC Power input (P_{AC})

$$P_{AC} = I_{RMS}^2 R_{Total} \qquad I_{RMS} = \frac{I_m}{2}$$

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

$$\boxed{P_{AC} = \frac{I_m^2}{4} \times (R_f + R_L + R_s)}$$

⟹ Rectifier Efficiency (η)

$$\eta = \frac{\text{D.C output power}}{\text{A.C input Power}}$$

R_f = forward diode Resistor

R_L = Load Resistor

R_s = secondary side Transformer. Resistor

$$\eta = \frac{\frac{I_m^2}{\pi^2} R_L}{\frac{I_m^2}{4}(R_f + R_L + R_s)} = \frac{(4/\pi^2) R_L}{(R_L + R_f + R_s)}$$

$$\eta = 0.406 \times 100 = \boxed{40.6\%}$$

→ Ripple factor (γ).

→ Output of half wave rectifier is not pure d.c but a pulsating d.c. The output contains pulsating components called ripples.

→ The measure of such ripples present in the output is with the help of a factor called ripple factor.

Denoted by γ

Ripple factor $\gamma = \frac{\text{R.m.s value of a.c component of o}}{\text{Average or d.c component of outp}}$

$$I_{Rms} = \sqrt{I_{ac}^2 + I_{DC}^2}$$

$$I_{ac} = \sqrt{I_{Rms}^2 - I_{DC}^2}$$

$$\text{Ripple factor } \gamma = \frac{I_{ac}}{I_{DC}}$$

$$\gamma = \frac{\sqrt{I_{Rms}^2 - I_{DC}^2}}{I_{DC}}$$

$$\gamma = \sqrt{\left(\frac{I_{Rms}}{I_{DC}}\right)^2 - 1}$$

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

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

$$\boxed{\gamma = 1.211}$$

→ PIV (Peak Inverse voltage).

→ The Peak Inverse voltage is the peak voltage across the diode in the reverse direction.

→ PIV occurs at the peak of each negative half cycle of the input, when diode is reverse biased and not conducting.

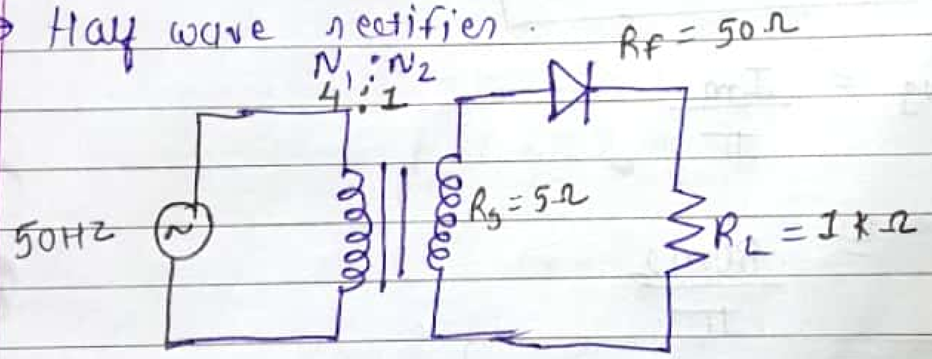
$$\boxed{PIV = -V_m}$$

Assignment Q: 10.

Q.10. For the half wave rectifier circuit, AC supply given to the primary of the transformer is 240V AC RMS with 50 Hz. The resistance of the secondary is 5 Ω, forward resistance of the diode $R_f = 50\,\Omega$, load Resistance is 1 kΩ. Also note transformer primary to secondary turns ratio is 4:1, calculate the following.

(1) Average I_{Load}, Average V_{Load}
(2) RMS I_{Load}, RMS V_{Load}
(3) DC Load power & AC input power
(d) Rectification Efficiency

→ Half wave rectifier.



Data given values are,

$R_S = 5\,\Omega$
$R_L = 1K\,\Omega$
$R_F = 50\,\Omega$
$N_1 : N_2 = 4 : 1$

The given supply voltages are always r.m.s values

$V_1 (RMS) = 240V$

→ we know $\frac{V_2(RMS)}{V_1(RMS)} = \frac{N_2}{N_1}$ $N_2 = 1$, $N_1 = 4$

$= \frac{V_2(RMS)}{240} = \frac{1}{4}$

→ $V_2(RMS) = 240 \times \frac{1}{4} = 60V$

This is r.m.s value of the transformer secondary

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

V_{sm} = Secondary max. voltage

$$V_{sm} = \sqrt{2} \times V_{rms}$$

$$= \sqrt{2} \times 60$$

$$\boxed{V_{sm} = 84.85\,V}$$

$$I_m = \frac{V_{sm}}{R_f + R_L + R_s}$$

given $R_s = 5\,\Omega$
$R_L = 1\,k\Omega$
$R_f = 50\,\Omega$

$$= \frac{84.85}{5 + 1\,k\Omega + 50}$$

$$\boxed{I_m = 0.080429\ A} = 80.42\ mA$$

Half wave equation $I_{DC} = I_{avg} = \frac{I_m}{\pi}$

$$= \frac{80.42}{\pi}$$

1st Answer $\boxed{I_{avg} = 25.59\ mA}$

$$I_{Rms} = \frac{I_m}{2} \text{ for half wave}$$

$$= \frac{80.42\ mA}{2}$$

$$\boxed{I_{Rms} = 40.21\ mA}$$

2nd Answer (DC output voltage)

V_{DC} = [illegible]

$\Rightarrow$ 2nd Answer

$I_{DC} = 25.59 mA$

Average $V = I_{DC} \times R_L$

$= 25.59 \times 10^{-3} \times 1 \times 10^{3}$

~~D.C output Voltage, Vavg =~~ $\boxed{V_{DC} = 25.59 V}$

P_{DC} = d.c output power = $V_{DC} \times I_{DC}$

$V_{DC} = 25.59 V$
$I_{DC} = 25.59 mA$
$R_L = 1 K\Omega$

3 3rd Answer

$= 25.59 \times 25.59 \times 10^{-3}$

$\boxed{P_{DC} = ~~0.028W~~}$ / $0.654 W$

(in your exam only write any one calculation of P_{DC}

$\rightarrow$ Also can be obtained as,

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

$R_L = 1 K\Omega$
$I_m = 80.42 mA$

$$= \frac{(80.42 \times 10^{-3})^2}{\pi^2} \times 1 \times 10^3$$

$\boxed{P_{DC} = 0.655 W}$

A.C input power.

$$P_{AC} = I_{Rms}^2 \times (R_f + R_L + R_S)$$

$$= (40.21 \times 10^{-3})^2 \times (50 + 5 + 1 \times 10^3)$$

$I_{Rms} = 40.21 mA$
$R_f = 50\Omega$
$R_S = 5\Omega$
$R_L = 1 K\Omega$

$\boxed{P_{AC} = 1.705 W}$

$$\% \eta = \frac{P_{DC}}{P_{AC}} \times 100$$

4th Answer $\% \eta = 1.7057$

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Single phase full wave Rectifier

→ Full wave rectifier conducts during both Positive and negative half cycles of input a.c supply.

Two Type.

① Center tapped or (mid point)

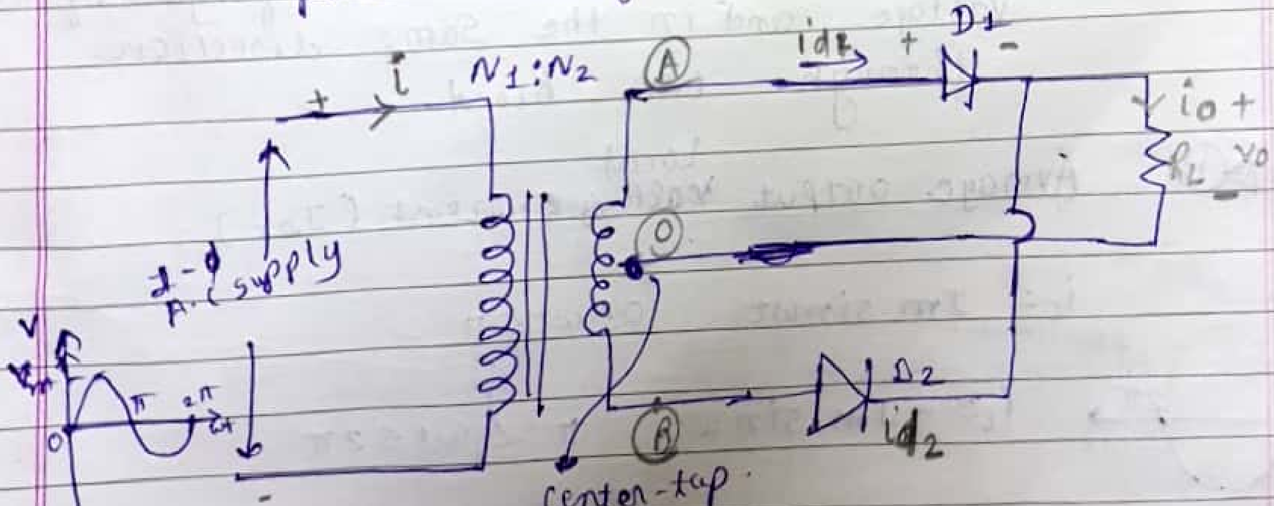
② Full wave diode bridge rectifier.

(i) Center-tapped or midpoint

→ In order to rectify both the half cycle of a.c input, two diodes are used in this circuit.

→ The diode feed a common load R_L with the help of a center tap transformer.

→ A.c voltage is applied through a suitable power transformer with proper turns ratio.



→ 1^{st} half cycle A is (+ve) → w.r.t to B
D_1 = conduct = F.B

→ 2^{nd} half cycle B is (-ve) with respect to A
D_2 conduct = F.B

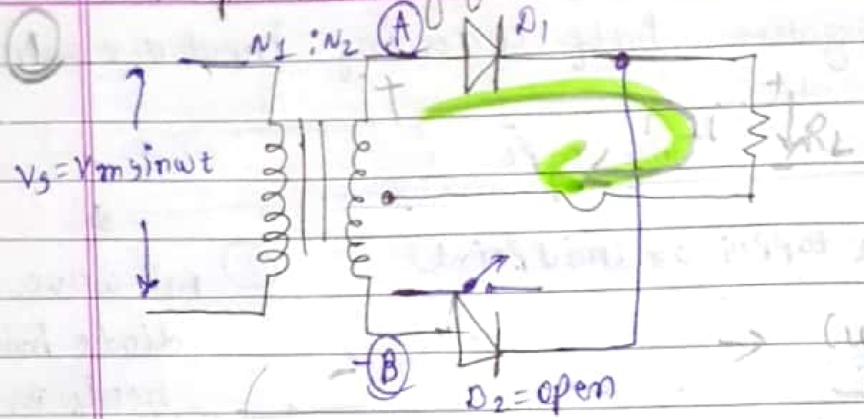
$$\boxed{\frac{N_2}{N_1} = \frac{E_{sm}}{E_{pm}}}$$

E_{sm} = Peak value of Secondary voltage
E_{pm} = Peak value of Primary voltage
N_1 = Primary Number of turns

Center tap full wave

Operation of full wave

(1)



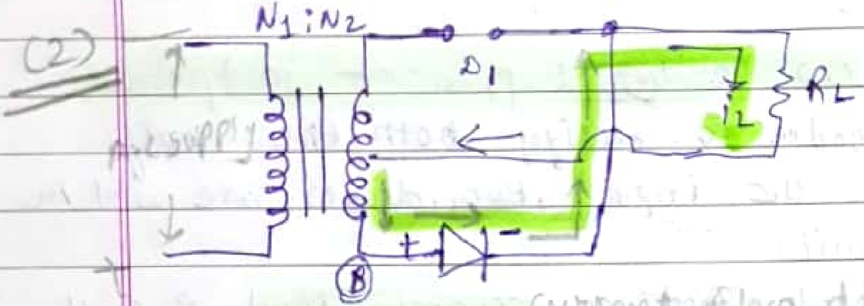
$\boxed{i_L = i_{d1}}$

D_1 = conduct (F.B)

D_2 = R.B

→ Current flow during positive half cycle.

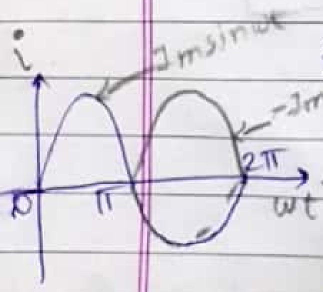
(2)



Current flow during Negative half cycle

→ NOTE:- I_{load} flows in both the half cycles of ac Voltage and in the same direction through the R_{load}.

→ (1) Average output ~~Voltage~~ load Current (I_{DC}).



$i_L = I_m \sin \omega t \quad 0 \le \omega t \le \pi$

$i_L = -I_m \sin \omega t \quad \pi \le \omega t \le 2\pi$

$$I_{av} = I_{DC} = \frac{1}{\pi} \int_0^{\pi} I_m \sin \omega t \, d(\omega t)$$

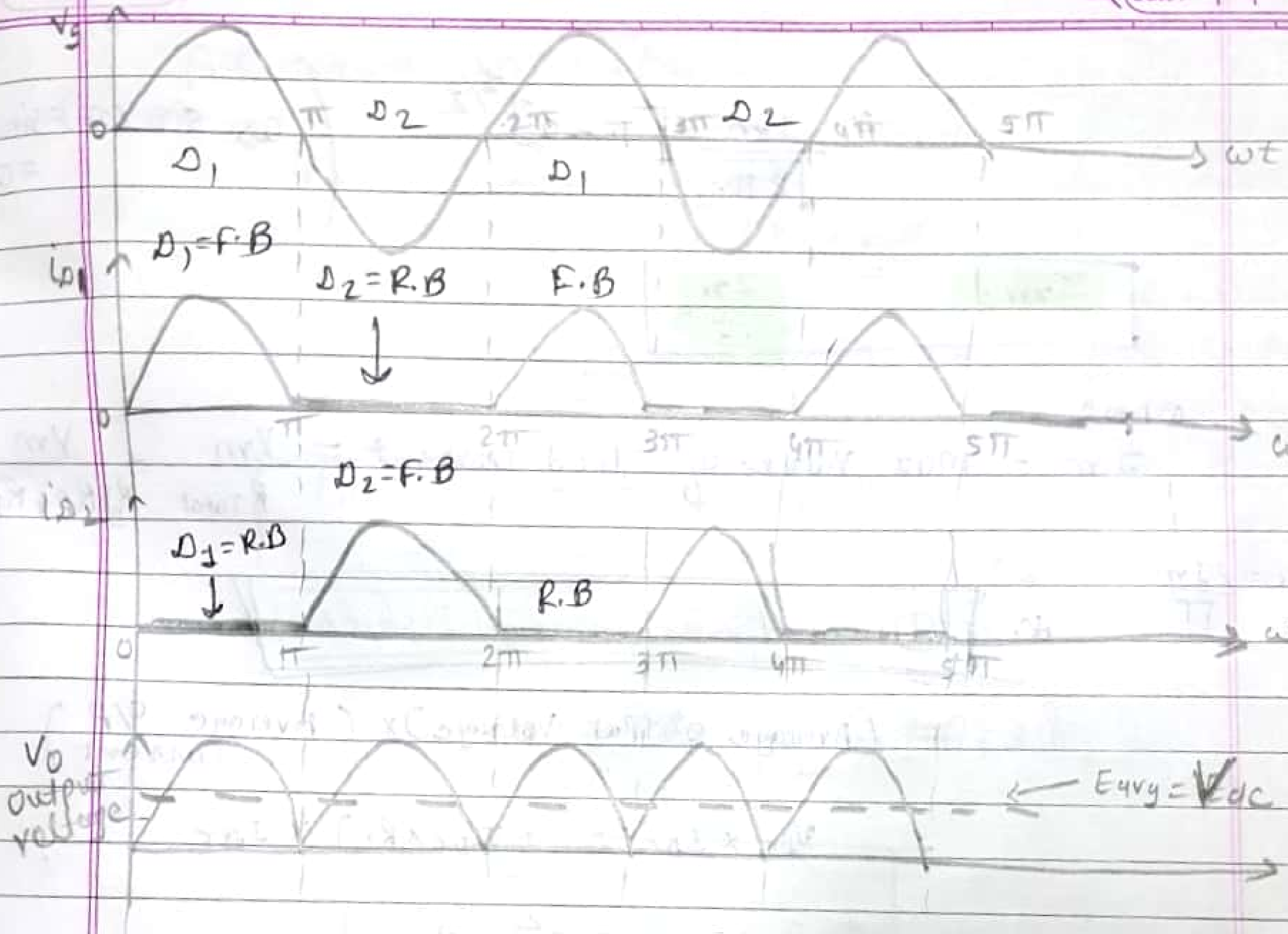
$\int \sin \omega t = -\cos \omega t$

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

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

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

center tap full wave waveform



→ Same for $V_{DC} = \frac{2V_m}{\pi}$

→ R.m.s value of load current (I_{Rms})

$$I_{Rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i_L^2 \, d(\omega t)} \qquad i_L = I_m \sin\omega t$$

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

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

$$= \frac{I_m}{\sqrt{2\pi}}\left[[\omega t]_0^{\pi} - \left[\frac{\sin 2\omega t}{2}\right]_0^{\pi} = 0\right]^{1/2}$$

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$$= \frac{I_m}{\sqrt{2\pi}} [\pi - 0]^{1/2}$$ (as $\sin(2\pi) = \sin(0) = 0$

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

→ where
I_m = Max. value of load current $= \frac{V_m}{R_{Total}} = \frac{V_m}{R_s + R_f + R_L}$

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

* **D.C Power output (P_{DC})**

P_{DC} = (Average output voltage) x (Average O/P current)

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

$$= I_{DC}^2 R_L$$

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

$$\boxed{P_{DC} = \frac{4}{\pi^2} \times I_m^2 R_L} \rightarrow equ^n(i)$$

Substitute value of I_m we get,

$$\boxed{P_{DC} = \frac{4}{\pi^2} \times \frac{E_m^2}{(R_f + R_L + R_s)^2} \times R_L}$$

⇒ R_f = Forward Diode Resistor
R_L = Load Resistor
R_s = Secondary transformer Resistor

A.C power input (P_{AC}).

$$P_{AC} = I_{Rms}^2 \times R_{Total}$$

$$= I_{Rms}^2 \times (R_f + R_L + R_s)$$

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

$\because I_{Rms} = \frac{I_m}{\sqrt{2}}$

$\therefore R_f$ = Diode Resistor
R_L = Load Resistor
R_s = secondary side transformer Resistor

$$\boxed{P_{AC} = \frac{I_m^2}{2}(R_f + R_L + R_s)} \rightarrow \text{equ}^n (2)$$

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

Substitute Value of I_m we get,

$$P_{AC} = \frac{V_m^2}{2(R_f + R_L)^2} \times (R_f + R_L)$$

$$\boxed{P_{AC} = \frac{V_m}{2(R_f + R_L + R_s)}} \rightarrow \text{equ}^n (3)$$

→ Rectifier Efficiency (η)

$$\eta = \frac{P_{DC}\ \text{output}}{P_{AC}\ \text{Input}}$$

$$= \frac{4/\pi^2\, I_m^2 R_L}{\frac{I_m^2}{2}(R_f + R_L + R_s)} \quad \begin{matrix}\rightarrow \text{equ}^n (i) \\ \rightarrow \text{equ}^n (2)\end{matrix}$$

$$\boxed{\%\eta = \frac{8}{\pi^2} = 81.2\%}$$

$R_f << R_L = R_L$

Center tap full wave

Ripple factor =

The output contains pulsating components called Ripples.

The measures of such ripples present in the output is with the help of a factor called Ripple factor.

$$\text{Ripple factor } \gamma = \frac{\text{R.m.s value of a.c component of o/p}}{\text{Average or d.c component of o/p}}$$

where

I_{ac} = R.m.s value of a.c component present in o/p

I_{dc} = Average value present in o/p

$$\gamma = \frac{I_{ac}}{I_{DC}}$$

I_{Rms} = R.m.s value of Total o/p current $= \sqrt{I_{ac}^2 + I_{dc}^2}$

$$\gamma = \frac{\sqrt{I_{Rms}^2 - I_{DC}^2}}{I_{DC}}$$

$I_{Rms} = \frac{I_m}{\sqrt{2}}$

$$\gamma = \sqrt{\frac{\pi^2}{8} - 1}$$

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

$$\boxed{\gamma = 0.48}$$ Full wave

→ This indicates that the ripple contents in the output are 48% of the d.c component which is much less then that for half wave circuit.

Center tap full wave

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Peak inverse voltage :- (PIV)

→ Peak inverse voltage is the peak voltage across the diode in the reverse direction i.e. when the diode is reverse biased.

→ Peak inverse voltage occurs at the peak of each negative half cycle of the input, when diode reverse biased and diode not conducting.

→ PIV of diode
→ Half wave = V_m
full wave = $2V_m$

(where V_m = max. value of a.c voltage across half secondary of transformer

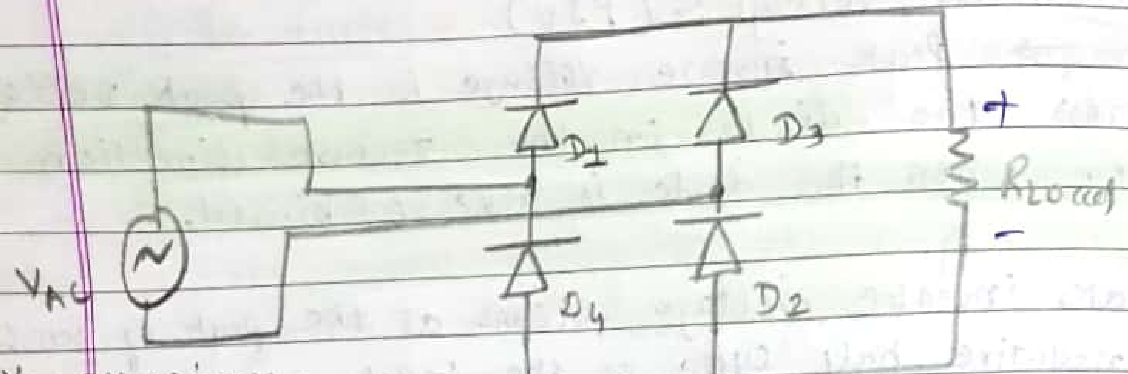
→ If the diode drop is considered to be 0.7V then the PIV of reverse biased diode is,

PIV of diode = $2V_m - 0.7$ — full wave
PIV of diode = $V_m - 0.7$ — Half wave

→ **Advantage**
(i) Low ripple factor as compared to Half wave
(2) Better rectification efficiency.
(3) No possibility of transformer core saturation.

Disadvantage :-
→ PIV of diode is $2V_m$ Hence size of diode is large.
→ Cost of center tapped transformer is High.

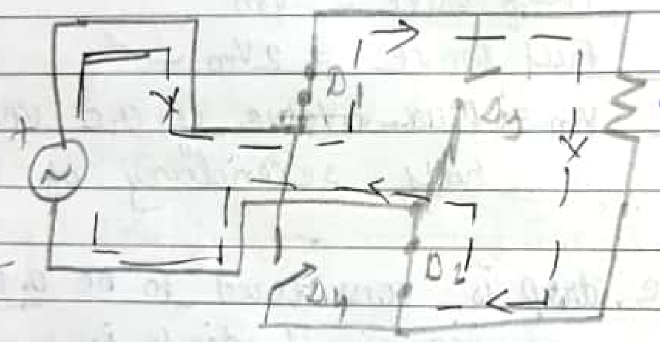
full wave Bridge Rectifier.



$V_{AC} = V_m \sin \omega t$.

→ During +ve half cycle.

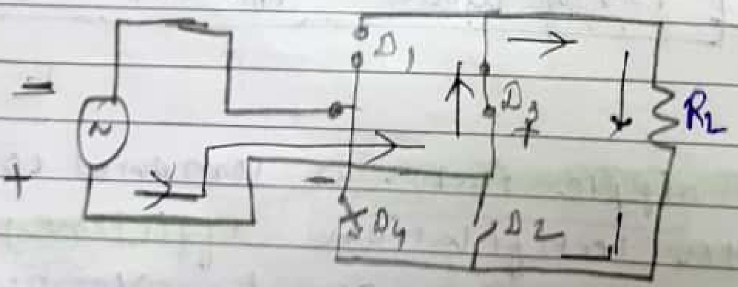
$(D_1, D_2$ = F.B = Conduct
= forward bias



$0 \le \omega t \le \pi$

D_3, D_4 = R.B.
= Reverse bias.

→ During Negative half cycle:-



D_3, D_4 = forward bias.

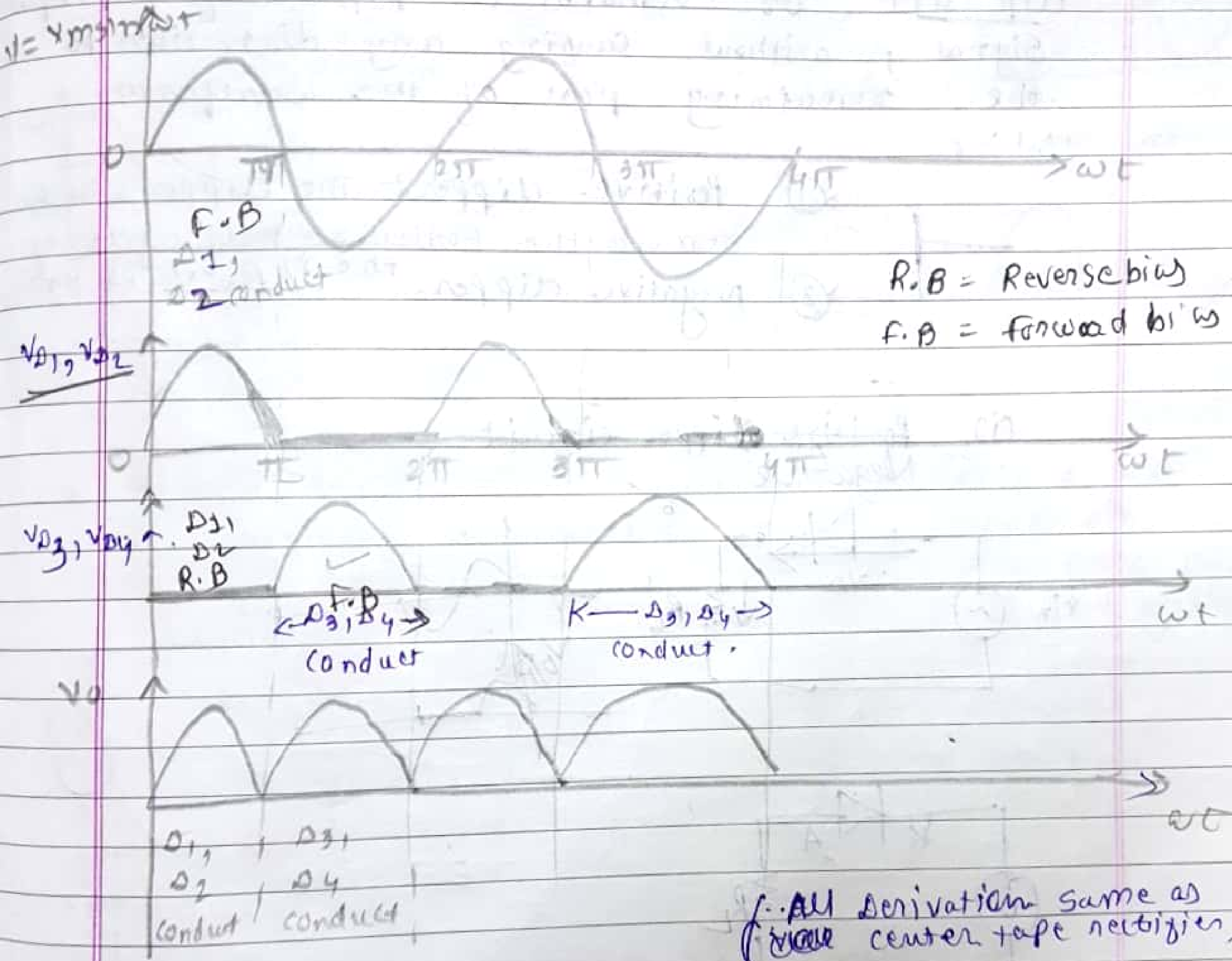
$\pi \le \omega t \le 2\pi$.

Advantage :- – It requires a small size transformer.
– The circuit is most suitable for the high voltage applications.

Disadvantages :-
The Number of diodes used is four instead of two for FWR (fullwave rectifier). As

R_f = forward Diode Resistor
R_S = secondary side Transformer Resistor
~~R_L = Load Resistor~~

two diodes conducts simultaneously the voltage drop ↑, output voltage.



R.B = Reverse bias
F.B = forward bias

(∴ All Derivation same as center tape rectifier)

- Average output voltage $V_{o(avg)} = \frac{2V_m}{\pi}$

$$\left(\because I_m = \frac{V_m}{R_S + 2R_f + R_L}\right)$$

- Average output current $I_{o(avg)} = I_{DC} = \frac{2I_m}{\pi}$
- RMS current $I_{RMS} = \frac{I_m}{\sqrt{2}}$, RMS voltage $= \frac{V_m}{\sqrt{2}}$
- $\eta = 81.2\%$, Ripple factor $= 0.482$

Advantages of Bridge Rectifier-

1. The current in both the primary and secondary of the power transformer flows for the entire cycle and hence for a given power output, power transformer of a small size & less cost may be used.

2. No center tap is require in the transformer secondary. Hence wherever possible, ac voltage can directly be applied to the bridge.

3. The current in the secondary of the transformer is in opposite direction in two half cycles. Hence net d.c component flowing is zero which reduces the losses and danger of saturation.

4. Use high application.