6.11: Full-wave Rectifier: A full wave rectifier is an electronic circuit that converts AC ~~current~~ to ~~DC~~ DC using both the positive & negative ~~signal~~ halves of an AC signal. ~~B~~ current flows in the same direction.

common full-wave rectifiers are:

(i) Centre-tap-full-wave rectifier

(ii) Full-wave bridge rectifier.

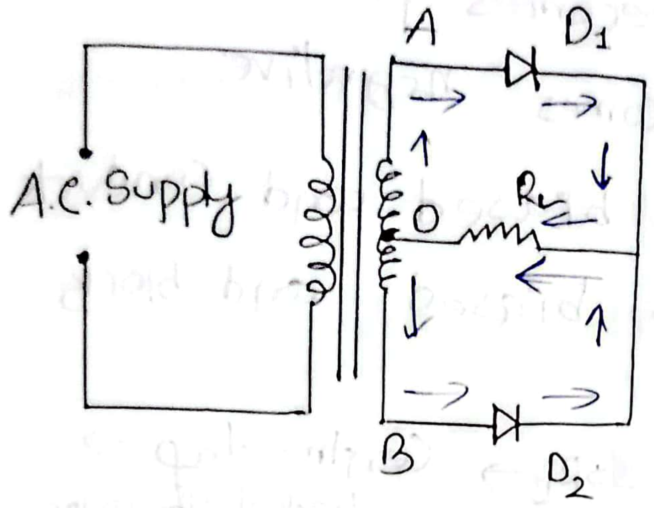
6.12: Centre-tap full-wave Rectifier:

A centre tap full wave rectifier is an electronic circuit that converts the entire input AC signal into DC using two diodes and a centre-tapped transformer

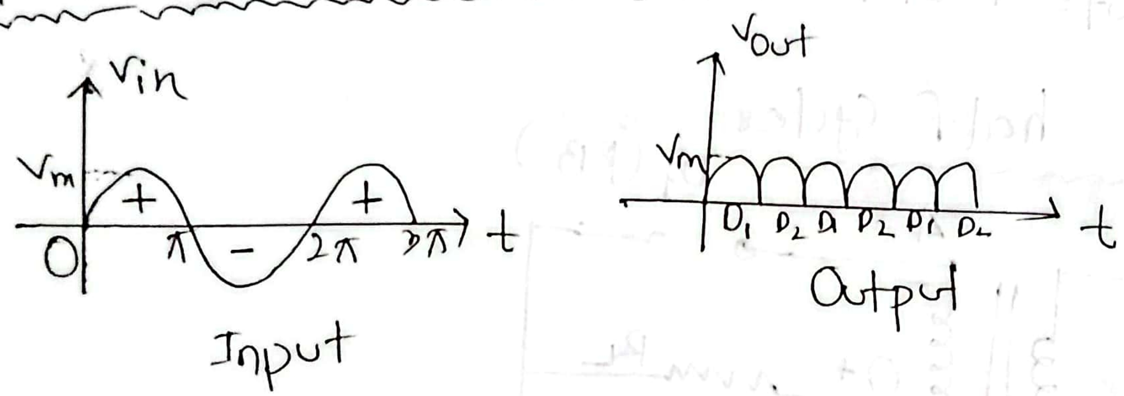
Circuit Components:

1. Center-Tapped transformer
2. Two diodes
3. Load Resistor
4. A.C input sourc.

Diagram:

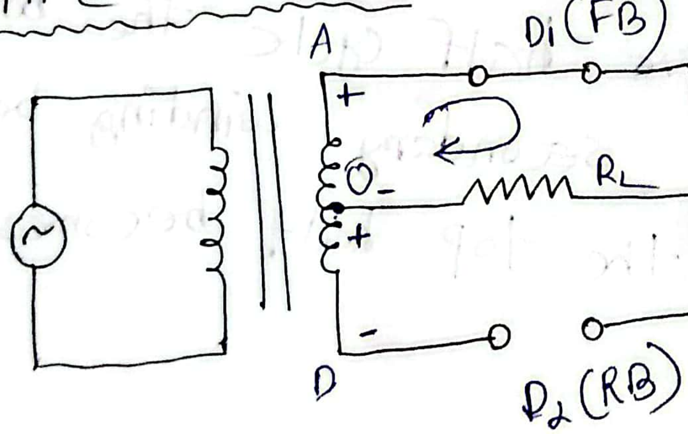


Input/Output voltage diagram:



Working Principle:

① Positive half cycle:



→ During Positive half cycle the top half of the secondary winding becomes positive, and the ~~but~~ bottom half becomes negative.

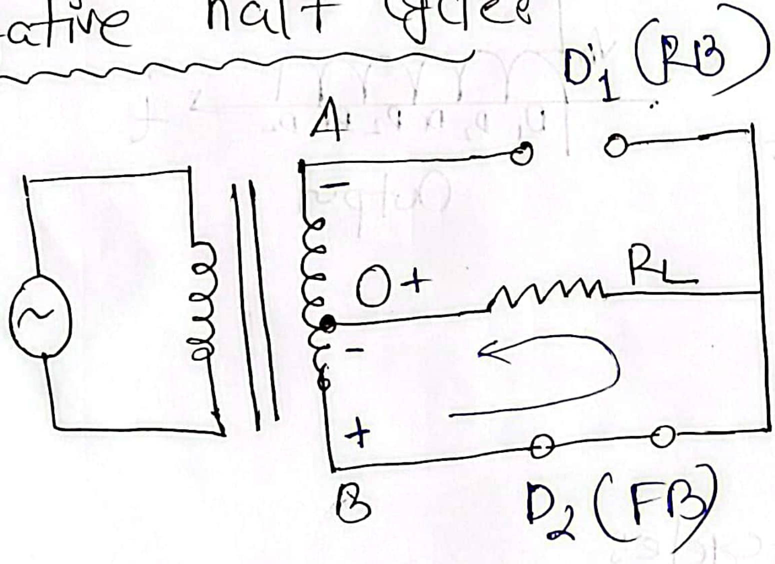
→ Diode D_1 is forward biased and conducts

→ Diode D_2 is reverse biased and blocks current.

→ current path: $D_1 \to R_L \to$ Centre tap → back to the source

→ Output: Positive voltage across R_L.

② Negative half cycle



→ During Negative half cycle the bottom half of the secondary winding becomes positive, and the top half becomes negative.

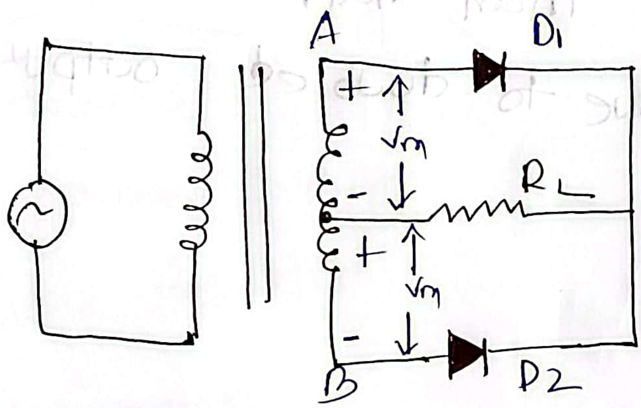
→ Diode D_2 is forward biased and conducts

→ Diode D_1 is reverse biased and blocks current

→ Current path : $D_2 \rightarrow R_L \rightarrow$ Centre tap. – back to the source.

→ Output: positive voltage across R_L

Peak Inverse Voltage (PIV):



Suppose V_m is the maximum voltage across the half secondary winding.

→ During the positive half-cycle D_1 conducts and D_2 is reverse biased.

→ The reverse ~~across~~ voltage across D_2 = Total secondary voltage $(2V_m)$.

→ Similarly $D_1 = 2V_m$ during the negative half-cycle.

So, the peak inverse voltage is twice the maximum voltage across the half secondary winding.

$$PIV = 2V_m.$$

Advantages:

→ higher efficiency than half-wave rectifiers

→ Lower ripple due to doubled output frequency (2f)

→ Simple Design.

Disadvantages:

→ It is difficult to locate the centre tap on the secondary winding.

→ The diodes used must have high peak inverse voltage.

→ The d.c. output is small as each diode utilises only one-half of the transformer secondary voltage.

6·13: Full-wave Bridge Rectifier:

A full-wave bridge rectifier ~~was~~ is an electronic circuit that converts an alternating current (AC) into a Direct curren (DC) using four diodes arranged in a bridge configuration.

Circuit Components:

1. Four diodes.
2. A.C Power suppy
3. Load Resistor

Circuit Diagram:

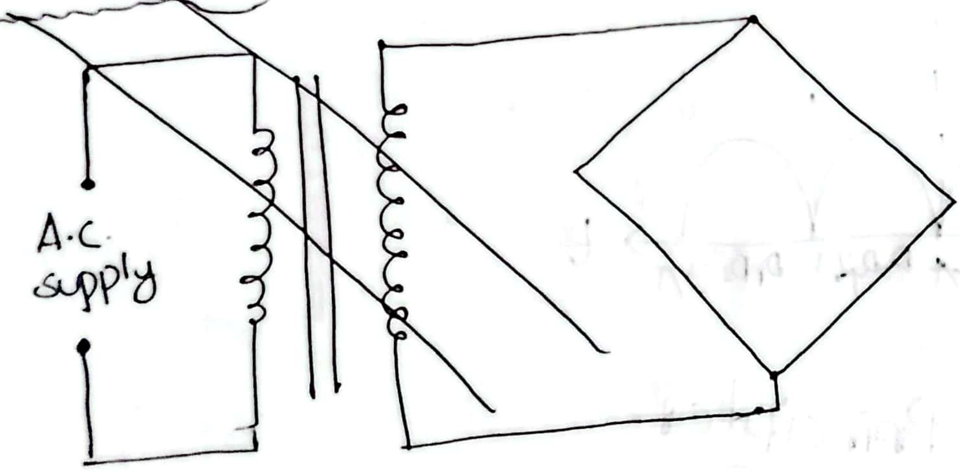
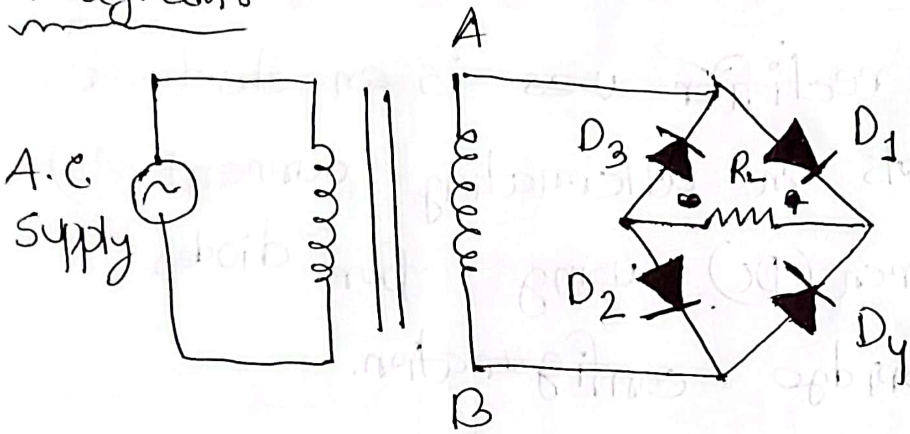
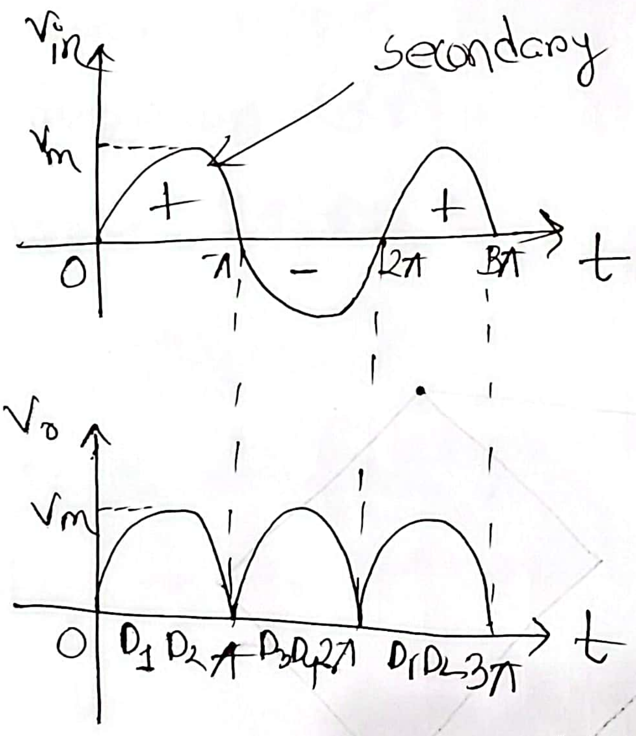


Diagram:



I/O Voltage Diagram:



Working Principle:

① Positive half-cycle:

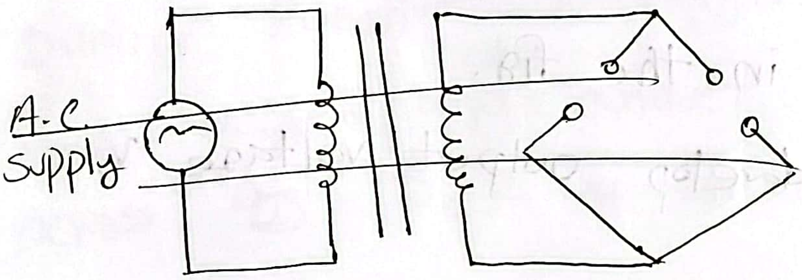
→ Point A is positive and B is negative.

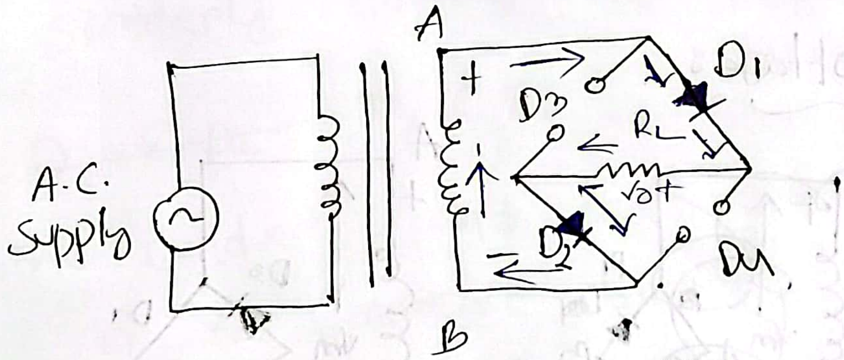
→ Diodes D_1 & D_2 are forward biased. (~~conducting~~)

→ Diodes D_3 & D_4 are reverse biased (~~blocking~~)

→ D_1 & D_2 conduct, current flows through R_L as shown in the fig.

→ This current will develop output voltage across R_L.



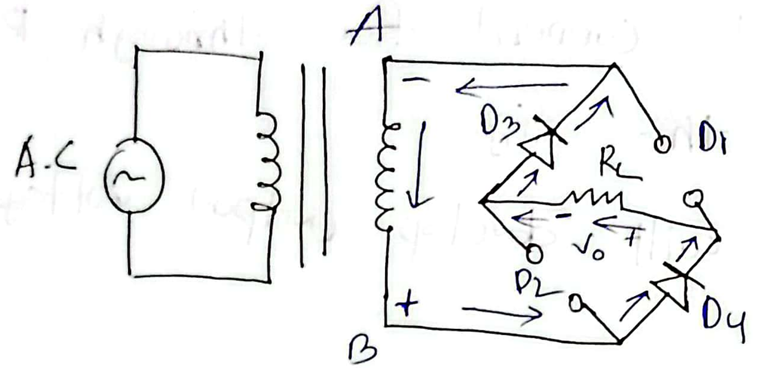


② Negative Half-Cycle:

→ Point A is negative & B is positive.

→ Diodes D_3 & D_4 are forward biased.

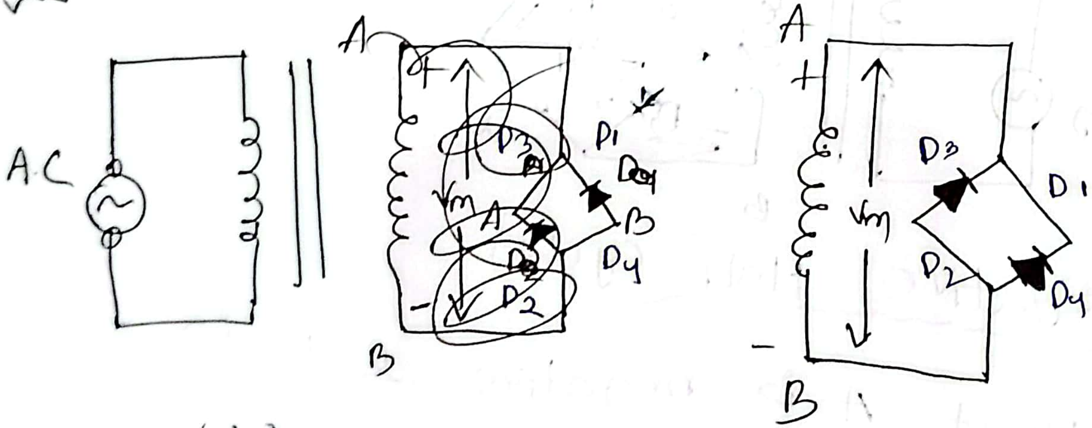
→ Diodes D_1 & D_2 are reverse biased.

→ 

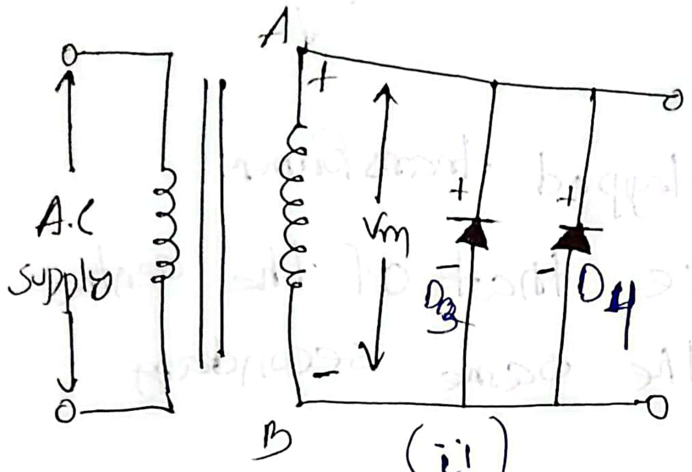
→ D_3 & D_4 conduct & current flows through R_L as shown in the fig.

→ The current develop output voltage V_o across R_L.

Peak Inverse Voltage:



(i)



(ii)

→ PIV is the maximum reverse voltage a diode experiences when it is not conducting.

→ During positive half-cycle, D_1 & D_2 are forward biased and conduct and the voltage across ~~D_2~~, D_3 & D_4 is V_m (reverse biased).

→ Similarly during the negative half-cycle, ~~D_1 & D_2~~ D_3 & D_4 are forward biased and conduct, and the voltage across D_1 & D_2 is V_m (reverse biased).

→ It is clear that in the fig (ii) two reverse biased diodes D_3 & D_4 and the secondary transformer are in parallel.

Hence,

$$PIV = V_m$$

Advantages:

→ No need for a centre-tapped transformer

→ The output is twice that of the centre tap circuit for the same secondary voltage.

→ The PIV is one-half that of the centre tap circuit (for same d.c. output).

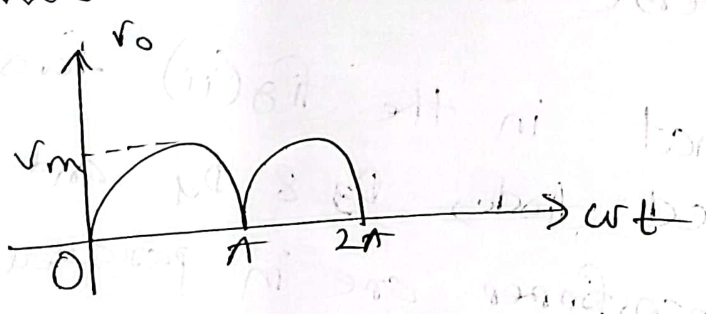
Disadvantages:

→ It requires four diodes.

→ Higher voltage drop.

[4] Average value of output Voltage & currents

Average dc voltage:



$v_o = V_m \sin \omega t$

$$V_{av} = V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \cdot d(\omega t)$$

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

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

$$= \frac{V_m}{\pi}(1+1)$$

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

Average DC current:

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

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

$$\therefore I_{av} = \frac{2I_m}{\pi} \qquad \left[I_m = \frac{V_m}{R}\right]$$

or,

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

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

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

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

$$\boxed{\therefore I_{av} = \frac{2I_m}{\pi}}$$

Efficiency of Full-wave Rectifier:

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

$$P_{ac} = (I_{rms})^2 \times (R_L + r_f)$$

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

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

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

For a full-wave rectified wave we have

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

$$\therefore P_{ac} = \left(\frac{I_m}{\sqrt{2}}\right)^2 \times (r_f + R_L)$$

$$\therefore \eta = \frac{(2I_m/\pi)^2 \times R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 \times (r_f + R_L)}$$

$$= \frac{8}{\pi^2} \times \frac{R_L}{r_f + R_L}$$

$$= \frac{0.812 R_L}{r_f + R_L}$$

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

The efficiency will be maximum if r_f is negligible as compared to R_L

$\therefore$ Maximum efficiency $= 81.2\%$.

$\rightarrow$ Full wave rectifier is more effective than half wave rectifier.

Exm: 6.16:

$r_f = 20\Omega$, $R_L = 980\Omega$

~~$V = 50V$~~

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

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

$$= \frac{70.7}{20+980}$$

$$= 70.7mA$$

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

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

$$= 45mA$$

ii) R.M.S value of load current, $I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{70.7}{\sqrt{2}}$

$= 50mA$ (Ans)

Exm: 6.17.

Primary to secondary turns, $N_1/N_2 = 5/1$

R.M.S Primary voltage = 230 V

R.M.S. Secondary voltage = $230 \times \frac{1}{5} = 46V$

$\therefore$ ~~R.M.S~~ Maximum voltage across secondary $= 46 \times \sqrt{2} = 65V$

$\therefore$ Maximum voltage across half secondary winding is, $V_m = 65/2 = 32.5V$

i) $$I_{dc} = \frac{2V_m}{\pi R_L} = \frac{2 \times 32.5}{\pi \times 100} = 0.207A$$

$\therefore$ d.c output voltage, $V_{dc} = I_{dc} \times R_L$
$= 0.207 \times 100$
$= 20.7V$

ii) $PIV = 2 \times 32.5 = 65V$ Ans.

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

since $r_f \to 0$

$\therefore \eta = 81.2\%$ (Ans.)

Exm: 6.18:

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$V_2 = \cancel{23} V_1 \times \frac{N_2}{N_1}$$ [V_1 = Primary, V_2 = secondary]

$$= 230 \times \cancel{4} \frac{1}{4}$$

$\therefore$ R.M.S secondary voltage = $57.5V$

Maximum voltage across secondary $= 57.5 \times \sqrt{2}$

$V_m = 81.3V$

i) $\therefore V_{dc} = \frac{2V_m}{\pi}$

$= 51.75 V$ (Ans)

ii) $PIV = \cancel{2\times}\ 81.3 V$ Ans

iii) $f_{out} = 2 \times f_{in} = 2 \times 50 = 100\ Hz$

Exm: 6.21:

The a.c. voltage across transformer secondary is 12 V r.m.s.

$\therefore$ peak secondary voltage, $V_{s(pk)} = 12 \times \sqrt{2}$
$= 16.97\ V$

i) Peak output voltage is

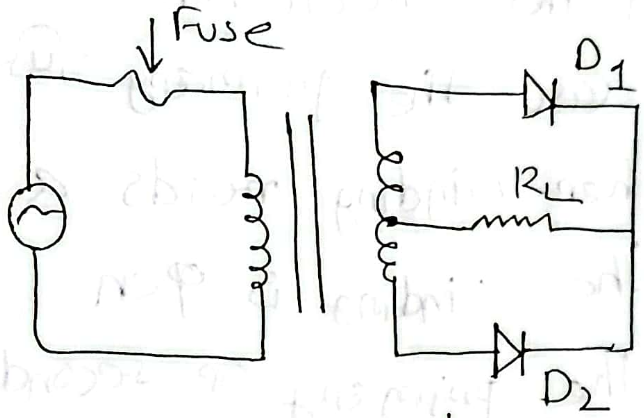
$$V_{out(pk)} = 16.97 - (2 \times 0.7)$$
$$= 15.57\ V$$

$$\therefore V_{dc} = \frac{2 V_{out(pk)}}{\pi} = \frac{2 \times 15.57}{\pi}$$
$$= 9.91\ V \text{ Ans}$$

ii) $$I_{dc} = \frac{V_{dc}}{R_L} = \frac{9.91}{12\,k\Omega}$$
$$= 825.8\ \mu A$$
Ans

Faults in Centre-tap Full wave Rectifier:

The faults in a centre-tap full wave rectifier may occur in the transformer or rectifier diodes.



A fuse is connected ~~to~~ in the primary of the transformer for protection purposes.

We can divide the rectifier faults into two classes:

1. Faults in Transformer 2. Faults in rectifier diodes

1. Faults in Transformer: The transformer in a rectifier circuit can develop the following faults:

i) A shorted primary or secondary winding: In most cases, a shorted primary or shorted secondary will cause the fuse in the primary to blow. If the fuse does not blow, the d.c output from the rectifier will be extremely low and the transformer itself will be very hot.

ii) An open primary or secondary winding: when the primary or secondary winding of the transformer opens, the output from the rectifier will drop to zero. In this case, the primary fuse will not blow. If either winding reads a very high resistance, the winding is open

iii) A short between the primary or secondary winding and the transformer frame: If either winding shorts to the transformer casing the primary fuse will blow. This fault can be checked by measuring the resistances from the winding leads to the ~~transfo~~ transformer casing. A low resistance measurement indicates that a winding-to-case short exists.

2. Faults in Rectifier Diodes: If a fault occurs in a rectifier diode the circuit conditions will indicate the type of fault:

i) If one diode in the centre-tap full wave rectifier is ~~oper~~ shorted, the primary fuse will blow. suppose in the fig D_2 is shorted. Then diode D_2 will behave as a wire. when diode D_1 is forward biased, the transformer secondary will be shorted through D_1. This will cause excessive current to flow in the secondary, causing the primary fuse to blow.

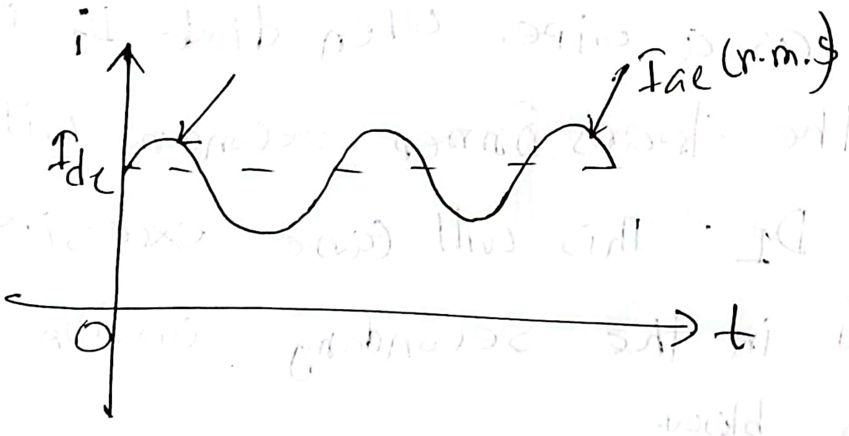
ii) If one diode in the centre-tap full wave rectifier is open, the output from the rectifier will resemble the output from a half wave rectifier. The remedy is to ~~p~~ replace the diode.

Ripple factor: The ratio of r.m.s value of a.c. component to the d.c. component in the rectifier output is known as ripple factor.

$$\text{Ripple factor} = \frac{\text{r.m.s. value of a.c component}}{\text{value of d.c. component}}$$

$$= \frac{I_{ac\,(r.m.s)}}{I_{dc}}$$

The smaller the ripple factor, the ~~mo~~ lesser the effective of a.c component, hence more effective is the rectifier.



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

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

$$\Rightarrow \frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}} \sqrt{I_{rms}^2 - I_{dc}^2}$$ [dividing throughout by I_{dc}]

$$\therefore \text{Ripple factor} = \frac{1}{I_{dc}} \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

i) For half-wave rectification:

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

$$\therefore \text{Ripple factor} = \sqrt{\frac{(I_m/2)^2}{(I_m/\pi)^2} - 1}$$

$$= 1.21$$

The results in greater pulsations in the output. Therefore, half-wave rectifier is ineffective for conversion of a.c into d.c.

ii) For full-wave rectification:

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

$$\therefore \text{Ripple factor} = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1}$$

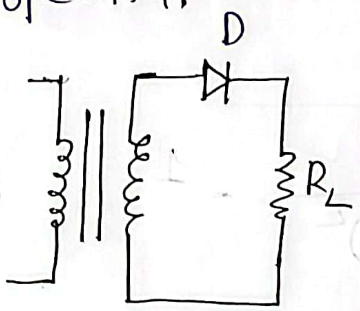
$$= 0.48$$

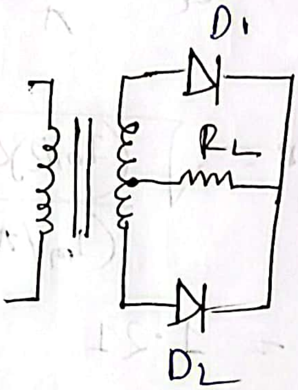
The pulsations in the output will be less than in half-wave rectifier. For this reason full wave rectifier is more effective for conversion of a.c into d.c.

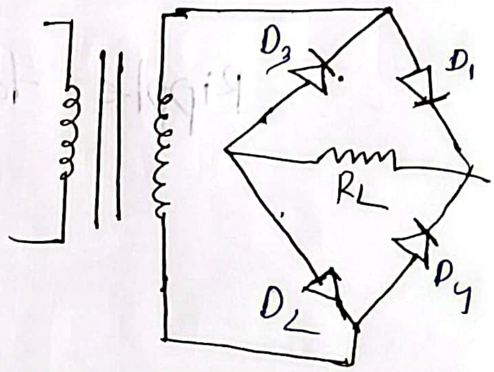
Comparison of Rectifiers:

Rectifier type: Half wave | Full-wave Centre tap | Full wave Bridge Rectifier

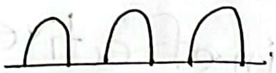
Schematic diagram:

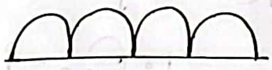


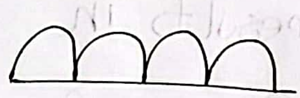




Typical output waveform:



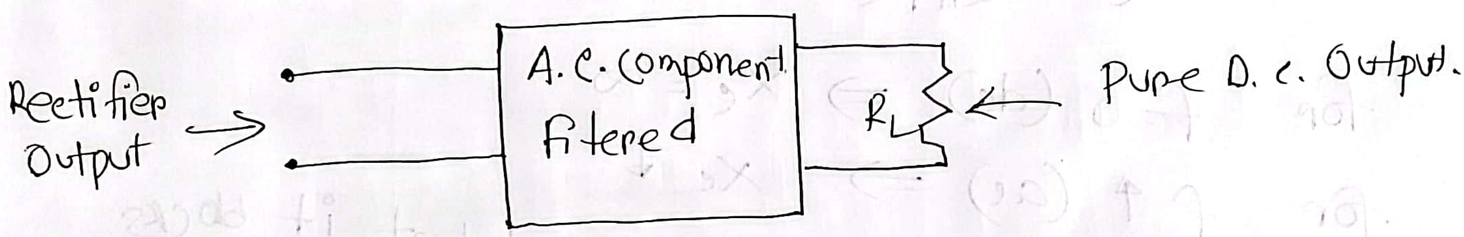




SL. NO.	Particulars	Half-wave	Centre-tap	Bridge type
1	NO. of diodes	1	2	4
2	Transformer necessary	no	yes	no
3	Max. efficiency	40.6%	81.2%	81.2%
4	Ripple factor	1.21	0.48	0.48
5.	Output frequency	f_{in}	$2f_{in}$	$2f_{in}$
6	Peak Inverse voltage	V_m	$2V_m$	V_m

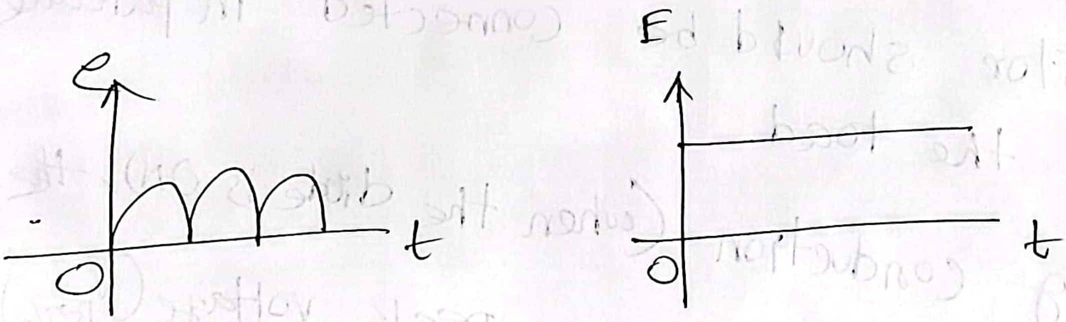
□ Filter circuits: A filter circuit is a device which removes the a.c component of rectifier output but allows the d.c component to reach the load.

A filter circuit should be installed between the rectifier and the load as show in the following fig. A filter circuit is generally a combination of inductors and capacitors.



~~fig: fil~~

Filter circuit



Types of Filter circuits:

i) **Capacitor filters** A capacitor filter is the simplest and most common filter used in power supplies to reduce ripple voltage in the rectifier output. It consists of a capacitor connected in parallel with the load resistor.

Working Principle:

$$X_c = \frac{1}{2\pi f c}$$

for $f = 0$ (dc) $\Rightarrow X_c = \infty$

for $f \uparrow$ (ac) $\Rightarrow X_c \downarrow$

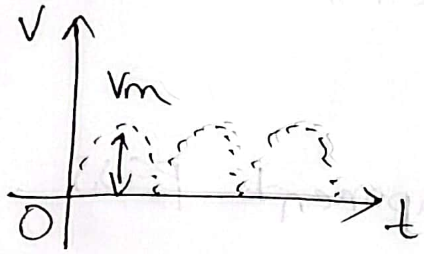
→ capacitor allows ac current but it blocks dc current

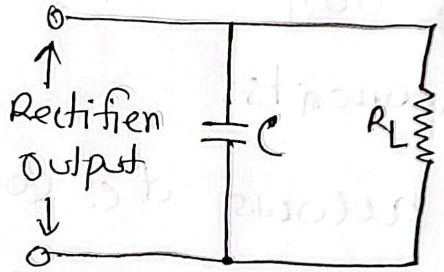
→ capacitor should be connected in parallel with the load.

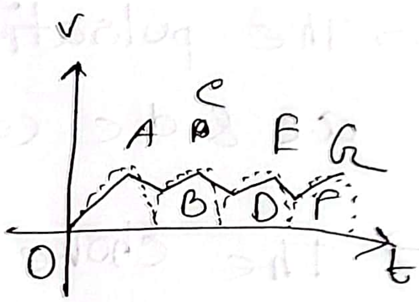
→ During conduction (when the diode is ON), the capacitor charges to the peak voltage (V_{peak}).

→ During non-conduction (when the diode is OFF), the capacitor discharges through the load, maintaining a ~~smol~~ smoother DC output.

~~Advantages~~







Advantages:

→ Simple & Low-cost

→ Small size

→ Little weight

→ Provides a high peak voltage.

ii) Choke input filter: A choke input filter is a type of filter circuit used after a rectifier to reduce the ripple in DC output. It uses an inductor connected in series with the load and a capacitor in parallel to smooth the rectified DC output.

Working Principle:

→ The pulsating output of rectifier contains a.c & d.c components.

→ The choke allows d.c. component pass but not allow to pass a.c. component.

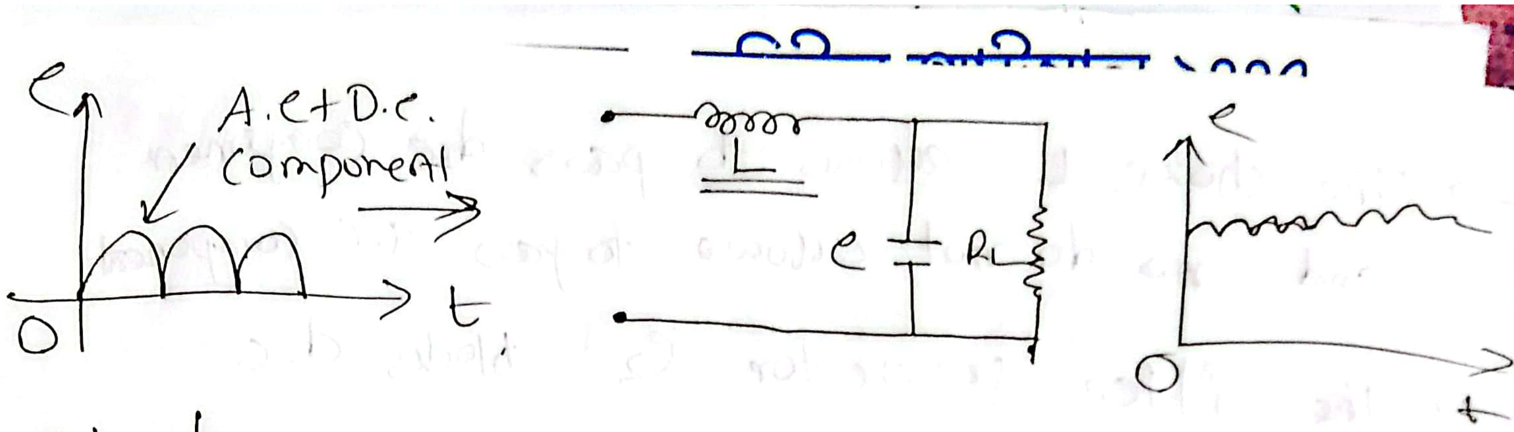
→ ~~The capacitor~~ Now the rectifier output contains d. c. component & the remaining part of a.c. component which was a.c. component

⇒ Now the ~~loo~~ capacitor allows to pass but do not allow to pass d.c. component because,

for d.c, f = 0

$$X_C = \frac{1}{2\pi f c} = \infty$$

→ Therefore only dc component reaches the load. In this way, the filter circuit has filtered out the a.c. component from the rectifier output.



Advantages:

→ Low Ripple voltage

→ Efficient for high current

iii) Capacitor input filter or π-filter:

A capacitor input filter or π filter consists of a filter capacitor C_1 connected across the rectifier output, a choke L in series and another filter capacitor C_2 connected across the load.

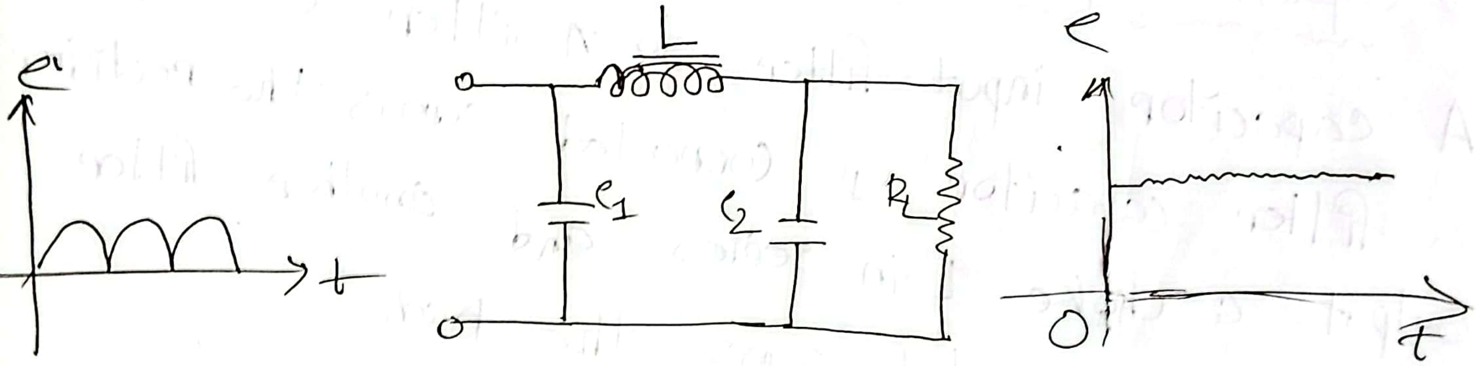
Working Principle:

→ The pulsating output from the rectifier contains a.c & d.c. components

→ The filter capacitor C_1 allows a.c. component to pass through it but block d.c. component and d.c pass through continuous during the L.

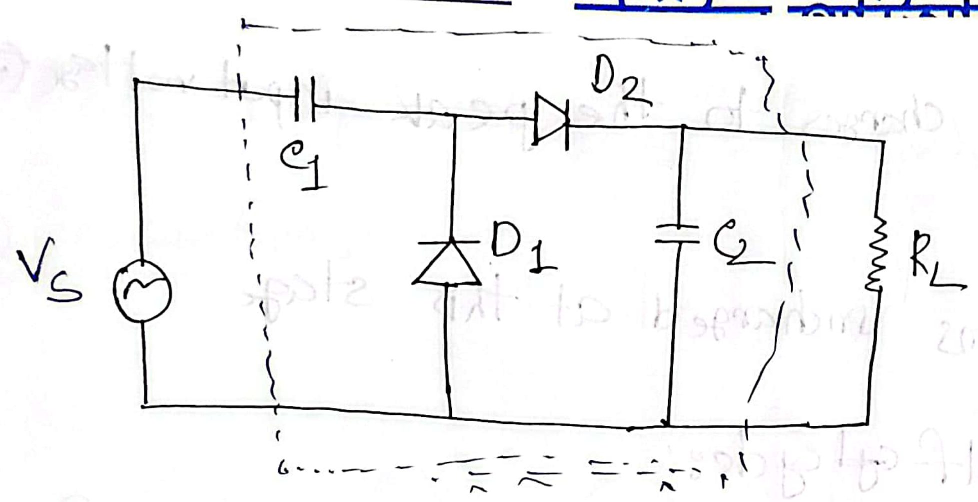
→ The choke L allows to pass d.c component and do not allows to pass a.c component.

→ The filter capacitor C_2 blocks d.c. component but allows a.c component to pass through on it. Thus only d.c component appears across the load.



Half-wave Voltage ~~Divider~~ Doubler:

A half-wave voltage doubler is a type of voltage multiplier circuit that doubles the input AC voltage using two diodes & two capacitors.



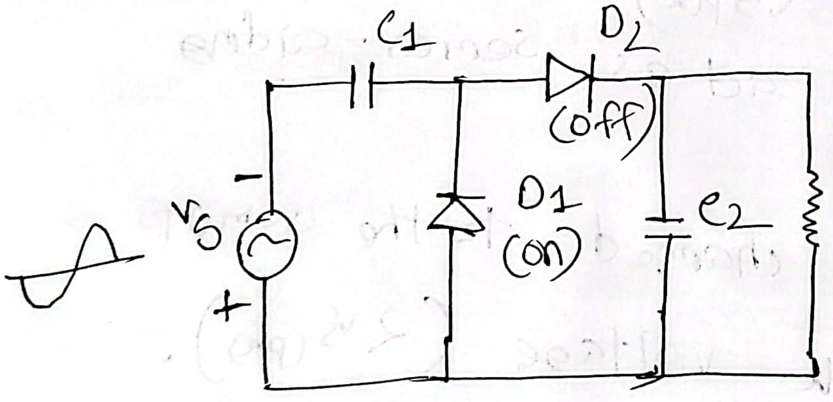
Half-wave voltage Doubler

Working Principle:

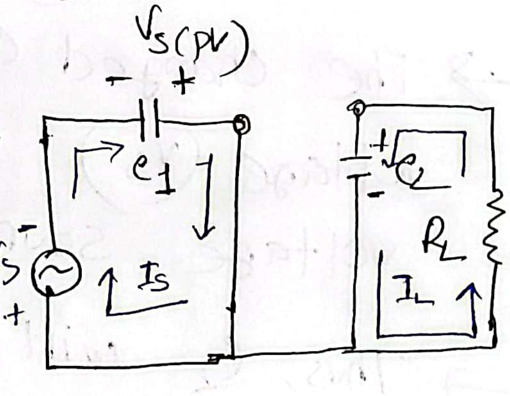
1. ~~Positive half-cycle:~~ Negative half-cycle:

→ D_1 is forward biased & D_2 is reverse biased.

→ D_1 can be represented by a short & D_2 as an open. The equivalen circuit then becomes as shown in fig (ii)



(i)

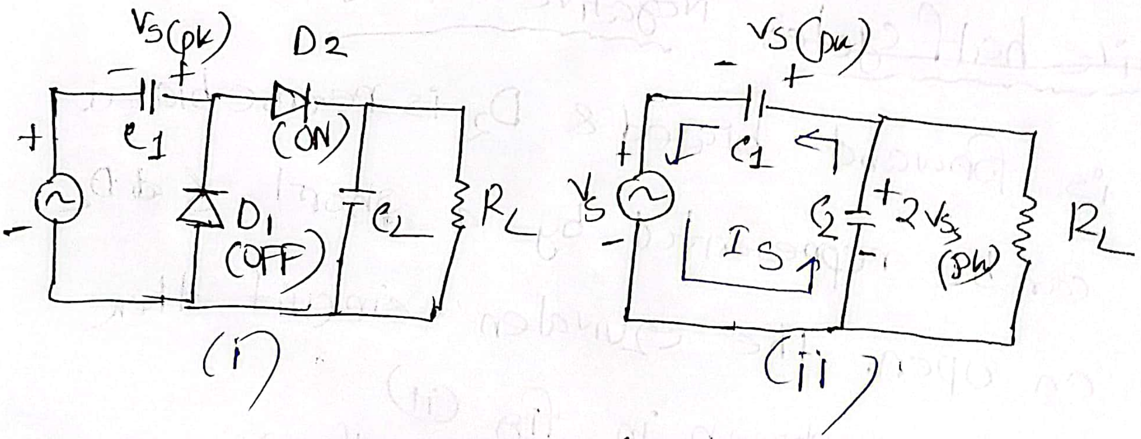


→ Capacitor C_1 charges to the peak input voltage ($V_{s(pk)}$) $V_{s(pk)}$.

→ C_2 remains uncharged at this stage.

2. Positive half-cycle:

→ D_1 is reverse biased and D_2 is forward biased and the equivalent circuit shown in Fig(i)

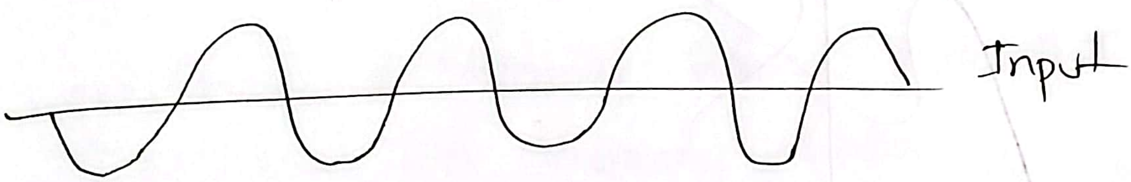


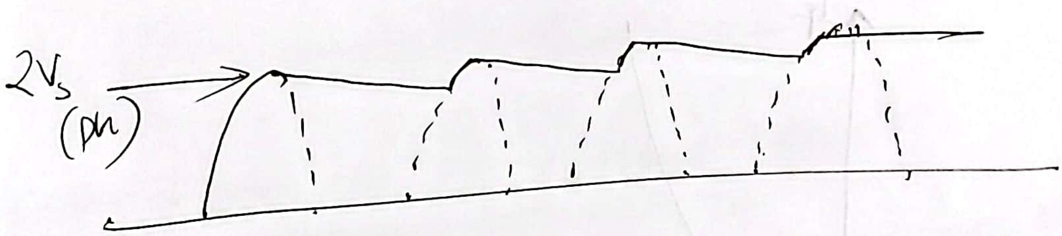
→ The charged C_1 ($V_{s\,p(k)}$) and the source voltage (V_s) now act as series-aiding voltage sources.

→ Thus, C_2 will be charged to the sum of the series peak voltage ($2V_{s(pk)}$).

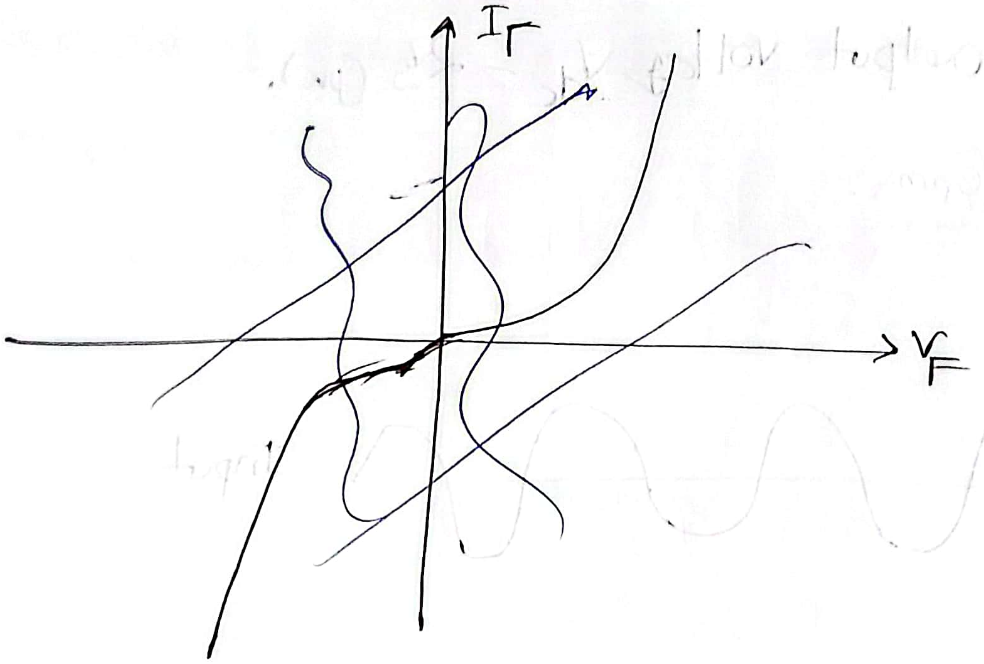
∴ D.C output voltag $V_{dc} = 2V_s$ (pk).

I/O waveforms:

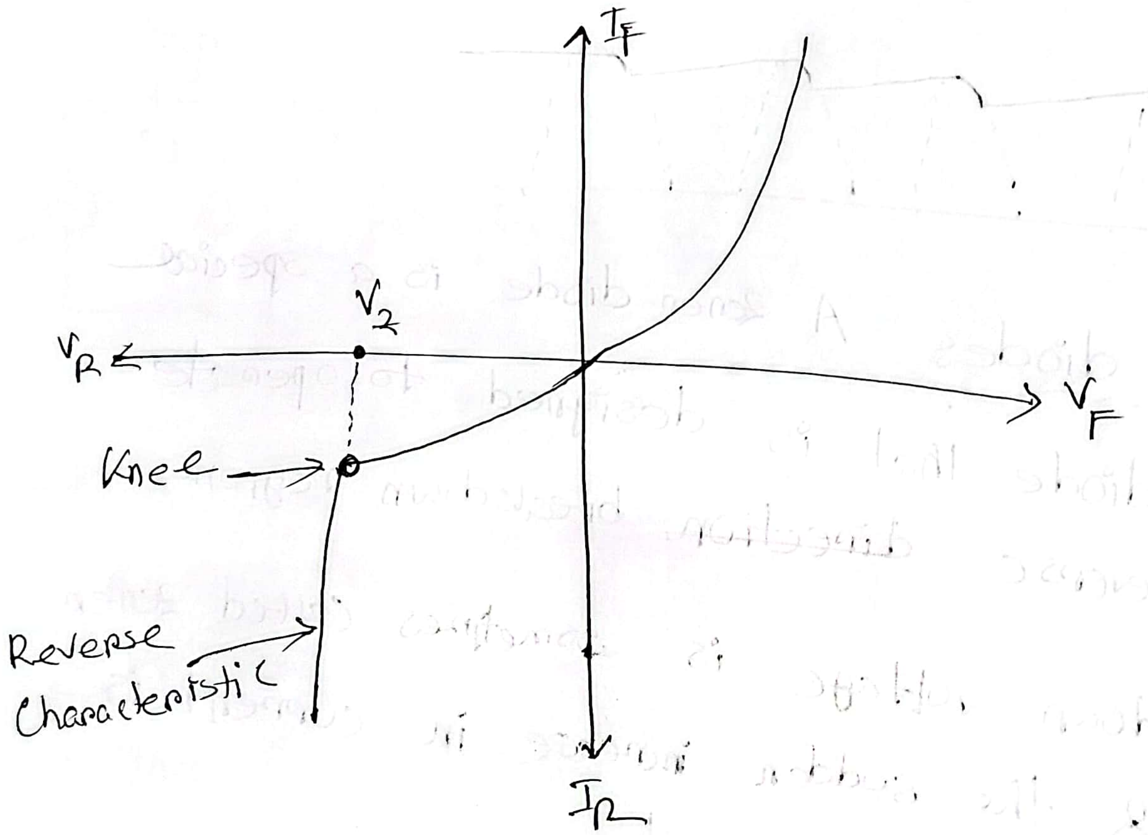




☐ Zener diode: A zener diode is a special type of diode that is designed to operate in the reverse ~~direction~~ breakdown region. The breakdown voltage is sometimes called zener voltage & the sudden increase in current is known as zener current.



I_F
V_F

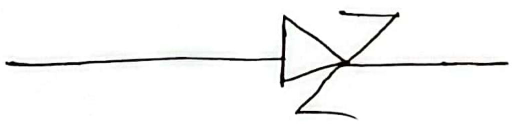


I_F
V_Z
V_R
V_F
Knee
Reverse Characteristic
I_R

→ A zener diode is always reverse connected. It is always reverse biased

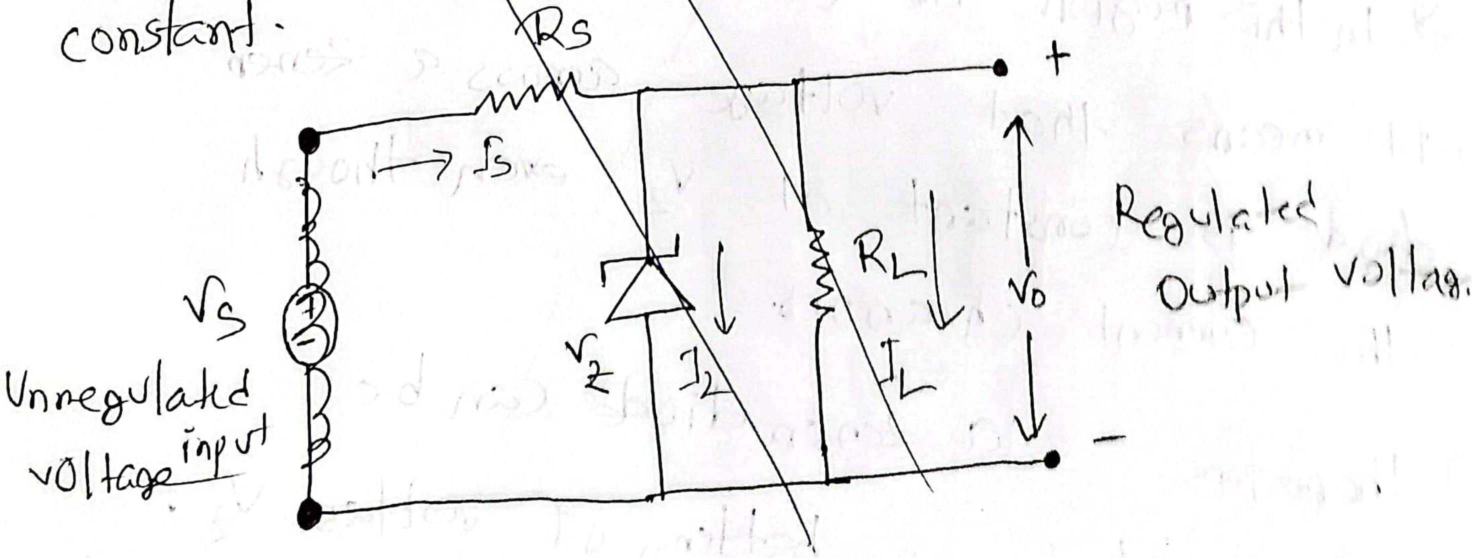
→ A zener diode has sharp breakdown voltage called zener voltage V_Z.

→ when forward biased, its characteristics are just those of ordinary diode.



Zener diode as a voltage regulator:

Voltage Regulator is designed to ensure that output voltage of a power supply remains constant.



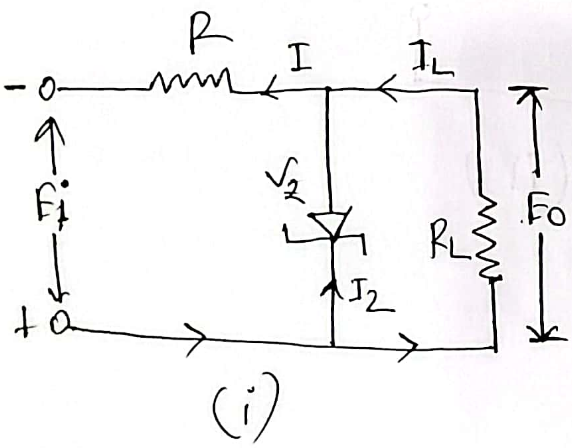
Zener diode as voltage stabiliser/regulator:

A voltage stabilizer or regular is designed to ensure that output voltage of a power supply remains constant. A zener diode can be used as a voltage regulator to provide a constant voltage from source.

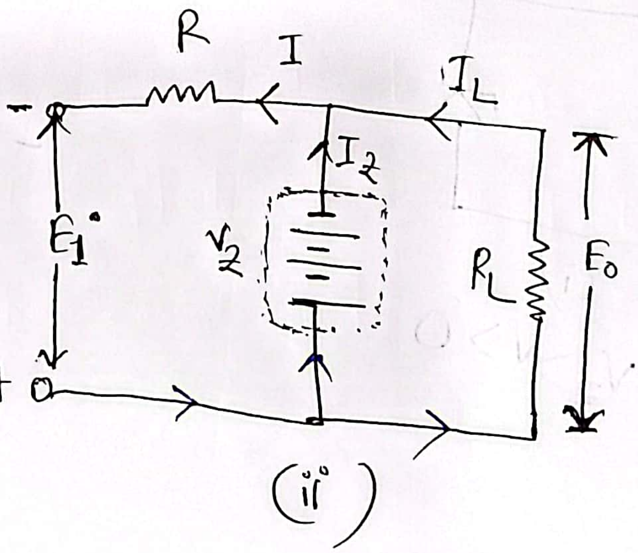
→ zener diode works as a voltage regulator in reverse bias.

→ R absorbs the output voltage to maintain constant voltage.

→ zener will maintain a constant voltage $V_z (=E_0)$ across the load.



(i)



(ii)

Working Principle:

Case:1: ~~Input voltage < Zener voltage~~ ($E_i < V_Z$)

Case-1: The input voltage increases:

→ Since the zener is in the breakdown region, the zener diode is equivalent to a battery V_Z.

→ It is clear that output voltage remains constant at V_Z (= E_0).

→ Excess input voltage is dropped across R.

→ The zener will conduct the increase of current in I while the load current remain constant.

→ Hence, output voltage E_0 remains constant.

Case-2: Input voltage is constant but the load resistance R_L decreases:

→ This will cause an increase in load current.

→ Zener diode does not conduct.

→ The additional load current will come

from a decrease in zener current I_Z.

→ The output voltage stays at constant value.

Voltage drop across $R = E_i - E_0$

current through $R, I = I_Z + I_L$

$$R = \frac{E_i - E_0}{I_Z + I_L}$$

☐ Vaccume diode: A vaccume diode is the simplest form of vaccume tube that consists of two electrodes - a cathode & an anode. It allows current to flow in one direction only, similar to a semiconductor diode.

Construction:

→ Cathode: Heated to emit electrons

→ Anode: A metal plate to collect electrons

→ Envelope: High-vaccum glass or metal tube to prevent ~~election~~ electron collisions. ~~with ga~~

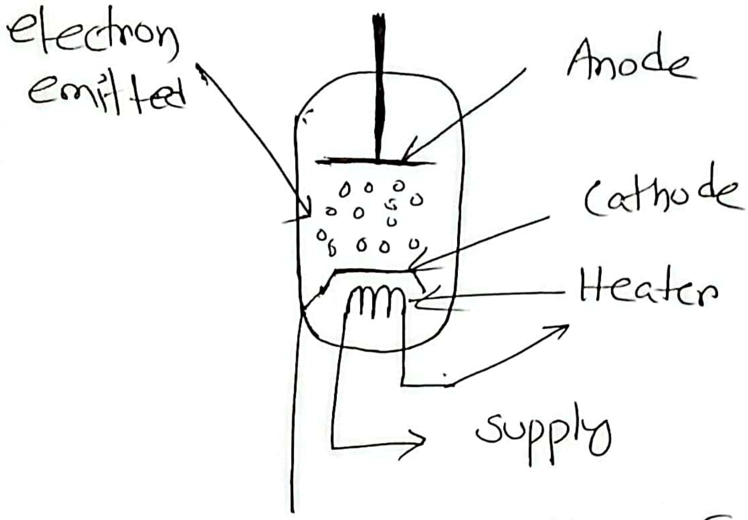


Fig: Construction of vaccum diode.

Working Principle:

→ when cathode ~~b~~ is heated, it emit electrons

→ If the anode is positive, electrons are attracted to it and current flows.

→ If the anode is negative, electrons are repelled, no current flows.

→ Hence, vaccum diode allows current in only one direction, acting as a rectifier.