

Experiment-1

V-I Characteristics of a Diode

Site link - vlabs.iitkgp.ernet.in/ke/exp5/index.html#

Aim - To study V-I characteristics of a diode

Apparatus - Fwd bias Si diode [1N4007], resistor, ammeter, etc

Theory - Structure of a P-N junction diode

The diode is a device formed from a junction of n and p-type semiconductor material. Load connected to p-type is anode and to n-type is cathode.

In fwd bias, diode +ve terminal of battery is connected to p side and -ve to n side. The holes in p-type and e^- in n-type are pushed towards junction reducing depletion zone width.

In reverse bias, the depletion width increases.

Silicon - In order to conduct fwd biasing, voltage should be greater than the barrier potential it acts like closed switch with potential drop of 0.6V across.

In reverse biasing depletion width increases and diode acts like open switch, there is no current flow.

↳ The process is similar for Germanium diode, except that the potential drop is around 0.3V.

Diode Equation

$$I_f = I_s \times \left(\exp \frac{V_f}{n \times V_T} - 1 \right)$$

fwd
current

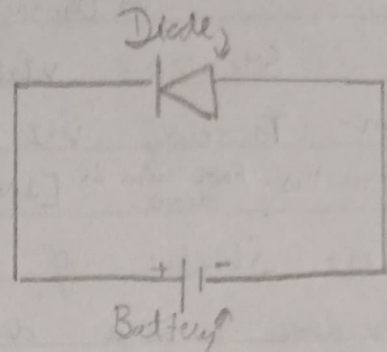
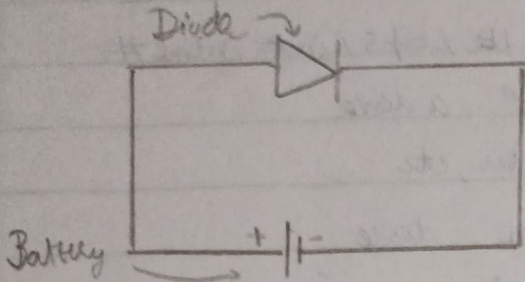
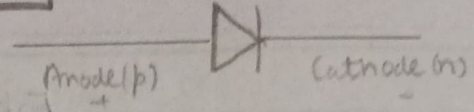
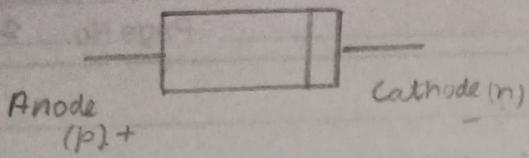
leakage
current

fwd
voltage

thermal
voltage

Diagrams →

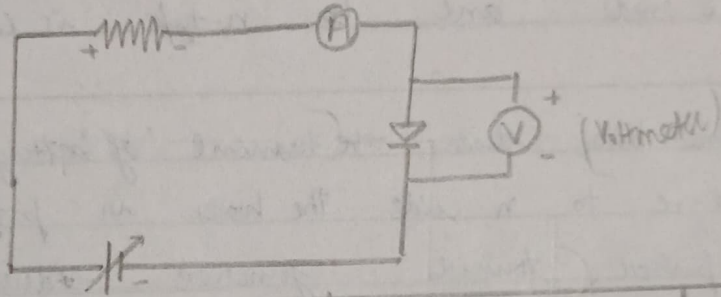
Structure of P-N Junction Diode



P-N junction diode function in

(a) fwd bias (Resistor) (Ammeter) (b) reverse bias

[FORWARD BIAS
SILICON DIODE
CKT Diagram
R=100Ω



→ Observation Table

S.No	V _{Battery} (V)	V _R (V)	Forward Voltage (V)	Forward Current (mA)	I _x R
1	0.6	0.6	0	0	0
2	0.7	0.172	0.528	0.0958	90.58
3	0.8	0.268	0.532	0.192	19.2
4	0.9	0.365	0.535	0.287	28.7
5	1	0.462	0.538	0.383	38.3
6	1.1	0.56	0.540	0.479	47.9
7	1.4	0.854	0.546	0.766	76.6
8	1.7	1.144	0.551	1.05	105
9	2.3	1.741	0.559	1.63	163
10	2.8	2.236	0.564	2.11	211

Precautions-

1. Proper connection of the circuit (correct polarity, Tight connections)
2. Gradual variation of voltage, limiting current
3. Handling orientation of diode and avoiding overheating

Result/Conclusion-

1. When the forward bias voltage exceeds around $0.6V$ (cut-off voltage)
2. Current increases suddenly, when $V_R = 2.5V$ known as reverse breakdown.

$R = 100 \Omega$

(FORWARD BIAS SILICON DIODE)

S.No	$V_{Battery}$	V_R	Reverse Voltage (V)	Reverse Current (mA)	$V_R = I \times R$
1	0.2	0.3	0.170	0.1	10
2	1.3	0.12	1.18	0.1	10
3	3.7	0.22	3.48	0.1	10
4	5.7	0.26	5.44	0.1	10
5	6.95	0.28	6.6	0.1	10
6	9.15	0.29	8.86	0.1	10
7	11.7	0.30	11.4	0.1	10
8	14.3	0.20	14.1	0.1	10
9	17.95	0.15	17.8	0.1	10
10	20.3	0.10	20.2	0.1	10

$V_R \rightarrow$ Voltage across resistor
 $\Rightarrow (V_B - V_D)$

$R = 1000 \Omega$

FORWARD BIAS

S.No	V_B (V)	V_D (V)	I_D (mA)	$V_R (V_B - V_D)$ (V)	$V_R (I \cdot R)$ (V)
1	0.2	0	0	0.2	0
2	0.7	0.636	0.1	0.17	0.1
3	1	0.539	0.4	0.461	0.4
4	1.3	0.546	0.7	0.714	0.7
5	1.6	0.651	1	1.049	1
6	1.9	0.555	1.3	1.345	1.3
7	2.2	0.588	1.6	1.641	1.6
8	2.5	0.568	1.9	1.937	1.9
9	2.8	0.568	2.2	2.234	2.2
10	3.1	0.571	2.8	3.129	2.8

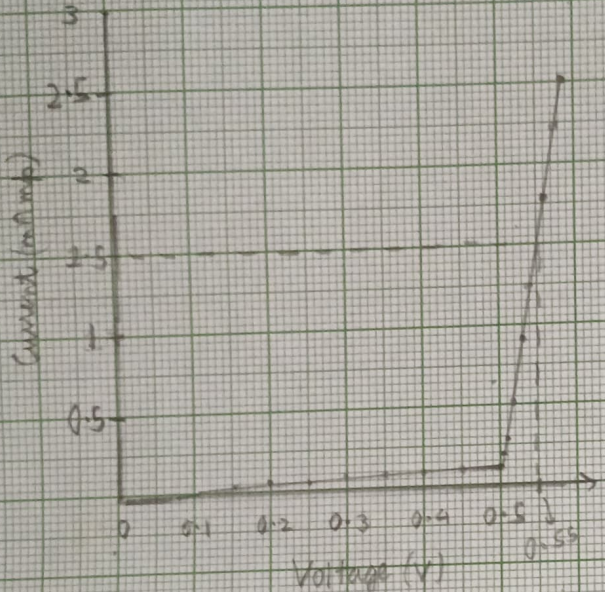
$V_B \rightarrow$ Voltage of Battery
 $V_D \rightarrow$ Voltage of Diode
 $I_D \rightarrow$ Current of Diode
 $V_R \rightarrow$ Voltage of resistor

SCALE
 1 cm = 0.5 mA (Y-axis)
 2 cm = 0.1 V (X-axis)
 R = 100 Ω

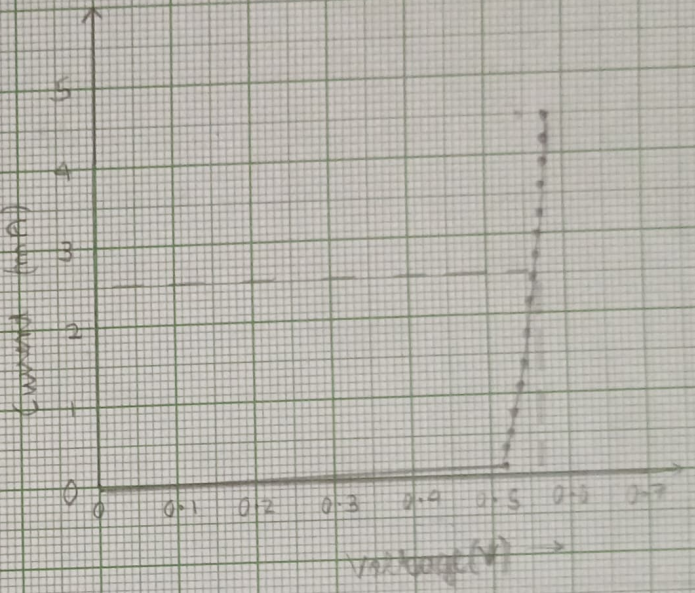
FORWARD BIAS

SCALE
 2 cm = 1 mA (Y-axis)
 1 cm = 0.1 V (X-axis)

R = 2 kΩ



Dynamic resistance → 2.72



Dynamic resistance

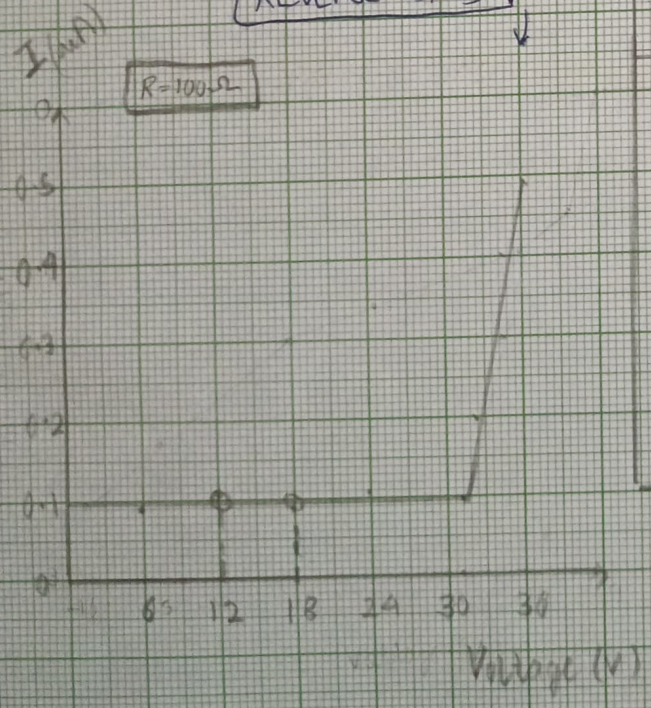
$$\frac{V_2 - V_1}{I_2 - I_1} = \frac{0.570 - 0.300}{4.5 - 0.3}$$

$$= 0.2709$$

→ 2.72

REVERSE BIAS

R = 100 Ω



Dynamic Resistance

$$Y = 0.1$$

$$\rightarrow \frac{0.1 - 0.1}{15 - 2} \rightarrow 0$$

SCALE
 ① 1 cm = 0.1 mA (Y-axis)
 ② 1 cm = 6 V (X-axis)

Experiment - 2

BJT Common Emitter Characteristics

Aim - To verify and find input and output characteristics of BJT Common emitter

Apparatus - BJT (Bipolar Junction Transistor), Resistor, connecting wires, Ammeter (0-10 mA, 0-100 μ A), DC power supply (0-30V), etc
(Site Link) - <https://www.geogebra.org/m/1kq11/india.html#>

Theory - A BJT is a single piece of Si with 2 back to back PN junction. BJT's can be made either as PNP or NPN. They have 3 regions and 3 terminals emitter, base and collector - E, B and C. When transistor is conducting normally, an easy way to remember is NPN stands for "Not Pointing IN".

Regions -

- Cutoff region - Base emitter junction is reverse biased, no current
- Saturation region - Base emitter junction is forward biased and collector base junction is forward biased.
- Active region - Base emitter junction is forward biased, collector base junction is reverse biased.

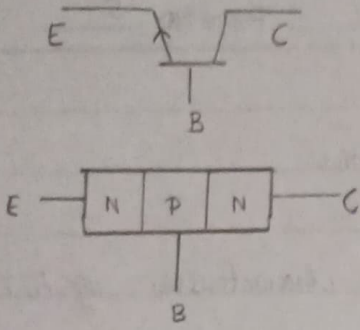
Breakdown region - I_c and V_{ce} exceed specifications and can cause damage to the transistor

Cutoff region - Both junctions are reverse biased

$V_{BE} < 0$ (Base) and $V_{CB} > 0$ (with reverse biasing, all currents are zero)

Structure of BJT

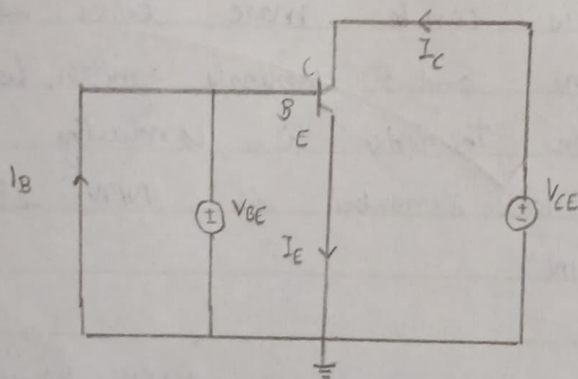
FOUR OPERATING CONDITIONS



BC Junction

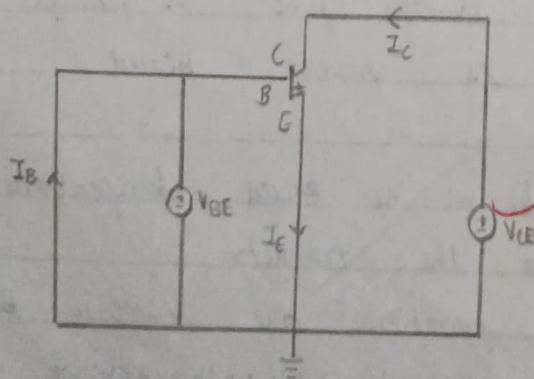
		BE Junction	
		Reverse	Forward
BC Junction	Reverse	Cut-off	Forward Active
	Forward	Reverse Active	Saturation

→ INPUT CHARACTERISTICS CKT



$I_B = \phi(V_{BE}, V_{CE})$
for constant V_{CE}

→ OUTPUT CHARACTERISTICS CKT



$I_C = \phi(V_{CE}, I_B)$
for constant I_B

Forward Active region-

Base is fwd biased ($V_{BE} > 0$) and collector is reverse biased ($V_{CB} < 0$). fwd bias will cause injection of both holes and e^- across the junction.

$$I_C = \alpha_F I_E + I_{C0}, \quad \alpha \text{ is forward current transfer ratio}$$

$I_{C0} \rightarrow$ collector reverse saturation current

Saturation region

Both junctions fwd biased, Base is $V_{BE} > 0$ and Collector-Base is $V_{CB} < 0$. Max current flow through transistor, only small voltage drop.

Reverse active region

Base-emitter is reverse biased ($V_{BE} < 0$) and collector base is fwd biased ($V_{CB} < 0$). Current gain is smaller.

Application - In digital circuits and analog switching circuits.

$$I_E = -\alpha_R * I_C + I_{E0}$$

$\alpha_R \rightarrow$ reverse current transfer ratio

$I_{E0} \rightarrow$ Emitter reverse saturation current

BJT - Common Emitter Circuit

↳ described as Ebers-Moll Model -

$$I_F = I_{ES} \times \left(\exp \frac{V_{BE}}{V_T} - 1 \right)$$

$$I_R = I_{CS} \times \left(\exp \frac{V_{CB}}{V_T} - 1 \right)$$

$I_{ES} \rightarrow$ base-emitter saturation current

$I_{CS} \rightarrow$ base-collector saturation current

(A)

S.No	Base emitter voltage (V)	Base current (uA)	R _h (Ω)
1	0.2	2.824	10
2	0.3	3.232	15
3	0.4	3.714	20
4	0.5	4.248	25
5	0.6	4.875	30
6	0.7	5.599	35
7	0.8	6.434	40
8	0.9	7.397	45
9	1	8.508	50
10	1.1	9.789	55
11	1.2	11.27	60
12	1.3	12.97	65
13	1.4	14.94	70
14	1.5	17.21	75
15	1.6	14.83	80

(a) $V_{CE} = 1V$
 $R_{h2} = 10\Omega$

(Cont)
 $R_{h2} = 100\Omega$
 $C_{E\text{ voltage}} = 10V$

INPUT
 CHARACTERISTICS

(B)

S.No	Base emitter voltage (V)	Base current (uA)	R _h Ω
1	0.02000	2.077	10
2	0.08000	2.261	15
3	0.1400	2.462	20
4	0.2000	2.680	25
5	0.2600	2.918	30
6	0.3200	3.178	35
7	0.3800	3.461	40
8	0.4400	3.769	45
9	0.5000	4.104	50
10	0.5600	4.470	55

(b) $V_{CE} = 2V$
 $R_{h2} = 20\Omega$

Precautions

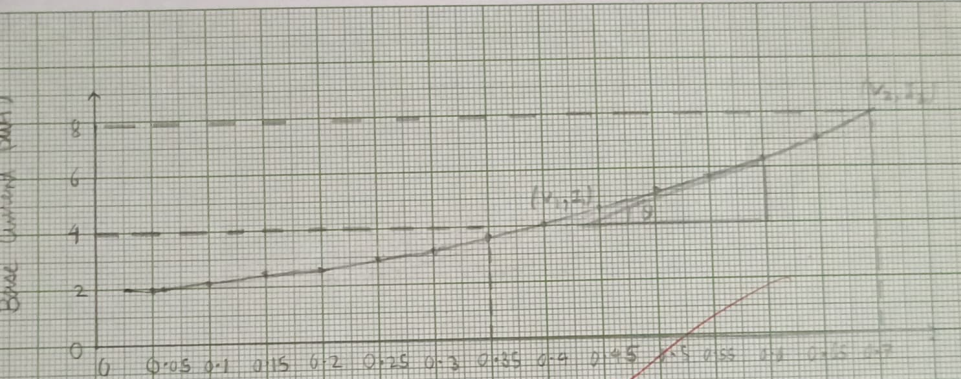
1. Ensure proper connection and biasing.
2. Check polarity and avoid overheating
3. Calibrate instruments and avoid static discharge

→ Result

The characteristic behavior of BJT in various regions such as active, saturation etc is shown.

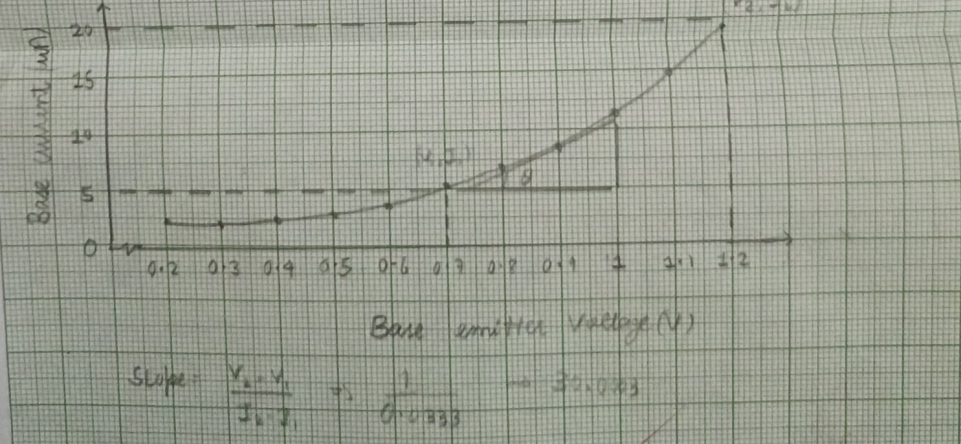
It may be helpful to design units involving BJT like - amplifiers and switches.

INPUT CHARACTERISTICS (V-I PLOT)



SCALE
 Y-axis
 Base current (mA)
 ① $I_{cm} = 2 \text{ mA}$
 X-axis
 Base emitter Voltage (V_{BE})
 ② $I_{cm} = 0.05 \text{ V}$

Base emitter Voltage (V_{BE})
 Slope = $\frac{V_2 - V_1}{I_2 - I_1} \Rightarrow \frac{0.4 - 0.35}{4 - 3} \Rightarrow 0.05 \text{ V}$
 $\Rightarrow \frac{1}{0.02} \Rightarrow 50 \text{ V}$
 Y axis
 $I_{cm} =$



Slope = $\frac{V_2 - V_1}{I_2 - I_1} \Rightarrow \frac{1}{0.033} \Rightarrow 30.303$

SCALE
 Y-axis
 Base current
 ① $I_{cm} = 5 \text{ mA}$
 X-axis
 Base emitter Voltage (V)
 ② $I_{cm} = 0.1 \text{ cm}$

S.No	Output Emitter Voltage (V)	Collector Current (mA)	R_{h_2} (Ω)
1	1	1750	10
2	1.5	2080	15
3	2	2215	20
4	2.5	2267	25
5	3	2286	30
6	3.5	2293	35
7	4	2298	40
8	4.5	2297	45
9	5	2297	50
10	5.5	2297	55
11	6	2298	60
12	7	2298	65
13	7.5	2298	70
14	8	2298	80

(A) $I_b = 15.35$
 $R_{h_1} = 15$

OUTPUT CHARACTERISTICS

(cont)

$R_{h_1} = 100\Omega$
 Base-current
 174.14 mA

(B)

S.No	Collector emitter Voltage (V)	Collector Current (mA)
1	0.1000	7.427
2	0.4000	35.08
3	0.7000	55.80
4	1.000	70.31
5	1.300	79.86
6	1.600	85.09
7	1.900	88.28
8	2.200	91.08
9	2.500	91.09
10	2.800	91.64

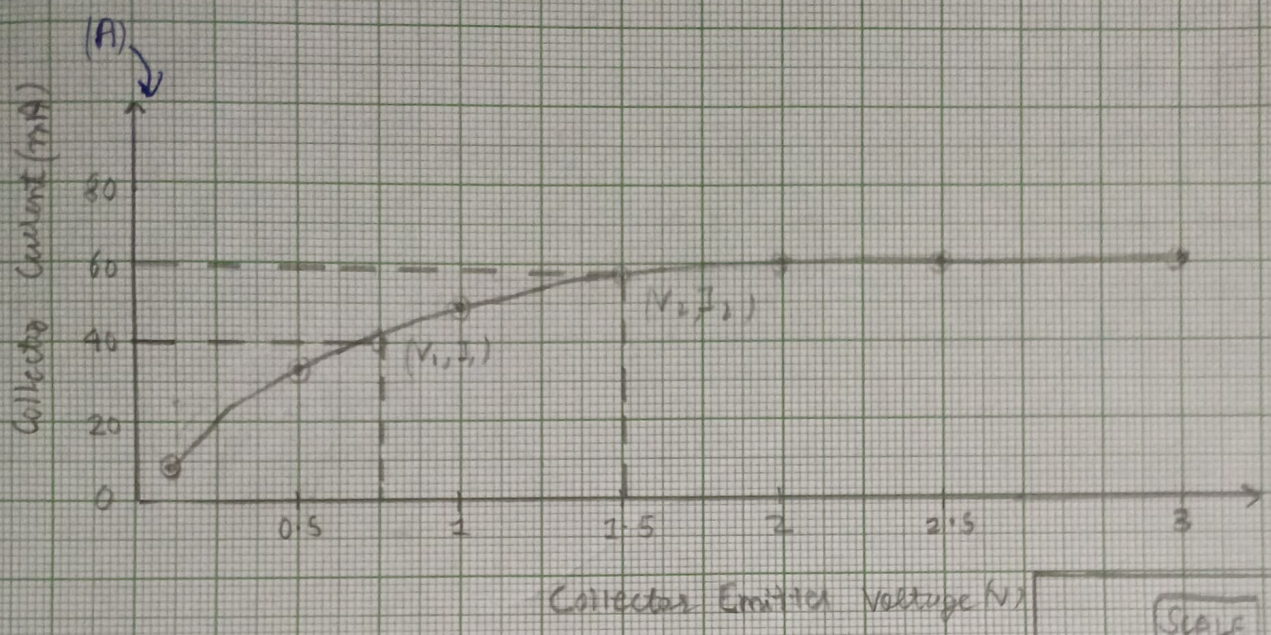
(B) $I_b = 20.43$
 $R_{h_1} = 25$

($I_b \rightarrow$ Base current)

(C)

S.No	Collector emitter Voltage (V)	Collector Current (mA)
1	0.1000	12.96
2	0.4000	49.42
3	0.7000	78.62
4	1.000	99.07
5	1.300	112.1
6	1.600	119.4
7	1.900	124.4
8	2.200	126.9
9	2.500	128.3
10	2.800	129.1
11	3.100	129.6
12	3.400	129.8

(C) $I_b = 25.67$ $R_{h_1} = 33$

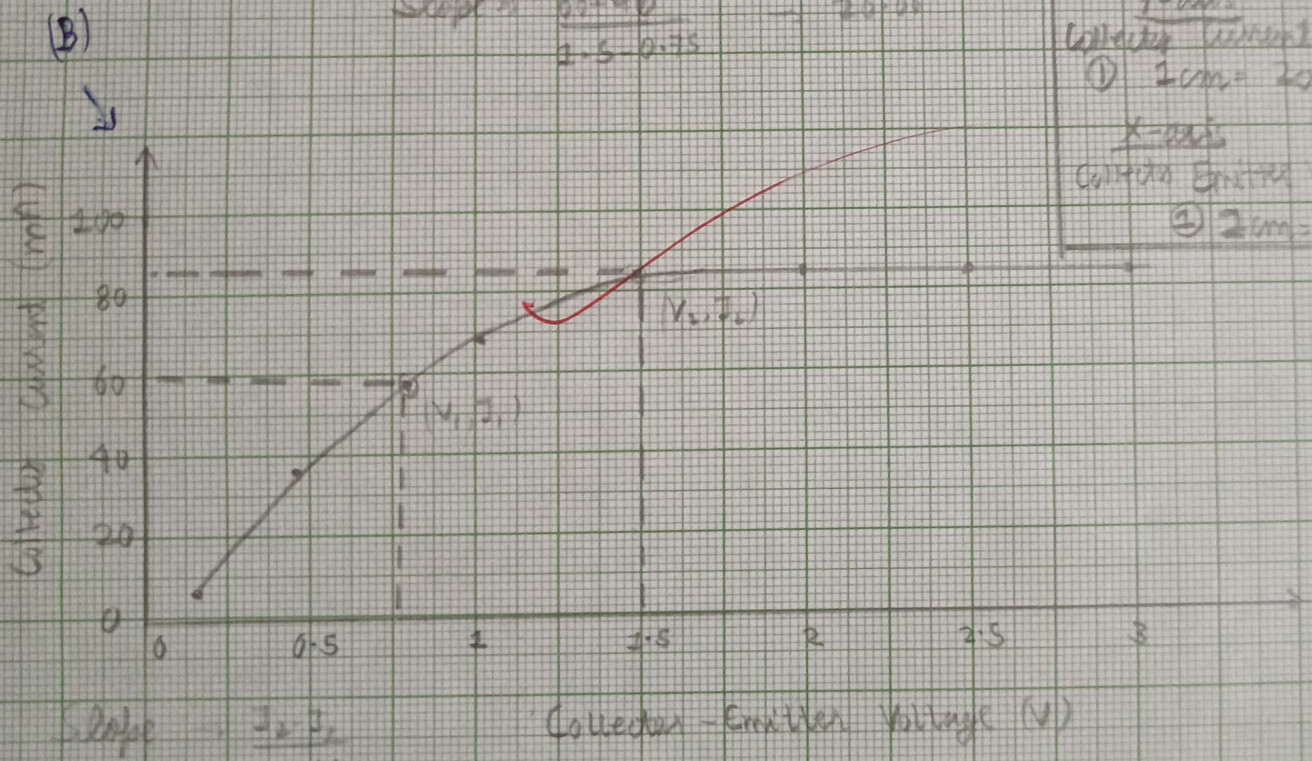


Slope = $\frac{I_2 - I_1}{V_2 - V_1} = \frac{60 - 40}{1.5 - 0.75} = 26.66$

SCALE

Y-axis
Collector Current
① 2cm = 20 mA

X-axis
Collector-Emitter Voltage
② 2cm = 0.5V



Slope = $\frac{I_2 - I_1}{V_2 - V_1}$

$\rightarrow \frac{80 - 60}{1.5 - 0.75}$

$\rightarrow \frac{20}{0.75}$

$\rightarrow 26.666$

SCALE

Y-axis
Collector Current
2cm = 20 mA

① X-axis
Collector-Emitter Voltage
② 2cm = 0.5V

Experiment-3

Full wave Rectification

Aim- To study full wave rectification

Apparatus- Oscilloscope, resistor (R_L), connecting wires

Theory-

Rectification - Device that converts AC to DC. It's of 2 types - a half wave and a full wave rectifier

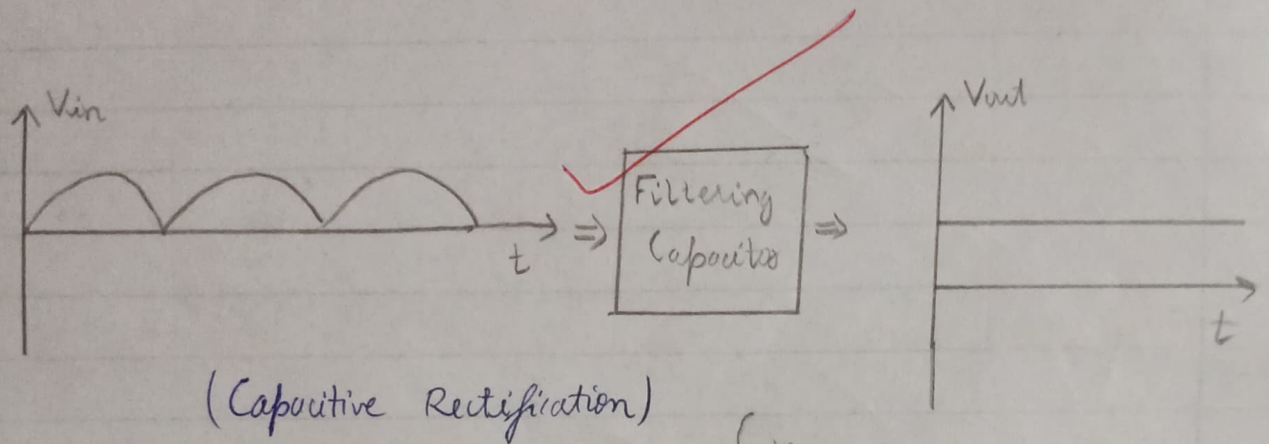
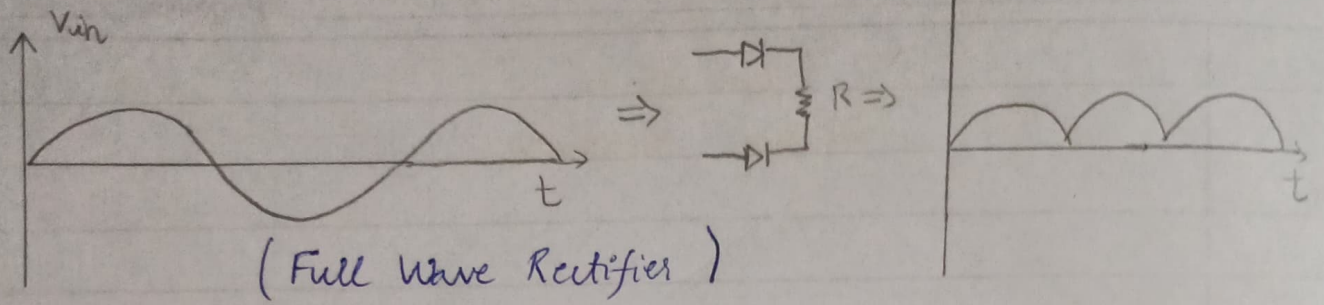
① Full wave Rectifier

It's exactly the same as half-wave but allows unidirectional current through the load during entire sinusoidal cycle. It converts the whole of the input waveform to one of constant polarity (positive or negative) at its input

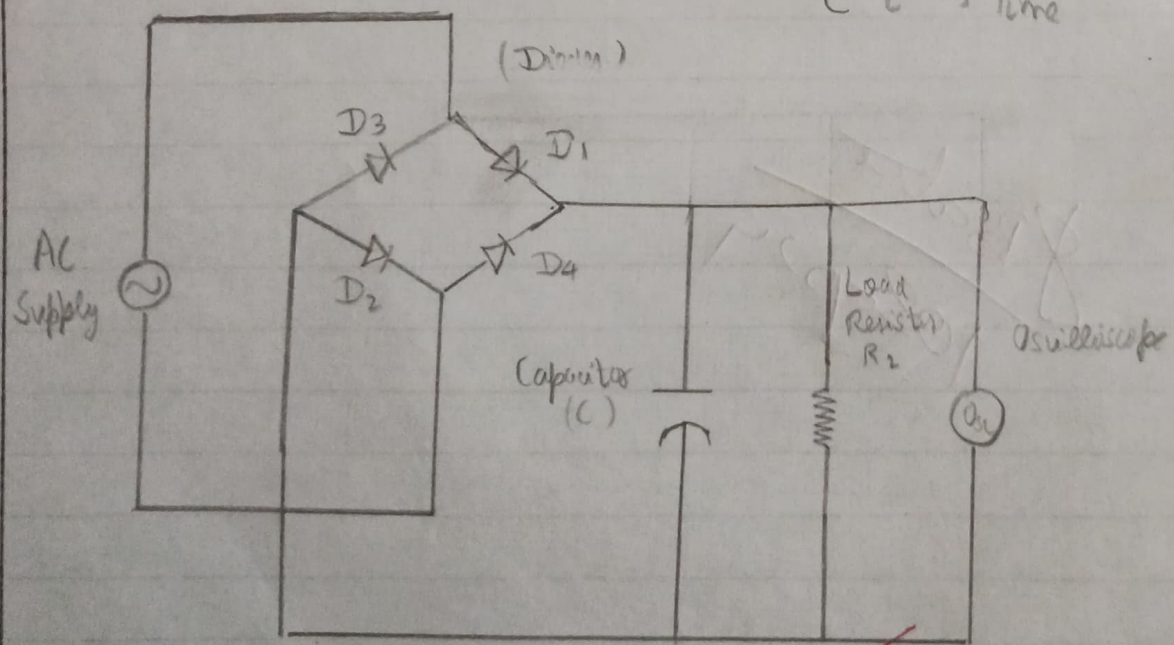
② Centre Tapped Transformer

A full wave rectifier can be constructed using centre Tapped transformer. Gives us two shifted sinusoids so exactly one of the waveform is positive at one time. Allows for conduction through load.

→ Diagrams



$V_{in} \rightarrow V_{input}$ (Input Voltage)
 $V_{out} \rightarrow V_{output}$ (Output Voltage)
 $t \rightarrow$ Time



Ckt diagram for full wave rectifier with filtering

(B) Bridge Rectifier

It uses 4 rectifying diodes connected in a bridge config. to produce desired output that doesn't require special tapped transformer thereby reducing cost and size.

$$\text{Avg DC Load Voltage} = V_{oc} = \frac{2V_m}{\pi}$$

$$\text{Avg Load Current} = \frac{2 \times I_m}{R}$$

$$\text{RMS Load Current} = \frac{I_m}{\sqrt{2}} \quad \text{RMS Load Voltage} = \frac{V_m}{\sqrt{2}}$$

$$\text{Form factor} = \frac{\pi}{2\sqrt{2}} = 1.11 \rightarrow \frac{V_m/\sqrt{2}}{2V_m/\pi}$$

(2) Capacitive Rectification

↳ Capacitive Rectification - A full wave rectifier converts the whole of input waveform to one of constant polarity at its output. But what is really desired to convert pulsating output of rectifier to a constant DC supply, thus filter input signal

↳ The simplest kind of filter that can perform filtering task is a capacitor. When connected, the AC components will have a low impedance path to ground and not appear in output.

Amp \rightarrow Amplitude (mV)

\rightarrow Observation Table

1. Full Wave Rectifier

(a) Set 1

$$f_{\text{req}} = 1000\text{Hz}$$

$$R_L = 500\Omega$$

(b) Set 2

$$f_{\text{req}} = 1000\text{Hz}$$

$$R_L = 400\Omega$$

(c) Set 3

$$f_{\text{req}} = 1000\text{Hz}$$

$$R_L = 300\Omega$$

(A)

S.No	Amp (V)	Peak Current (mA)
1	0	-1.4
2	0.5	-0.400
3	1	0.799
4	1.5	1.599
5	2	2.59

(B)

S.No	Amp (V)	Peak Current (mA)
1	0	-1.74
2	0.5	0.71
3	1	0.74
4	1.5	1.749
5	2	2.749

(C)

S.No	Amp (V)	Peak Current (mA)
1	0	-2.33
2	0.5	-0.66
3	1	0.91
4	1.5	2.33
5	2	4.33

Ripple Voltage and Ripple Factor

A new charging pulse occurs every half cycle the capacitor charges and discharges very quickly

The variable portion is known as ripple

Further, ratio of ripple voltage to avg. voltage is ripple factor.

↳ Precaution

- 1) Check the capacitor polarity
- 2) Monitor ripple voltage across load.
- 3) Ensure proper oscilloscope probing
- 4) Check diode orientation and connection

↳ Conclusion

↳ In this experiment, using a bridge rectifier with 4 diodes, both halves of AC waveform into pulsating DC output. Bridge rectifier provides a more efficient rectification process by utilizing entire AC cycle. The inclusion of capacitor reduced ripple in rectified output resulting in a constant DC voltage.

J. B. D. S.

23/9/29

② Capacitive Rectification

$$V_{p_{in}} = 1V$$

Position Y-axis = 0.1

Phase = 0 deg

Freq = 1000 Hz

$$V_{p_{out}} = 1V$$

Position X-axis = 0.1

Phase = 0 deg

freq = 1000 Hz

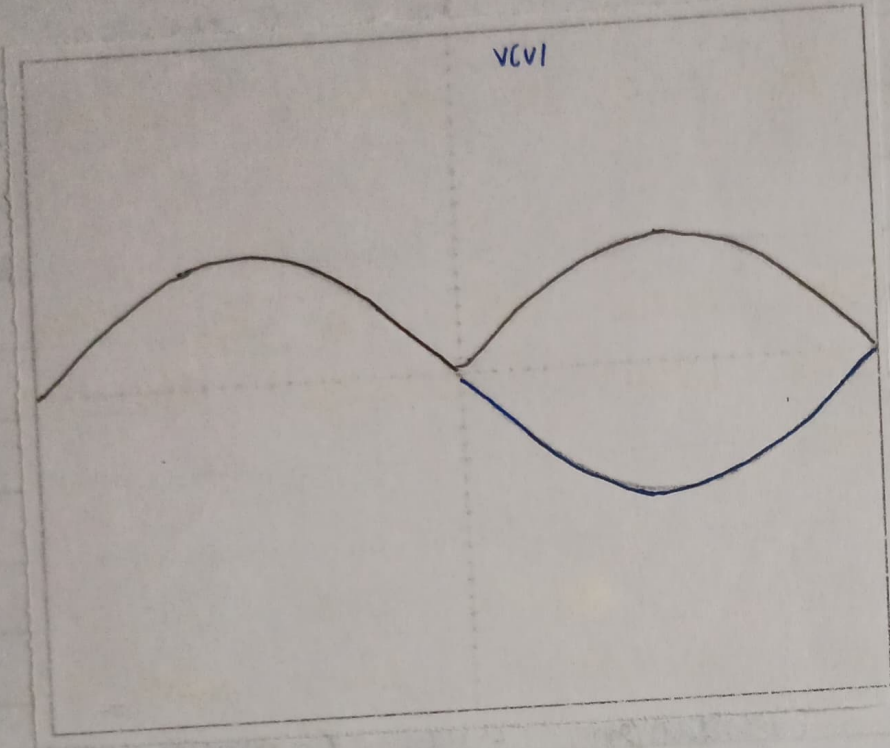
Oscilloscope Least Count = 0.01 (for Voltage)
1 ms (for time)

→ Calculations

$$\text{Form factor} = \frac{V_{rms}}{V_{avg}} \Rightarrow \frac{V_m/\sqrt{2}}{2V_m/\pi} \Rightarrow \frac{\pi}{2\sqrt{2}} = 1.11$$

$$\text{Ripple Factor} \Rightarrow \gamma \Rightarrow \sqrt{(\text{Form factor})^2 - 1} \times 100\% \\ \hookrightarrow 48.1\%$$

(a) Full Wave Rectifier



Black line represents
rectified output
DC and blue
line represents
input AC

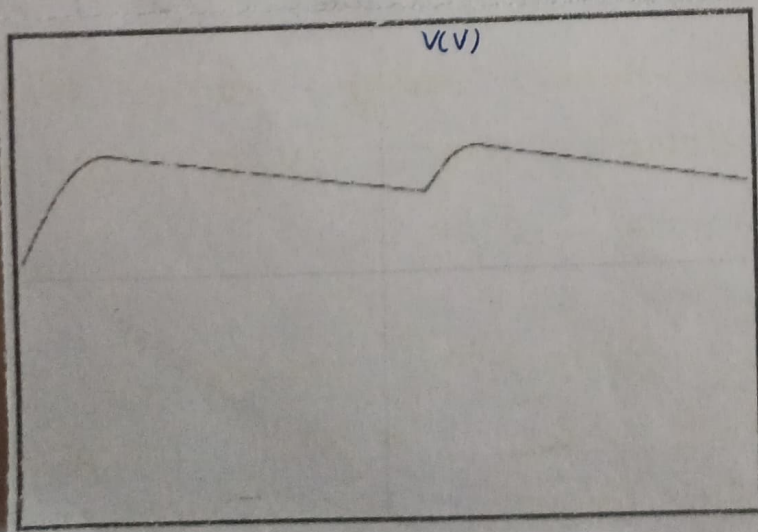
frequency = 1000 Hz

Amplitude = 1 V

$R_L = 500 \Omega$

(Load resistance)

(b) Capacitive Rectification



Rectified Output
DC

frequency = 1000 Hz

Experiment - 4

Half Wave Rectifier

Aim - To study half wave rectification

Apparatus - Oscilloscope, connecting wires, resistors, diode, AC supply,

Theory

Rectifier is a device that converts AC to DC, process known as rectification

Half Wave Rectification

On the positive cycle diode is forward biased and on negative cycle diode is reverse biased. Using diode, AC source is converted into a DC source. Half wave rectifier is a circuit that allows only part of an input signal to pass and single diode is in series with resistor (load).

↳ For positive half cycle -
Acts as a short circuit -

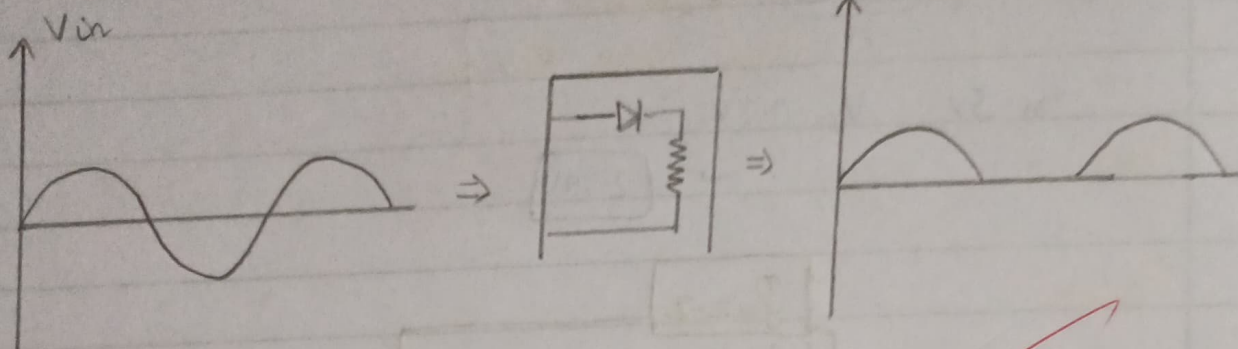
$$V_I - V_b - I \times r_d + I \times R = 0$$

Input
voltage

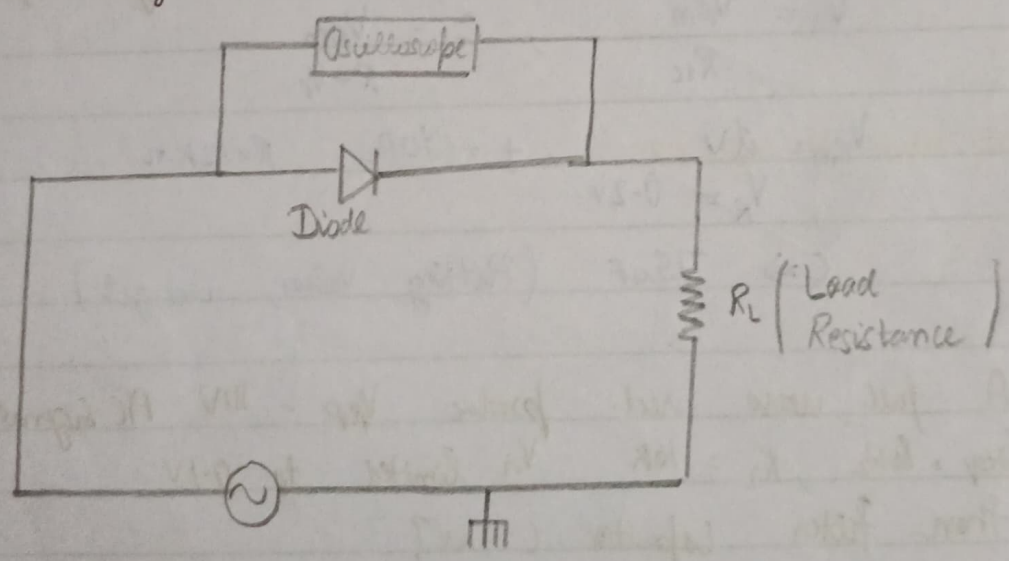
Barrier
Voltage

diode
resistance

→ Diagrams



↳ Circuit Diagram



$$V_o = I \times R = V_I = \frac{V_o}{r_o + R} \times R$$

$$V_o = V_I - V_b$$

↳ for negative half cycle
Acts as ~~open~~ circuit

$$V_o = 0 \text{ V since } I = 0$$

$$\text{Average output voltage} = \frac{V_m}{\pi} = 0.318 V_m$$

$$\text{RMS Voltage Load} = \frac{V_m}{2}$$

↳ Peak Inverse Voltage

It is the max value of reverse voltage which occurs at peak of input cycle when diode is reverse biased.

$$PIV = V$$

$$-V_m + V = 0 \Rightarrow V = V_m ; PIV \geq V_m$$

↳ Precautions

- 1) Ensure proper grounding
- 2) Observe ripple, ensure oscilloscope is sensitive enough to detect ripple voltage
- 3) Avoid overheating

Observation Table

(a) Set 1

freq = 3000 Hz

$R_L = 100 \Omega$

(b) Set 2

freq = 3000 Hz

$R_L = 200 \Omega$

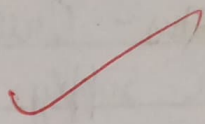
(c) Set 3

freq = 3000 Hz

$R_L = 300 \Omega$

(A)

S.No	Amp (V)	Peak Current (mA)
1	0	-6.99
2	0.5	-2.00
3	1	1.99
4	1.5	6.99
5	2	12.99



(B)

S.No	Amp (V)	Peak Current (mA)
1	0	-3.99
2	0.5	-1.00
3	1	1.48
4	1.5	3.99
5	2	5.99

Calculations

Form factor (F.F.)

$$\hookrightarrow \frac{V_{rms}}{V_{avg}}$$

$$\hookrightarrow \frac{V_{m/2}}{V_{av/2}} \Rightarrow \frac{\pi}{2} = \boxed{1.57}$$

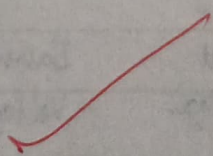
Ripple factor

$$\delta = \sqrt{(F.F.)^2 - 1} \times 100\%$$

$$\hookrightarrow \boxed{1.21\%}$$

(C)

S.No	Amp (V)	Peak Current (mA)
1	0	-2.33
2	0.5	-0.66
3	1	0.99
4	1.5	2.33
5	2	4.33

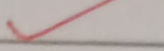


Experiment :

Date _____

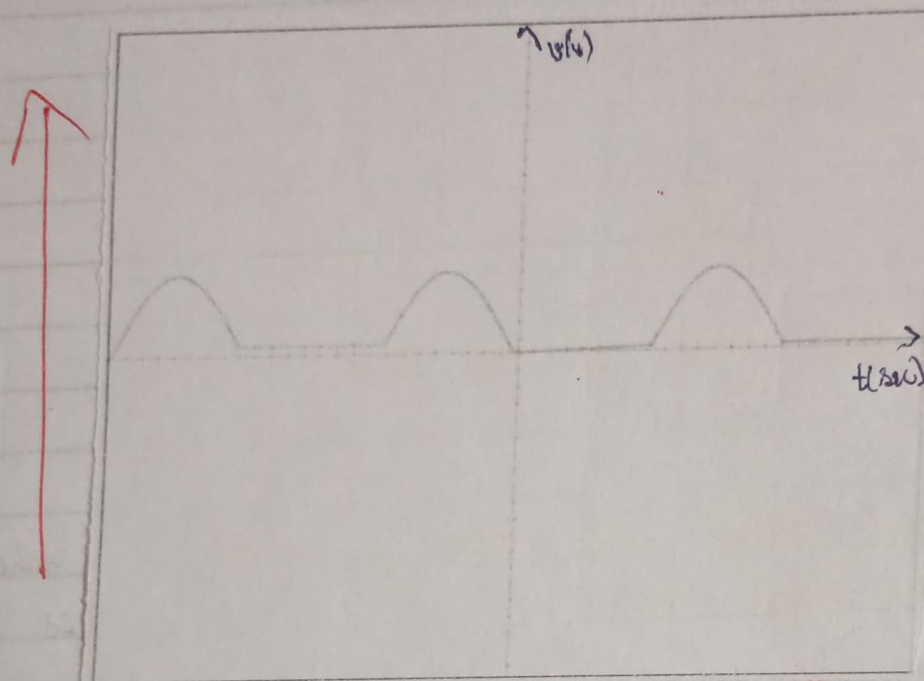
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↳ Conclusion

In half wave rectifier exp, AC converts into pulsating DC output. Only one half of AC cycle is utilized while the other ~~half~~ is blocked by diode resulting in  significant amount of ripple in output.

Graph

Half Wave Rectification



Rectified
Output DC
(frequency)

freq \rightarrow 3000 Hz

$R_L \rightarrow$ 200 Ω

(Load
resistance)

Amp = 1.5V

(Amplitude)

(channel -2)

Oscilloscope Least Count = 0.01V (for voltage)
= 1ms (for time)