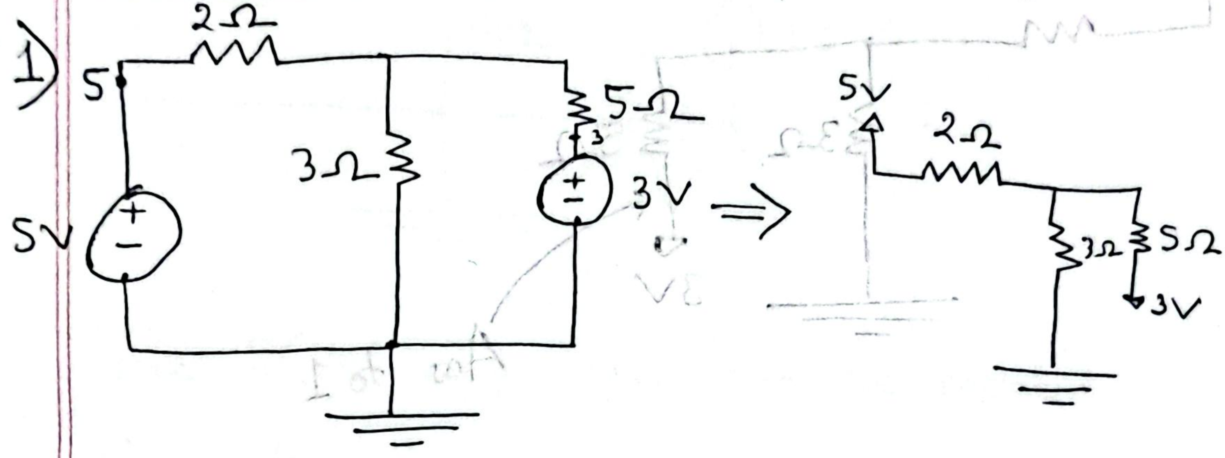
CSE-251

9/2/25

lecture-1

CSE-250 review

1)



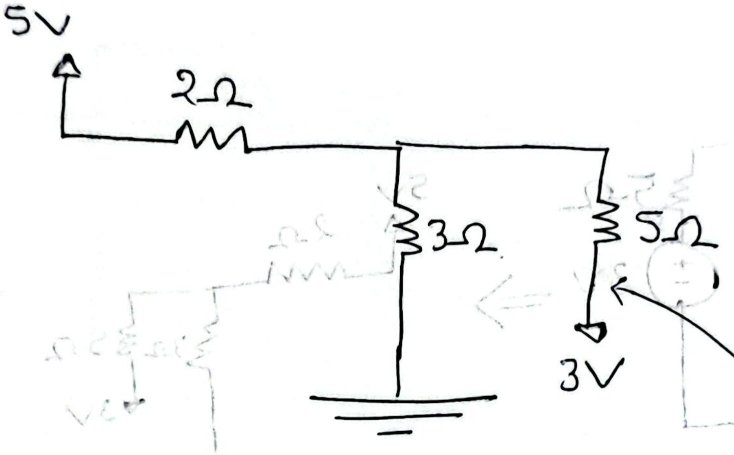
Line representation

1) Decide a ground such that floating voltage sources are minimized (Maximum voltage source will have a ground)

Non-floating

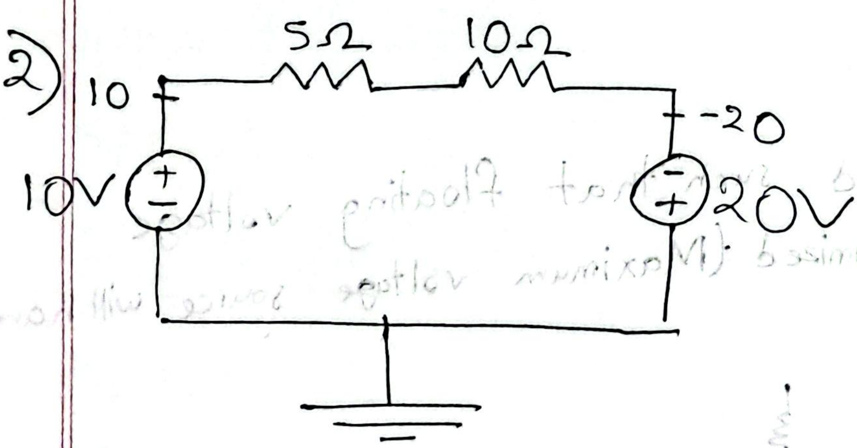
floating

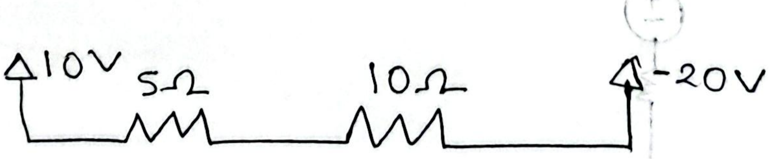
1) Replace voltage sources with known node voltages



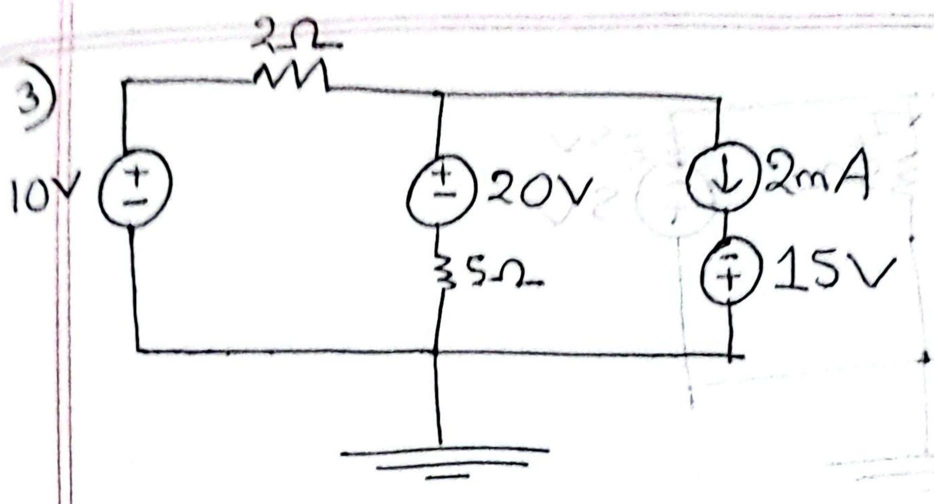
Ans to 1

2)



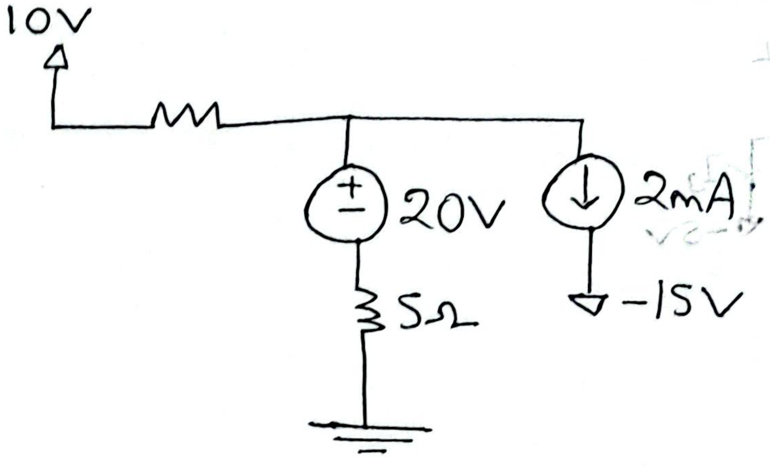


3)

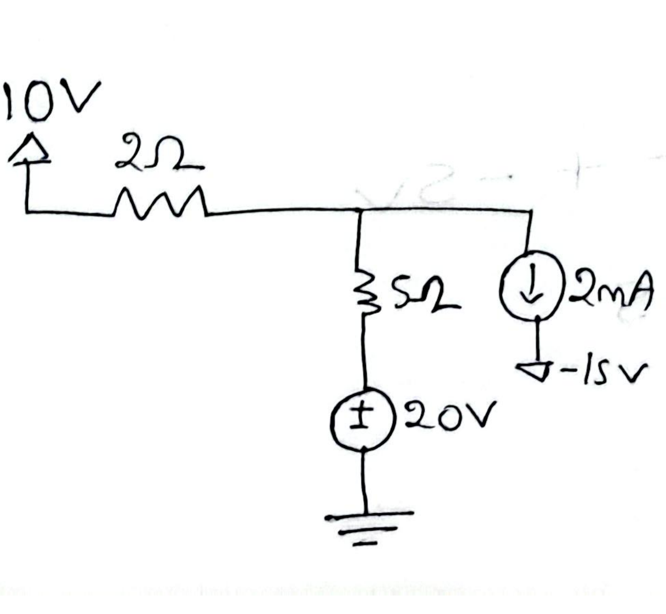


The 20V and 5Ω can be replaced

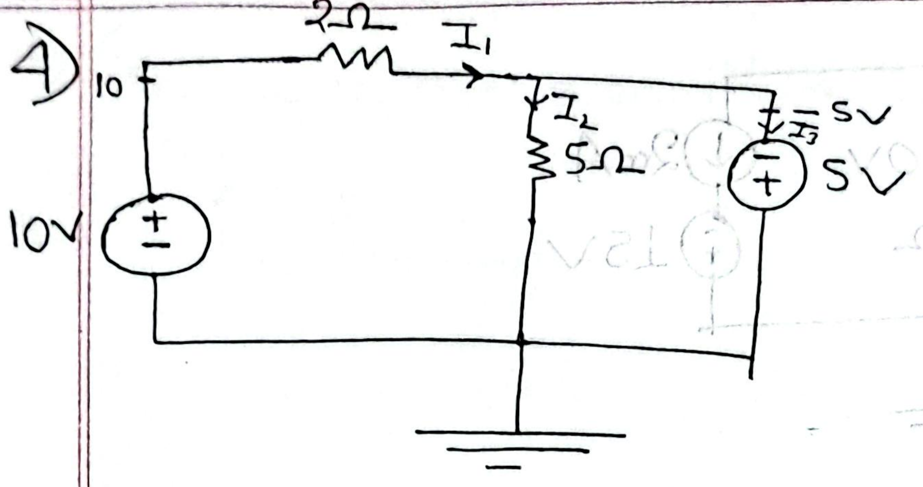
Hence the line representation will be,



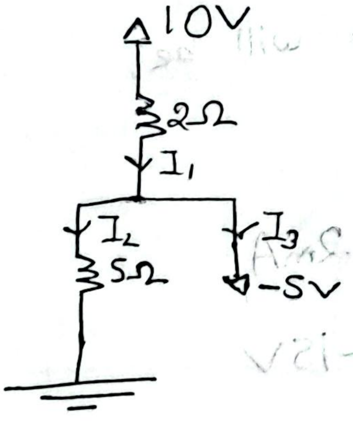
or



4)



Line representation we get;



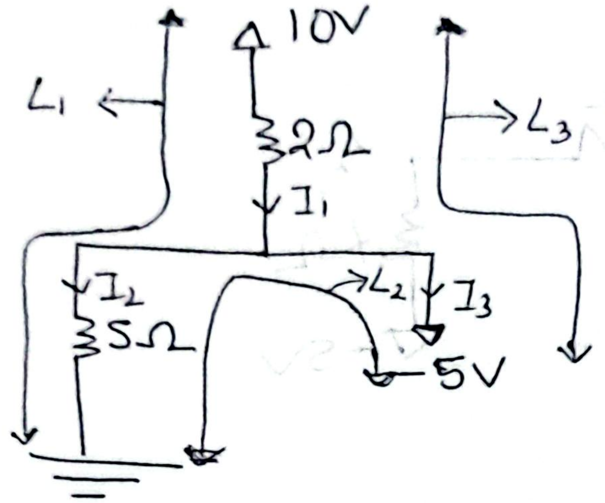
According to KCL,

$$I_1 = I_2 + I_3$$

$$\therefore \frac{10-V_1}{2} = \frac{V_1 - 0}{5} + -5V$$

$$\frac{10-V_1}{2} = \frac{V_1}{5} - 5$$

KVL in Line representation



- We will do KVL in terms of Line: There are 3 different voltages, hence there can be 3 equations

- A line will have a starting and ending voltage

Starting voltage - End voltage = All of the components in between

$$10 - 0 = 2I_1 + 5I_2 \quad (L_1)$$

$$10 = 2I_1 + 5I_2 \quad (1)$$

$$0 - (-5) = -5I_2 \quad (L_2)$$

$$5 = -5I_2$$

$$I_2 = -1A$$

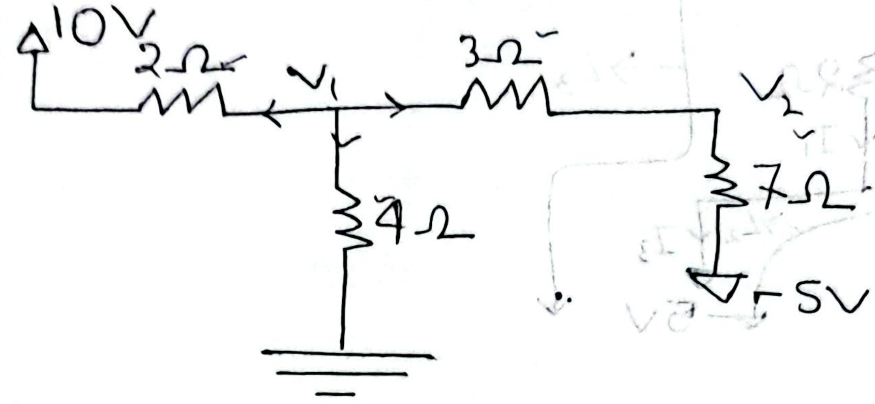
$$10 - (-5) = 2I_1$$

$$15 = 2I_1$$

$$I_1 = 7.5A$$

Nodal Analysis

1)



Applying Nodal at V_1 we get,

$$\frac{V_1 - 10}{2} + \frac{V_1 - V_2}{3} + \frac{V_1 - 0}{4} = 0$$

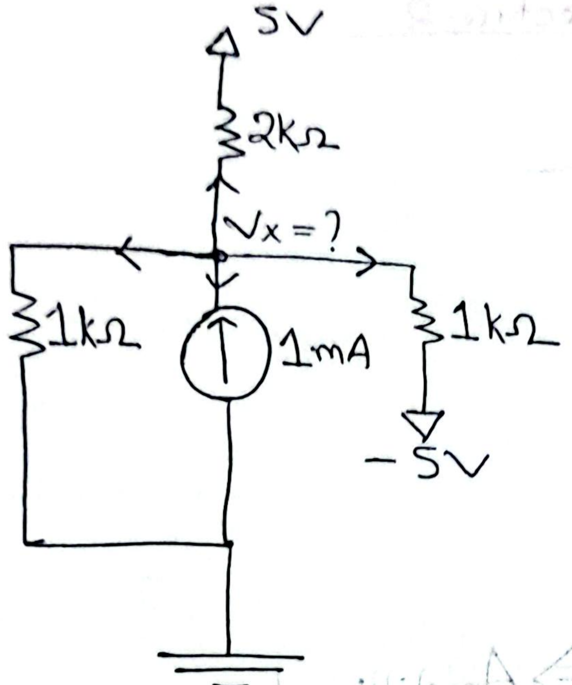
$$V_1\left(\frac{1}{2} + \frac{1}{3} + \frac{1}{4}\right) - \frac{10}{2} - \frac{V_2}{3} = 0$$

V_2 node

$$\frac{V_2 - V_1}{3} + \frac{V_2 + 5}{7} = 0$$

$$V_2\left(\frac{1}{3} + \frac{1}{7}\right) - \frac{V_1}{3} + \frac{5}{7} = 0$$

2)



$$\frac{V_x - 0}{1} + \frac{V_x + 5}{1} + \frac{V_x - 5}{2} - 1 = 0$$

$$V_x + V_x + 5 - 1 = \frac{5 - V_x}{2}$$

$$2V_x + 4 = \frac{5 - V_x}{2}$$

$$\cancel{V_x + 2 = 5 - V_x} \qquad 4V_x + 8 = 5 - V_x$$

$$\cancel{2V_x = 3} \qquad 5V_x = -3$$

$$\cancel{V_x =} \qquad V_x = \frac{-3}{5}$$

$$V_x = -0.6$$

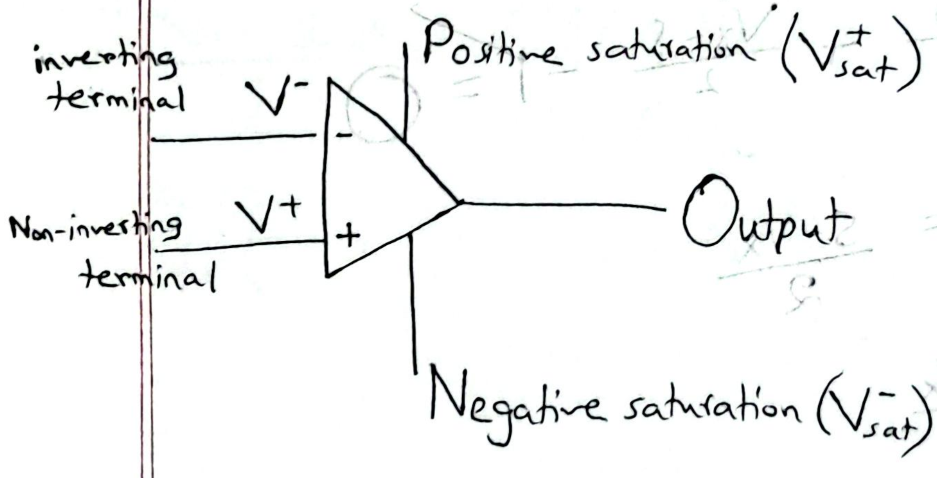
lecture-2

Syllabus for Mid-term

1) Op-Amp
2) Diode
3) MOSFET
4) BJT

Op-Amp

Operation-Amplifier ⇒ Amplifies the input voltage
⇓
Perform Mathematical operation



- Op-Amp is a difference amplifier

$V_d = V^+ - V^-$ (Noninverting - Inverting)

$V_o = AV_d$

A → Gain

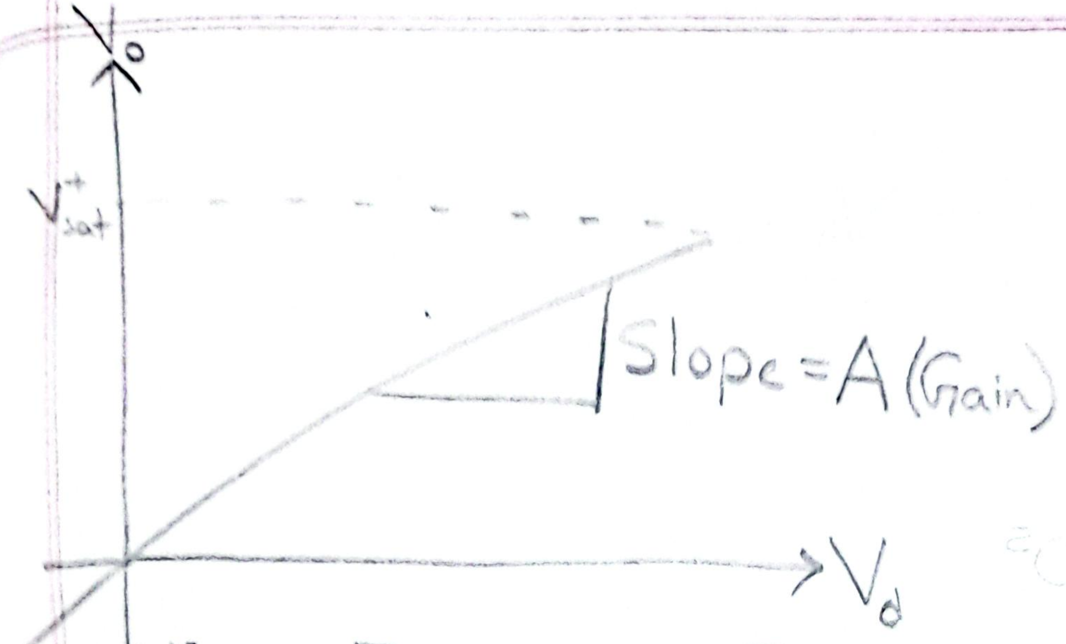


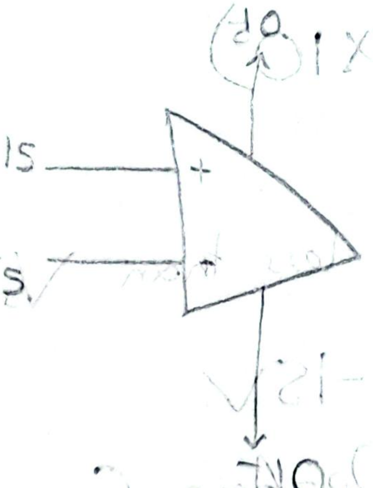
Fig: V_o vs V_d graph

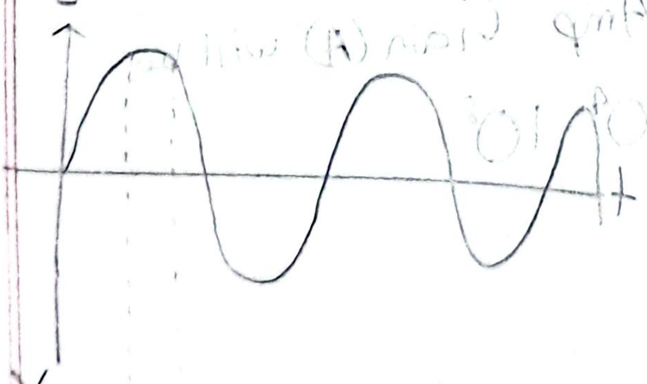
1) Given,

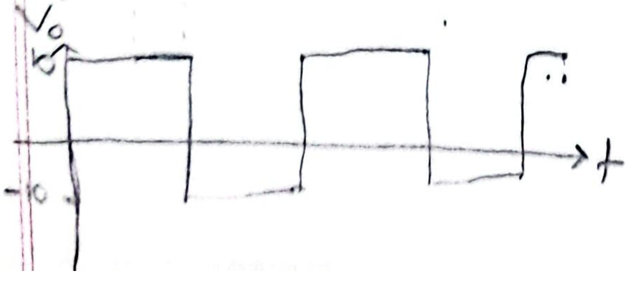
$V_{sat}^+ = 10V$

$V_{sat}^- = -10V$

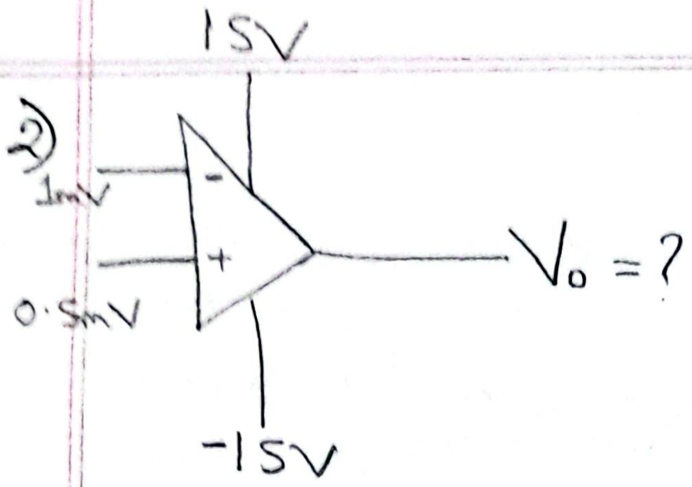
$A = 3$







2)



$A = 2 \times 10^5$

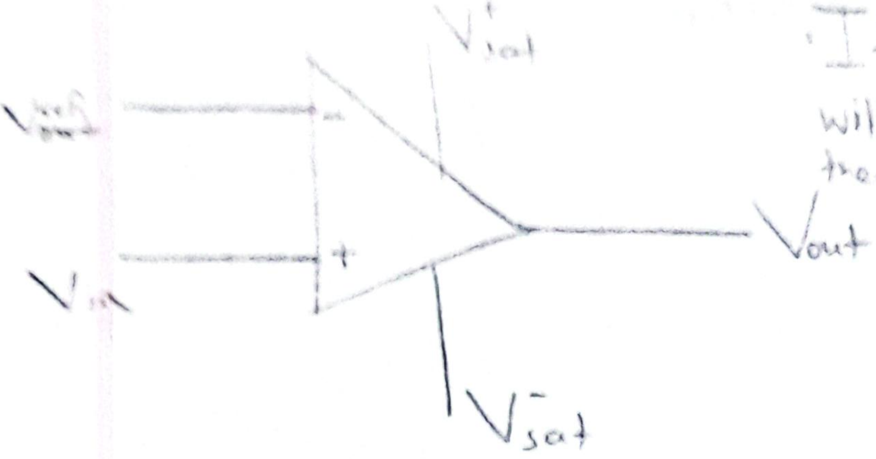
$V_o = (0.5 - 1) \times 10^{-3} \left[2 \times 10^5\right]$

$= (-0.5 \times 10^{-3})(2 \times 10^5)$

$= -100$

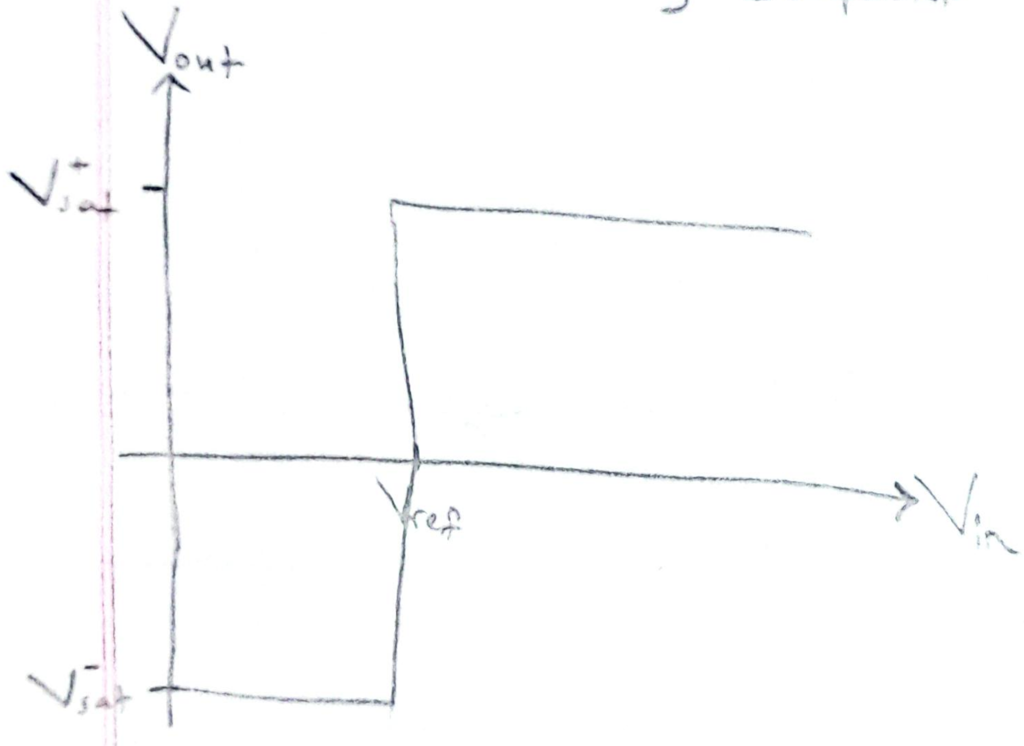
- Since $-100V$ is less than V_{sat}^- $(-15V)$, V_o will be $-V_{sat} = -15V$
- In an ideal Op-Amp Gain (A) will be ∞ but in reality $A = 10^4 - 10^8$

Comparator

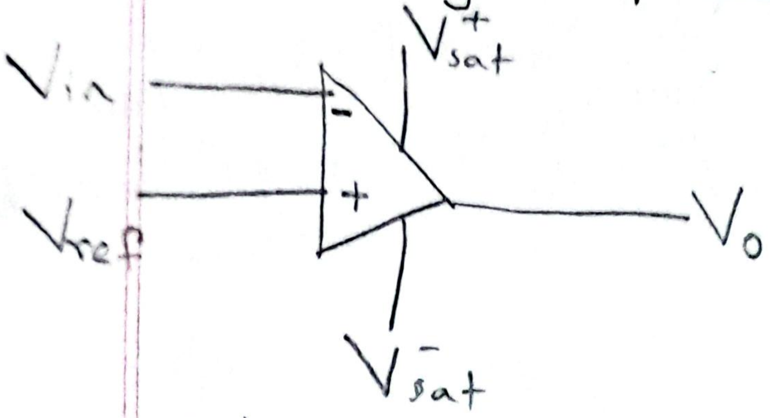


If $V_{ref} > V_{in}$ then V_{out} will be V_{sat}^+ and if $V_{ref} < V_{in}$ then V_{out} will be V_{sat}^-

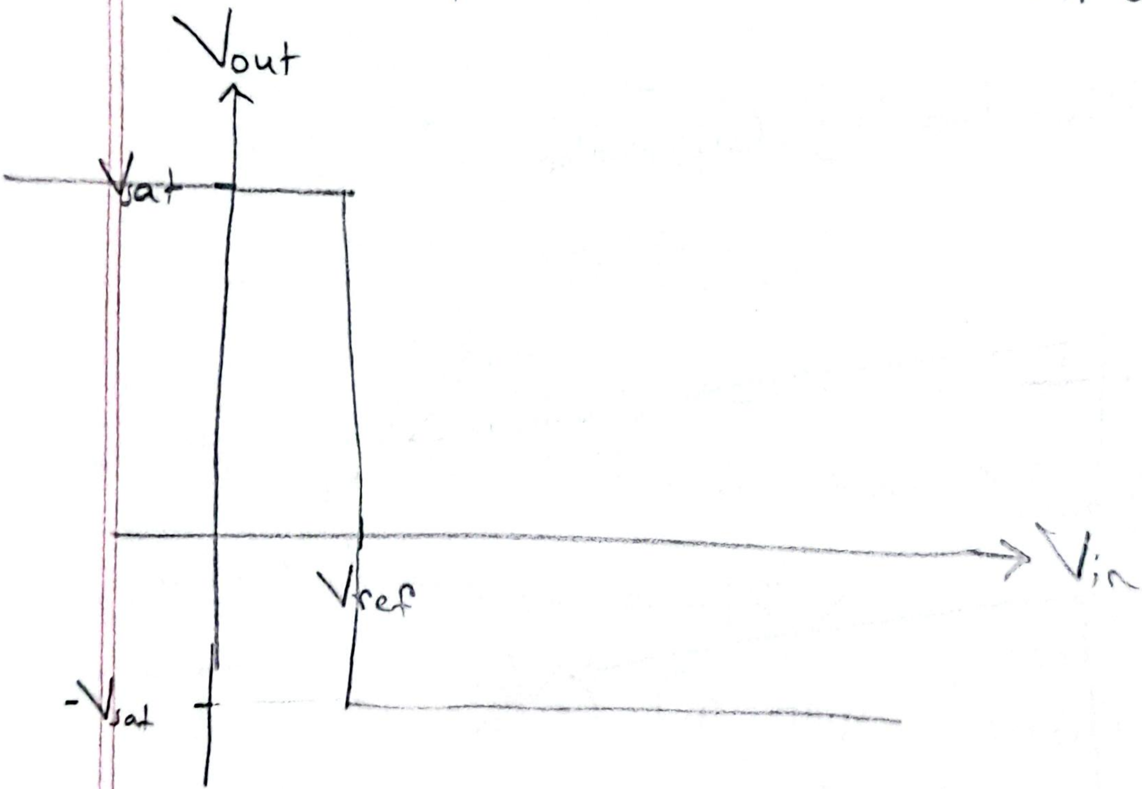
Fig: Non-inverting Comparator



Inverting Comparator



- If $V_{in} > V_{ref}$ then V_{out} will be V_{sat}^- and if $V_{in} < V_{ref}$ then V_{out} will be V_{sat}^+



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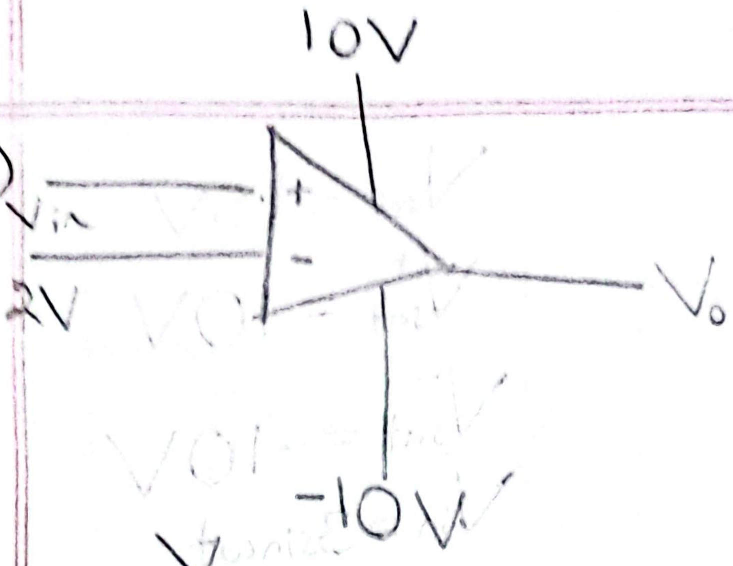

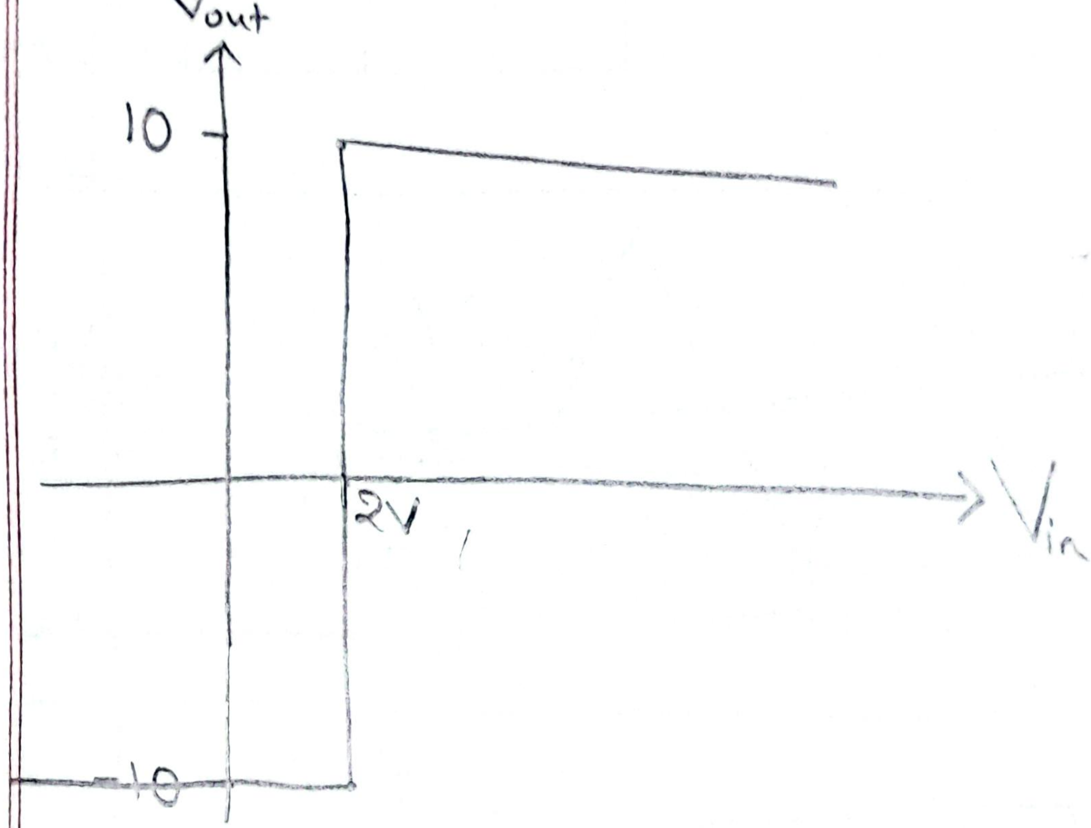

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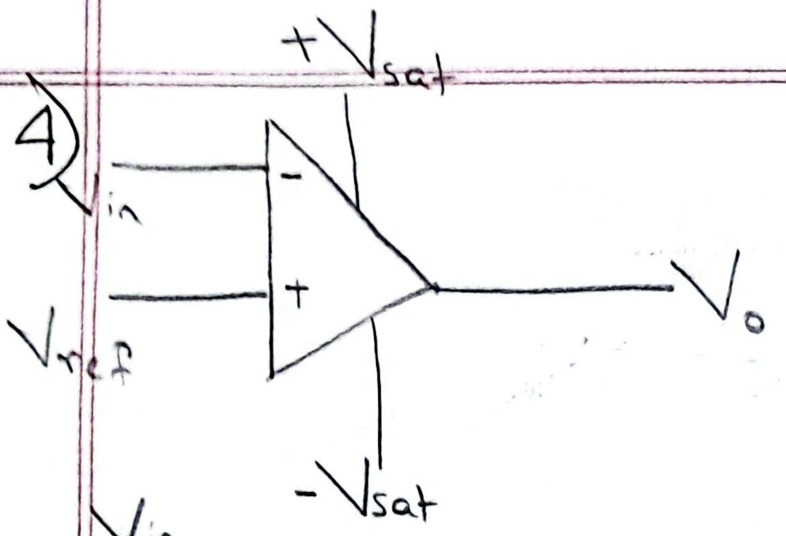
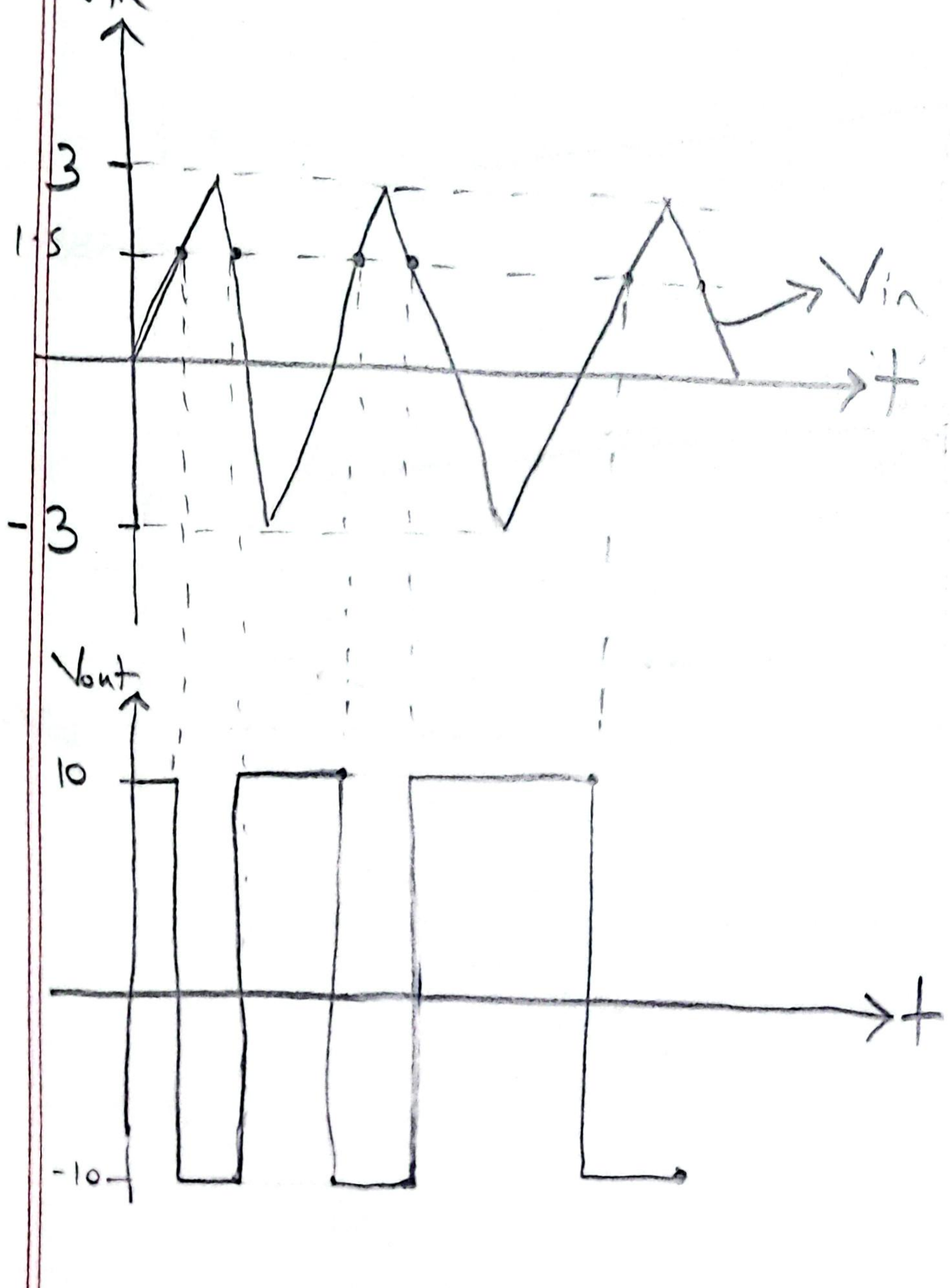


$V_{ref} = 1.5V$

$V_{sat}^{+} = 10V$

$V_{sat}^{-} = -10V$

$V_{in} = 3\sin\omega t$



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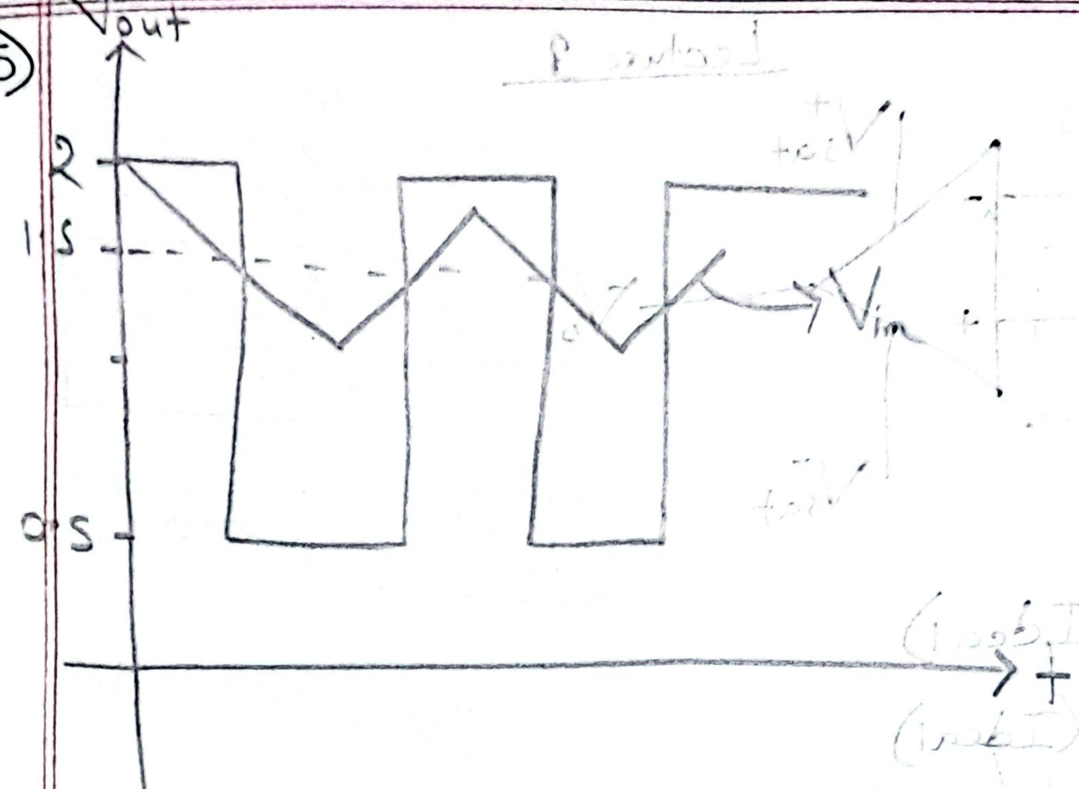

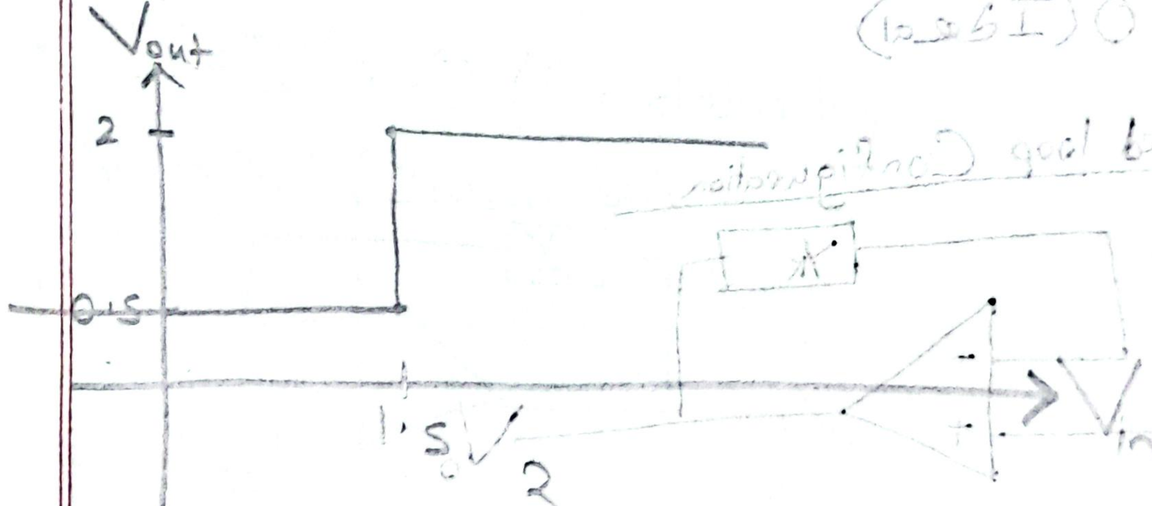

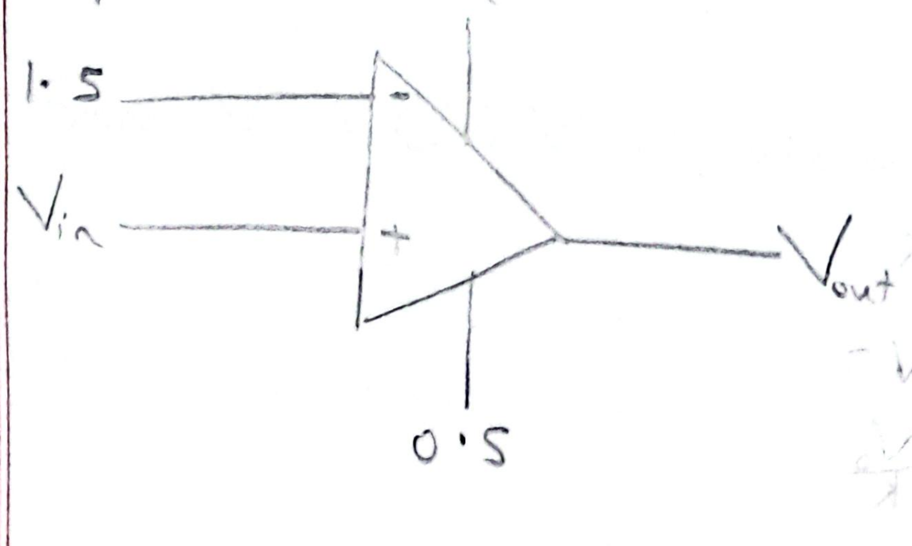

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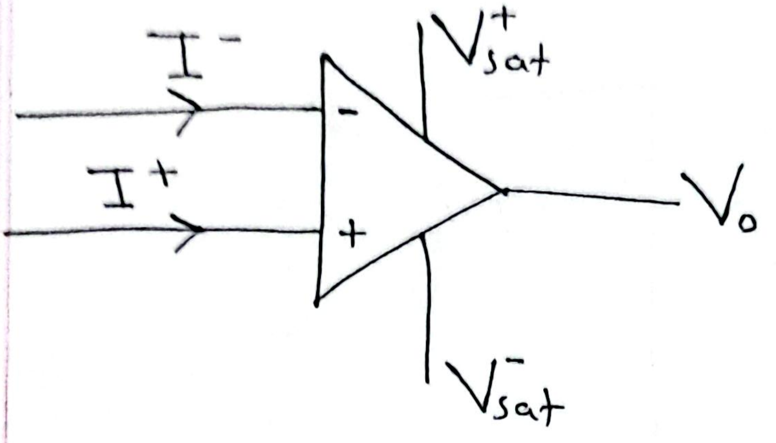
Lecture-3

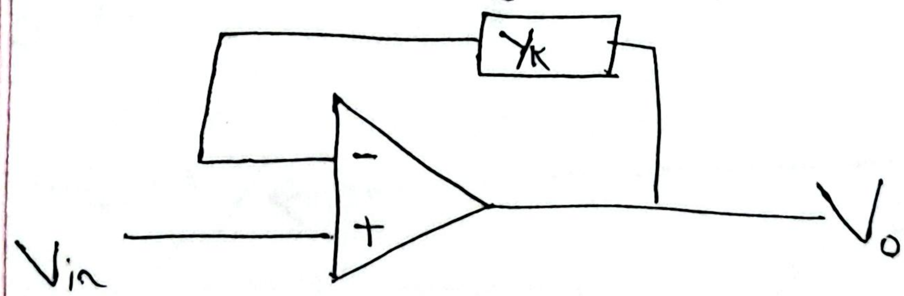


$A = \infty$ (Ideal)

$R_{in} = \infty$ (Ideal)

$R_{out} = 0$ (Ideal)

Closed loop Configuration



$V^+ = V_{in}$

$V^- = V_o / k$

$V_d = V^+ - V^-$

$V_d = V_{in} - \frac{V_o}{k}$

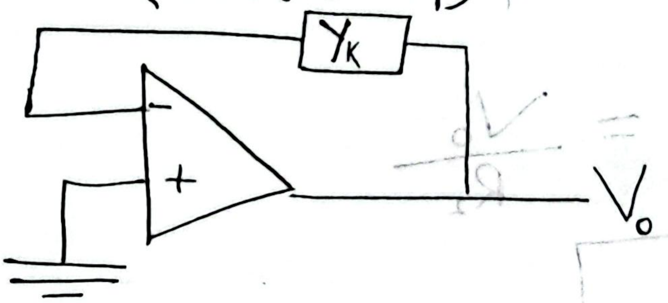
$\therefore$ $V_o = AV_d$

$V_o = A\left(V_{in} - \frac{V_o}{K}\right)$

$$\boxed{V_o = \left(\frac{A}{1+\frac{A}{K}}\right) V_{in}}$$

Ideal: $\boxed{V_o = KV_{in}}$

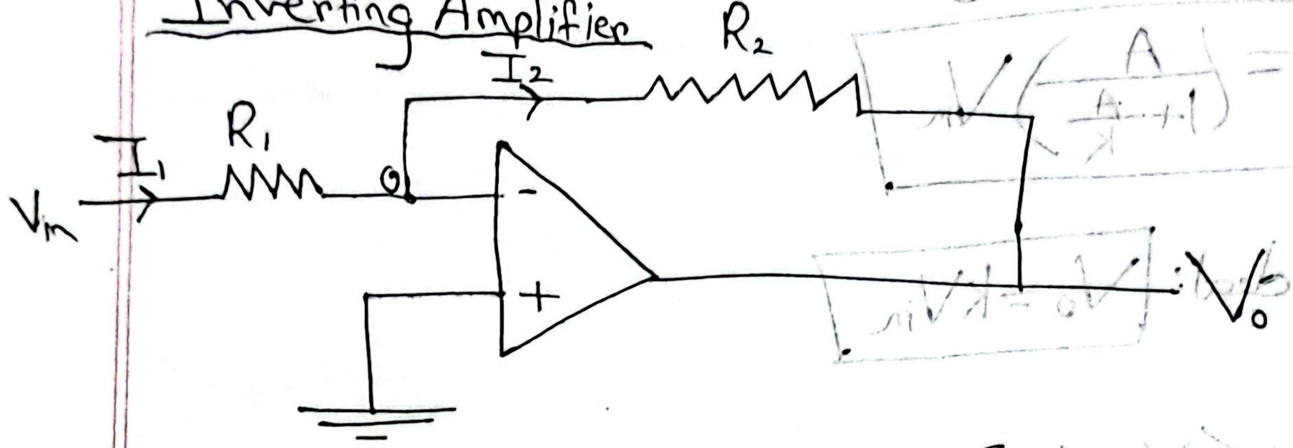
$V_{sat}^- < V_o < V_{sat}^+$

- $I^- = I^+ = 0$ (For closed loop
- $V^+ = V^-$ (Closed loop)
- 

Since V^+ is 0V, V^- will also be 0V. ($V^+ = V^-$)

Mathematical Operation

Inverting Amplifier



Since $V^+ = 0V$,
$V^- = 0V$

$V^- = 0V$

$$I_1 = \frac{V_{in} - 0}{R_1} = \frac{V_{in}}{R_1}$$

$$I_2 = \frac{V_o - 0}{R_2} = \frac{V_o}{R_2}$$

$$\boxed{V_o = \left(\frac{-R_2}{R_1}\right) V_{in}}$$

~~1) If $V_o = y$ and V_{in}~~

1) Form a circuit to form the equation $y = 4x$

Ans: Assuming $V_o = y$ and $V_{in} = x$

$y = \left(\frac{-R_2}{R_1}\right) x$

$\therefore \frac{-R_2}{R_1} = 4$

$-R_2 = 4R_1$

$R_2 = -4R_1$

Since resistance cannot be negative, Vin cannot be x,

$\therefore$ Assuming $V_o = y$ and $V_{in} = -4x$

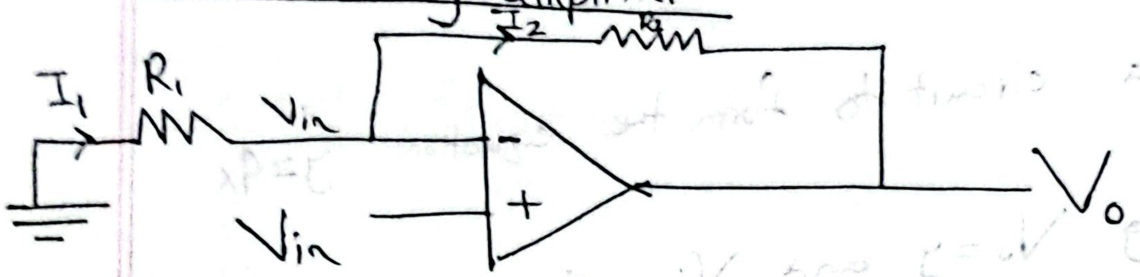
$y = -\left(\frac{R_2}{R_1}\right)(-4x)$

$\therefore \frac{R_2}{R_1} = \cancel{1\Omega}\ 1$

$R_2 = R_1$

$\therefore$ If $R_2 = 1\Omega$ and $R_1 = 1\Omega$ the circuit can be formed.

Non-inverting amplifier



$$I_1 = \frac{0 - V_{in}}{R_1}$$

$$I_2 = \frac{V_{in} - V_o}{R_2}$$

$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_{in}$$

2) Form a non-inverting amplifier with equation $y = 4x$

Ans: Assuming $y = V_{out}$ and $x = V_{in}$

$y = \left(1 + \frac{R_2}{R_1}\right) x$

$1 + \frac{R_2}{R_1} = 4$

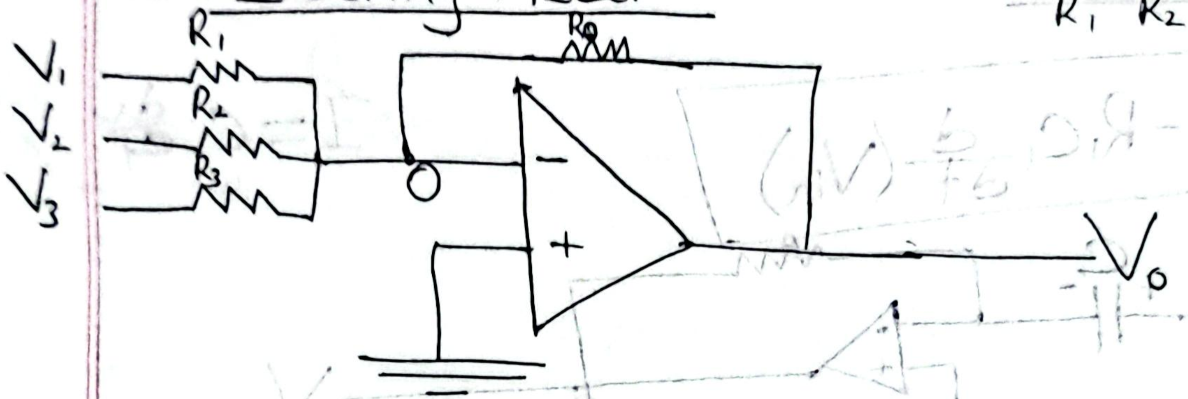
$\frac{R_2}{R_1} = 3$

$R_2 = 3R_1$

$\therefore$ R_1 can be $1k\Omega$ and R_2 can be $3k\Omega$

~~In~~ Inverting Adder

$$\frac{V_1}{R_1}+\frac{V_2}{R_2}+\frac{V_3}{R_3}=\frac{0-V_0}{R_f}$$



$$V_0=-\frac{R_0}{R_1}V_1-\frac{R_0}{R_2}V_2-\frac{R_0}{R_3}V_3$$

$$V_0=-\left(\frac{R_0}{R_1}V_1+\frac{R_0}{R_2}V_2+\frac{R_0}{R_3}V_3\right)$$

(3) $y=-2x+3y-4z$

$\cancel{=-(2x-3y+4z)}$

$y=-(2x-3y+4z)$

$2=\frac{R_0}{R_1}$

$2R_1=R_0$

$R_0-2R_1=0-(1)$

$\frac{R_0}{R_2}=-3$

$R_0=-3R_2$

$R_0+3R_2=0-(11)$

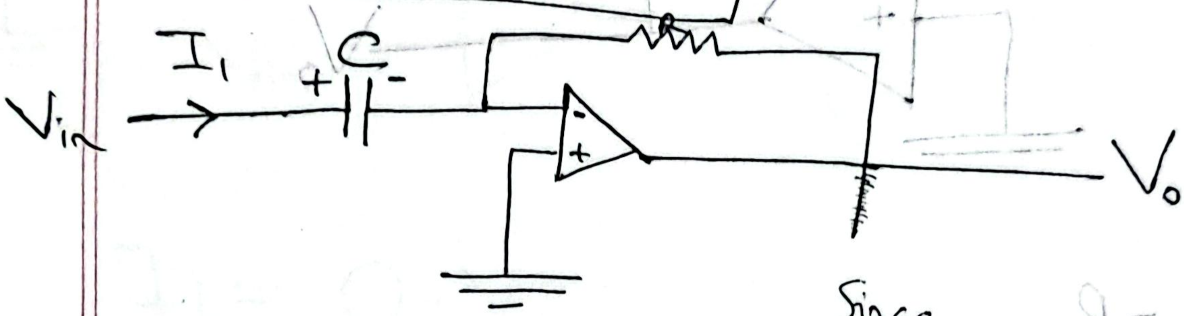
$\frac{R_0}{R_3}=4$

$R_0-4R_3=0-(111)$

Differentiator

$$\boxed{V_o = -R_1 C_1 \frac{d}{dt}(V_{in})}$$

$I = C\frac{dv}{dt}$



Since

$I_{C_1} = I_{R_1}$

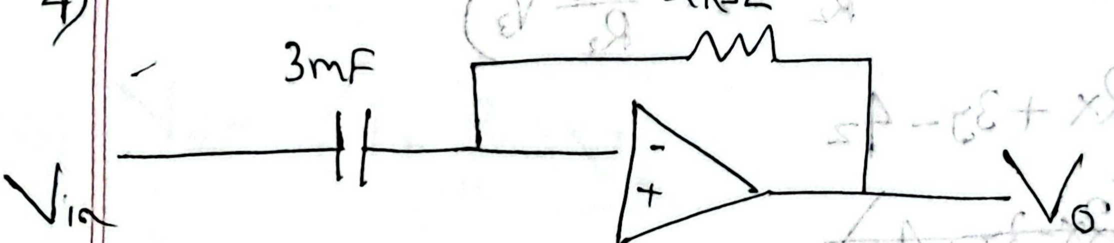
$C_1\left(\frac{d}{dt}V_{in}\right) = \frac{0 - V_o}{R_1}$

$\therefore V_o = -R_1 C_1 \frac{d}{dt}(V_{in})$

Integrator

$V_{in} = 10\cos 2t$

4)



$$\frac{d}{dt}(V_i) = \frac{d}{dt}(10\cos 2t)$$

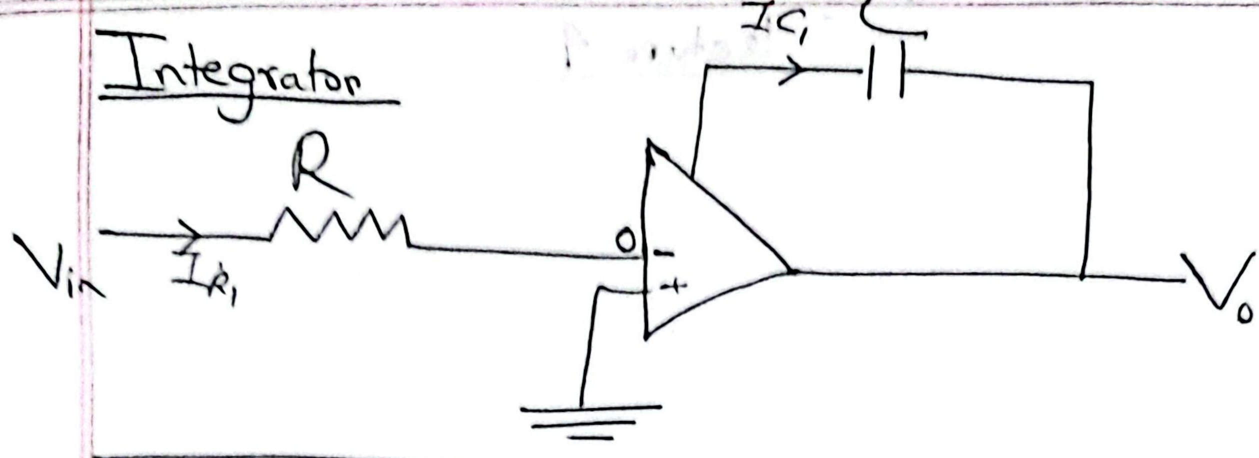
$$= 10[-2\sin 2t]$$

$$= -20\sin 2t$$

$$V_o = -(2\times\cancel{10^3}\times 3\times\cancel{10^{-3}}\times -20\sin 2t)$$

$$= 120\sin 2t$$

Integrator



$$\boxed{V_o = \frac{-1}{RC}\int V_{in}\,dt}$$

Since

$$I_{R_1} = \cancel{I_{C}}\; I_{C_1}$$

$$\frac{V_{in}-0}{R_1} = C\frac{d}{dt}\cancel{(V_o)}\,(0-V_o)$$

$$\frac{V_{in}}{R_1} = \cancel{C_1\left(\frac{d}{dt}V_o\right)}\; C_1\left(\frac{d}{dt}(0-V_o)\right)$$

$$\frac{V_{in}}{R_1C_1} = \frac{d}{dt}(-V_o)$$

$$\therefore\; -V_o = \int \frac{V_{in}}{R_1C_1}\,dt$$

$$V_o = \frac{-1}{R_1C_1}\int V_{in}\,dt$$

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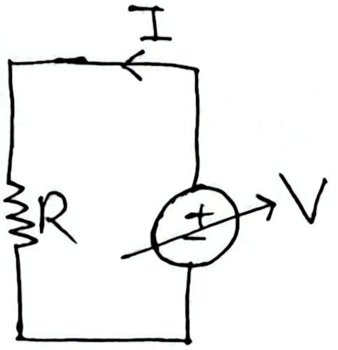
lecture-5

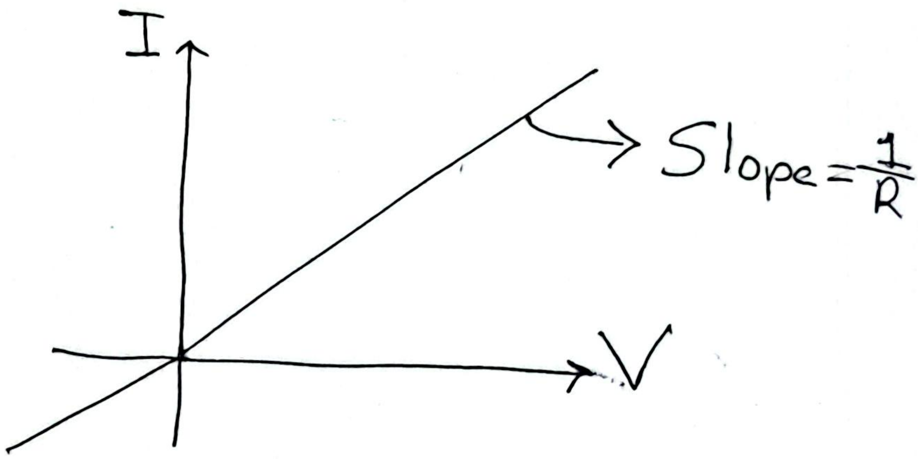
$I = f(V)$

$I = C\left(\frac{dV}{dt}\right)$

$V = f(I)$

Inductor $= V = L\frac{dI}{dt}$





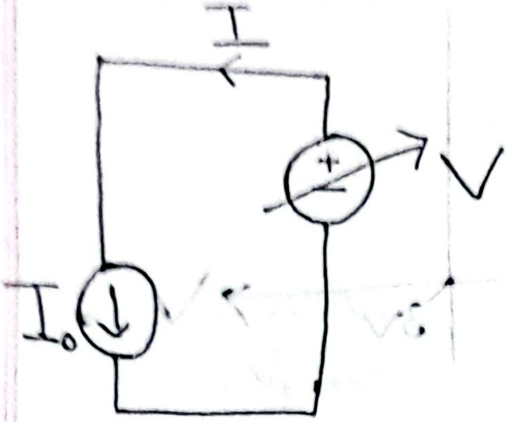
$I = V/R$

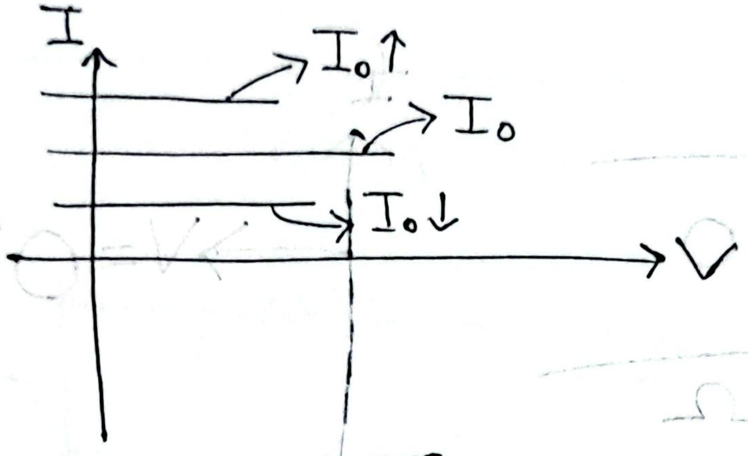
$y = mx + c$

$I = \left(\frac{1}{R}\right)V + 0$

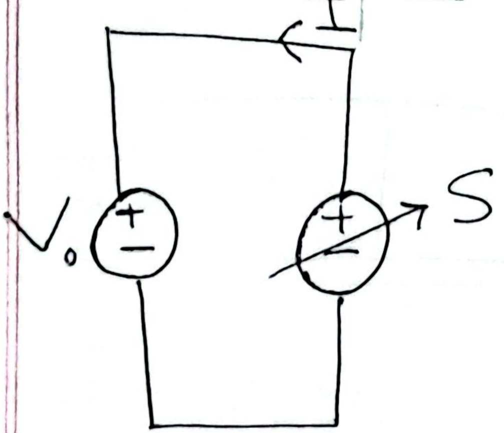
$\therefore m = \frac{1}{R}$ and $R = \frac{1}{m}$

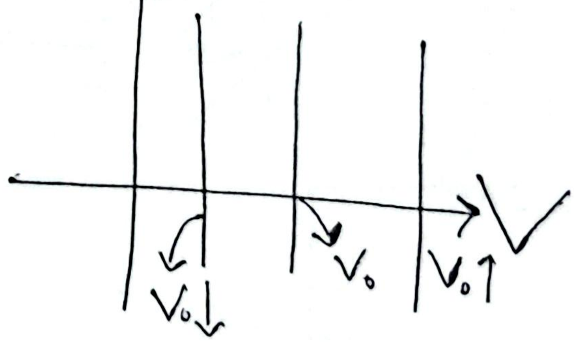
Current Source

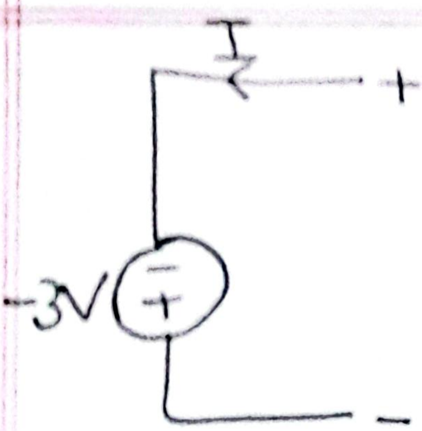


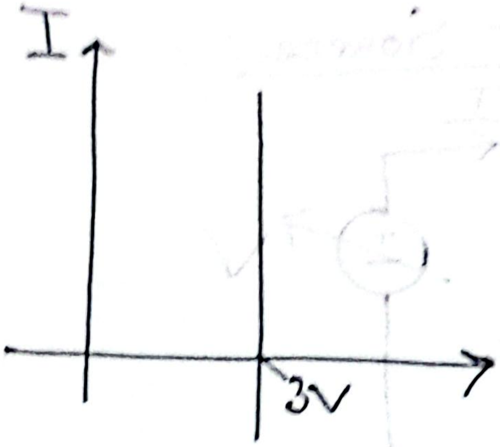


Voltage Source









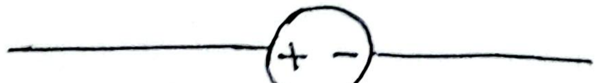
Short Circuit

1) 

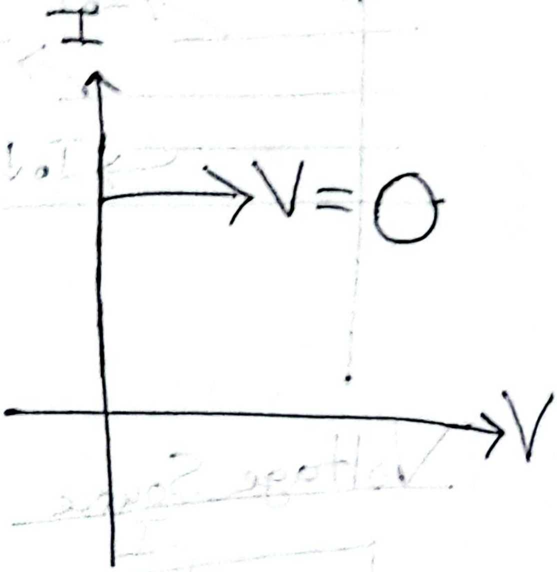
$V = 0$

2) 

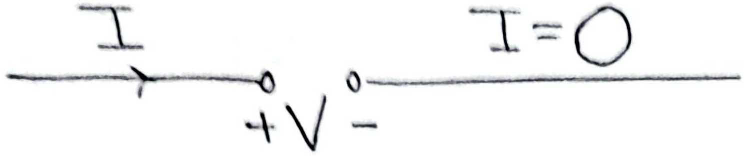
$R = 0\Omega$

3) 

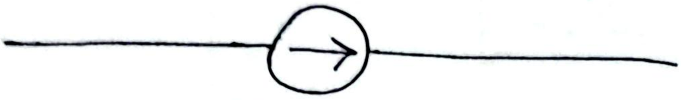
$V = 0V$

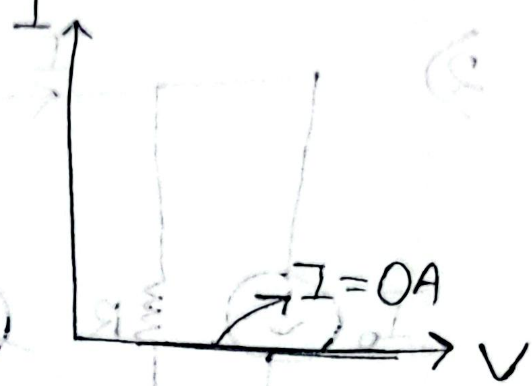


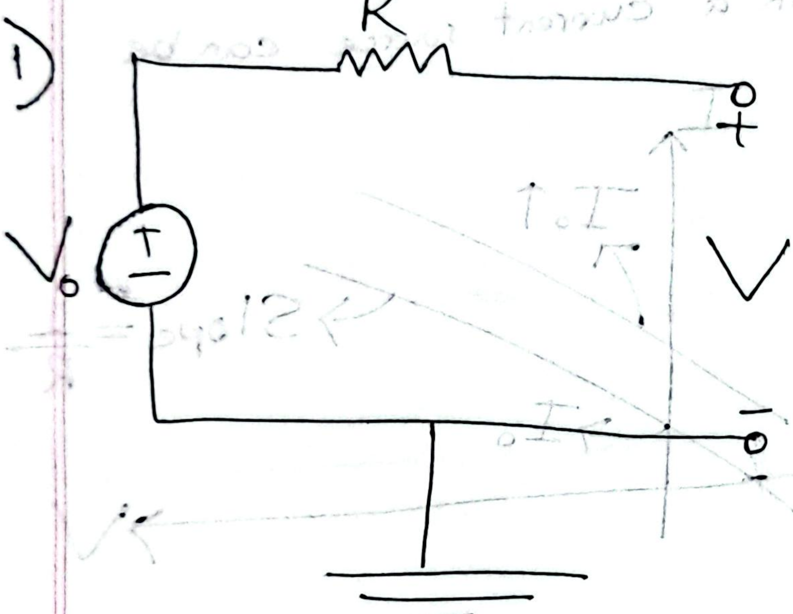
Open Circuit

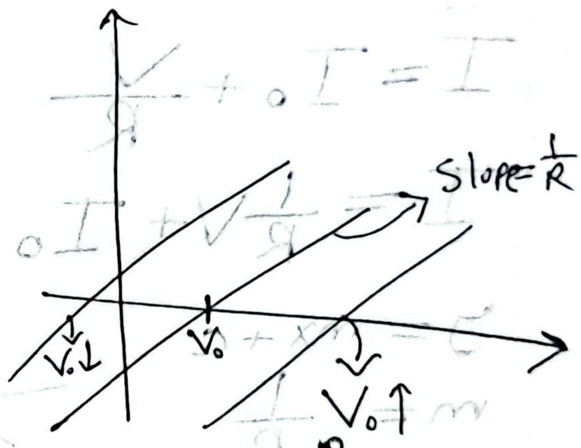
1) 

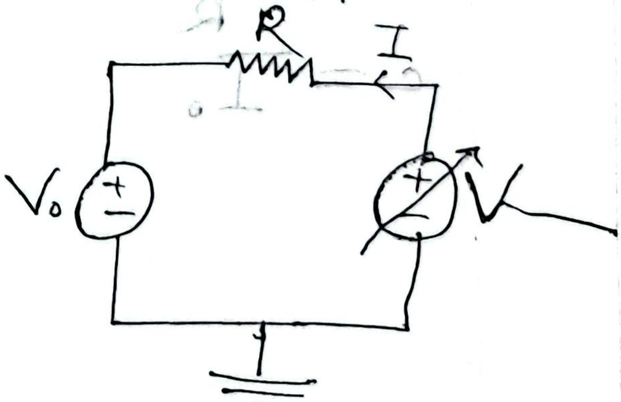
2) 

3) 



1) 





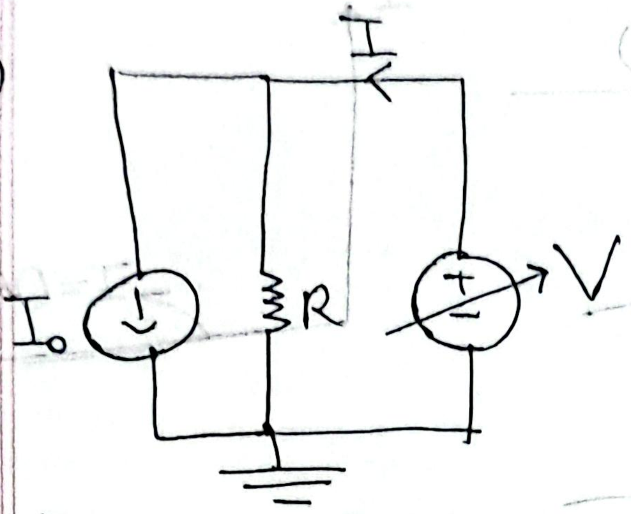
$$I = \frac{V - V_0}{R}$$

$$I = \frac{1}{R}V - \frac{V_0}{R}$$

$$c = -\frac{V_0}{R}$$

• If R is changed then slope decreases.

2)



• A resistor parallel with a voltage source and a resistor in series with a current source can be removed.

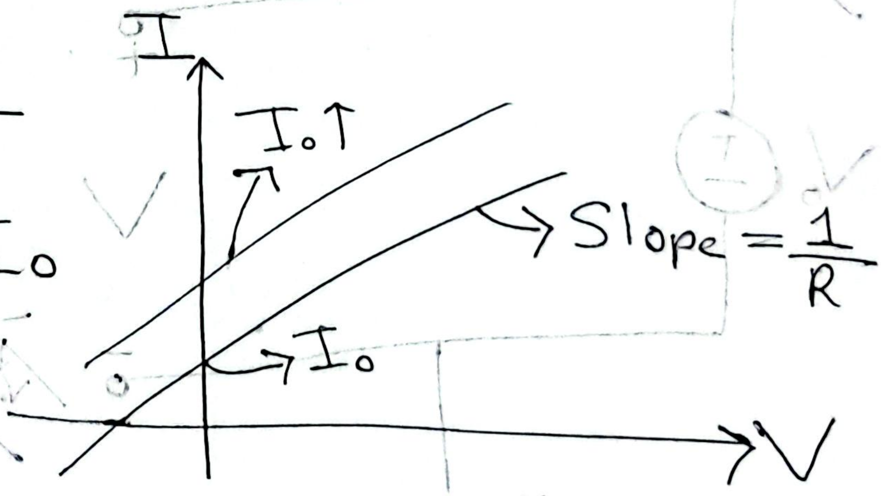
$$I = I_o + \frac{V}{R}$$

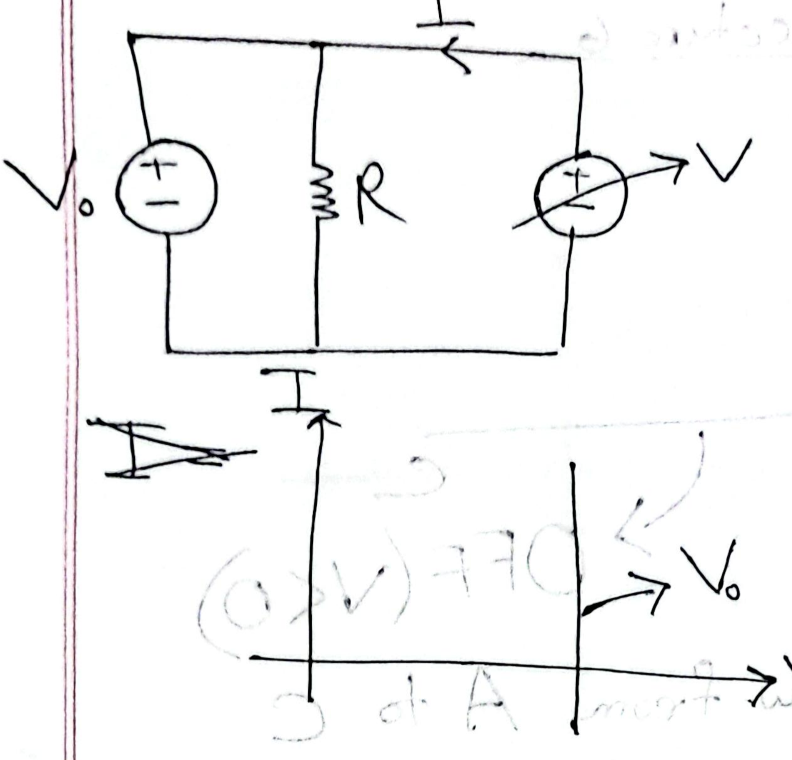
$$I = \frac{1}{R}V + I_o$$

$$y = mx + c$$

$$m = \frac{1}{R}$$

$$c = I_o$$





I
V_0
R
V
I
V_0
V

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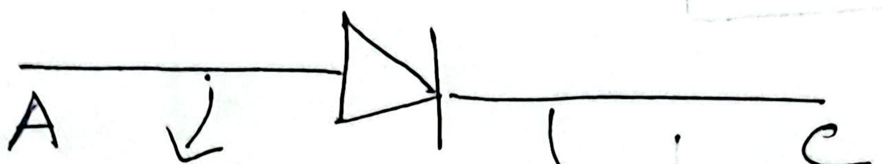
lecture-6

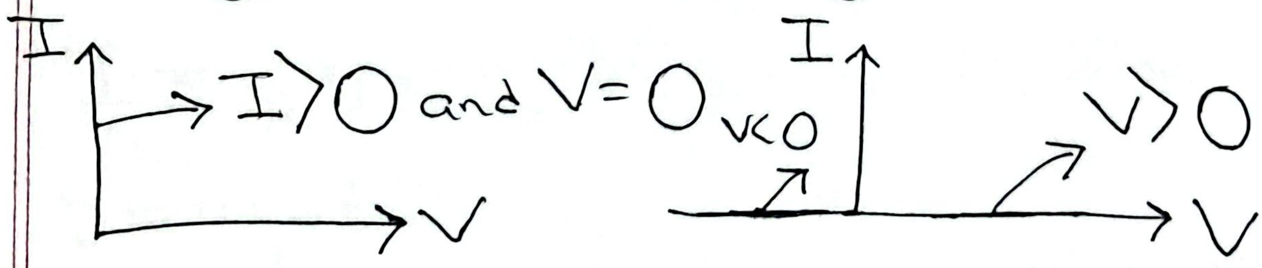
Diode-Ideal



ON$(I>0)$ OFF$(V<0)$

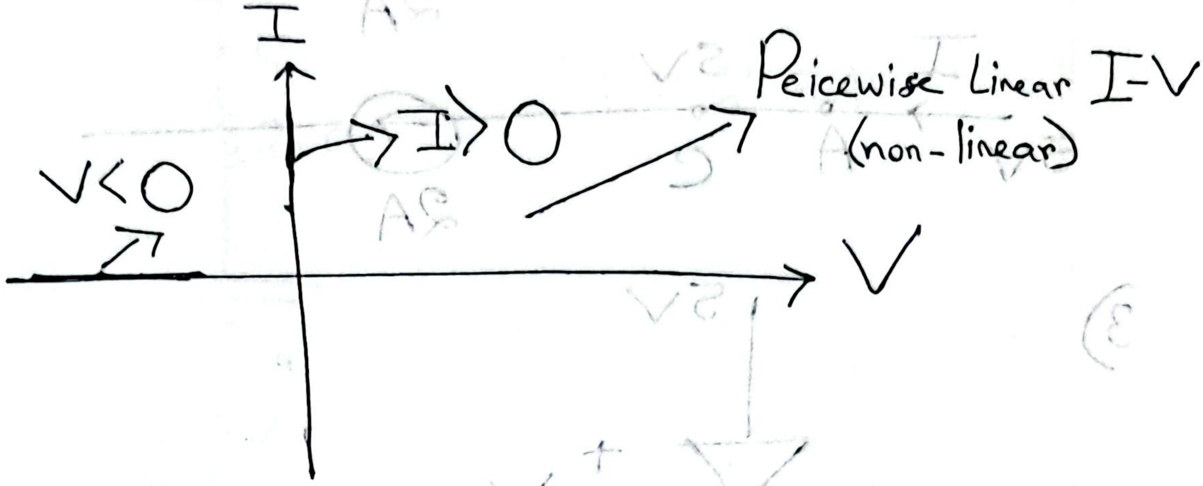
Current can flow from A to C

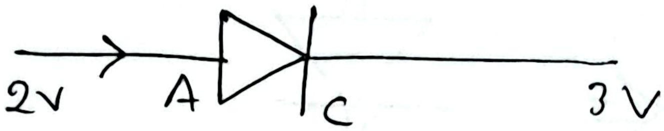
$V=0$ $I=0$



Diode will be off if $V_A - V_C < 0$

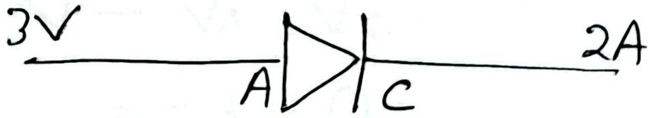
- Stoppage sign jeidike ; sheidike cathode ar opposite side a cathode.



1.1) 

$$V = 2-3$$
$$= -1 < 0$$

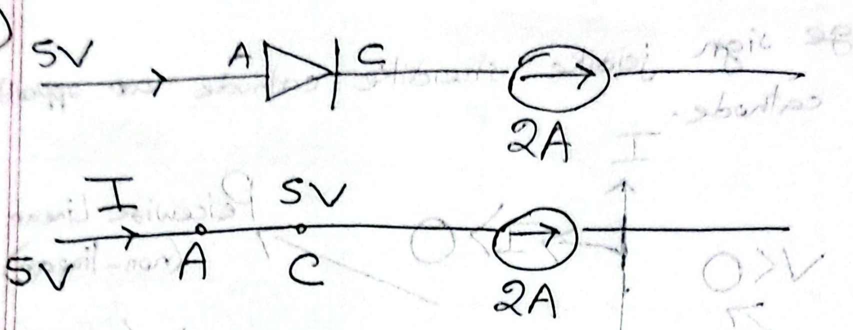
∴ Diode ~~a~~ is off and $I = 0A$

1.2) 

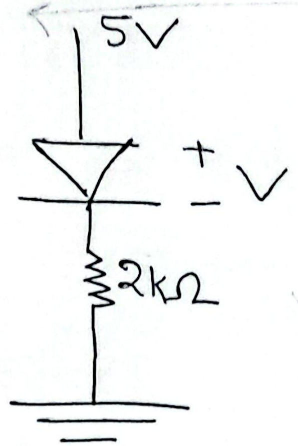
$$V = V_A - V_c$$
$$= 3-2$$
$$= 1V > 0$$

- Since there is no resistor I cannot be calculated hence circuit is invalid.

2)



3)



Voltage of anode is 5V and voltage of cathode is 0V. Hence.

$$V = 5 - 0$$
$$= 5V$$

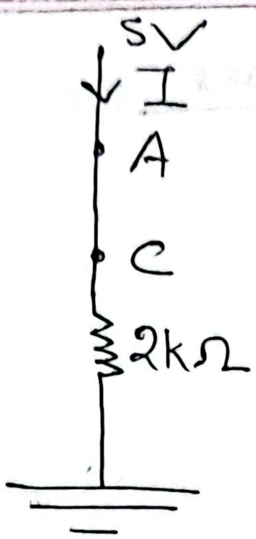
Since the diode is ON,

4)

$V = V_A - \ldots$

$= -3 - \ldots$

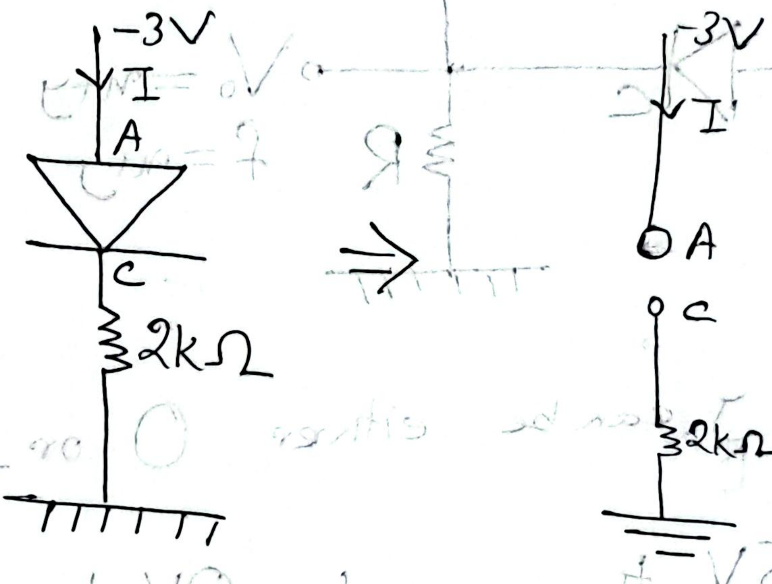
$= -3$



$$I = \frac{5}{2}$$

$$I = 2.5A$$

4) (iv)



$$V = V_A - V_c$$
$$= -3 - 0$$
$$= -3$$

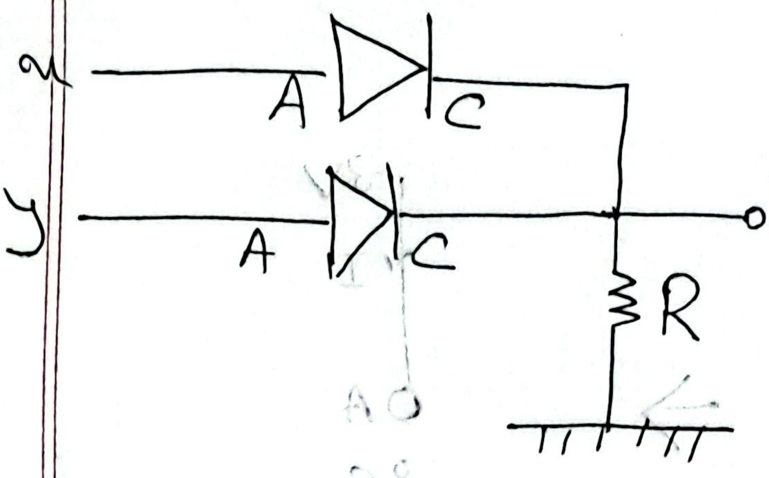
Since Diode is off, $I = 0A$

Logic Gate with Diodes

AND OR NOT

xy $x+y$ $\bar{x}$

OR



$V_o = x+y$

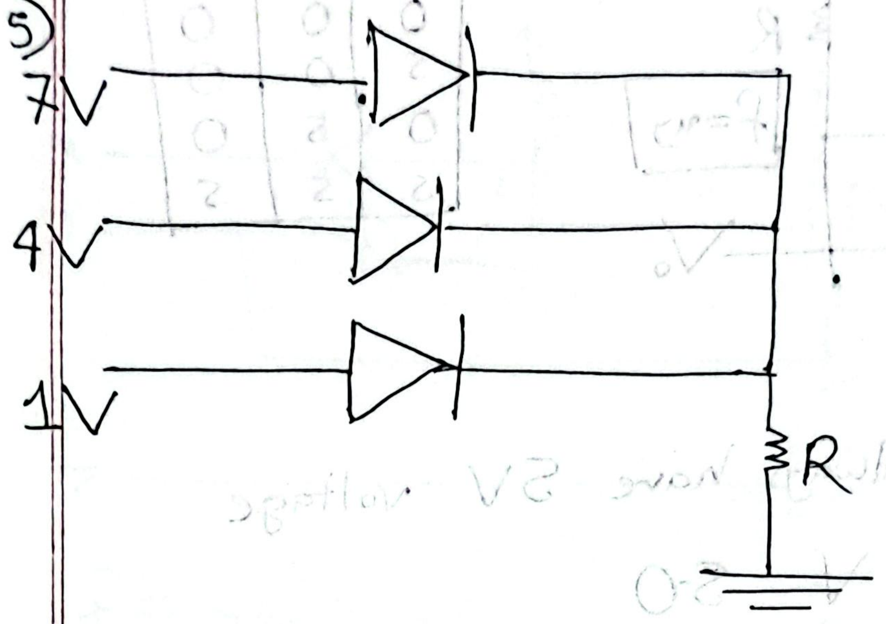
$f = x+y$

- x and y can be either 0 or 1
- If 5V then on else 0V then off
- If ~~x is of~~ x is 0V then the diode will be off else on.

x	y	V_o
0	0	0
5	0	5
0	5	5
5	5	5

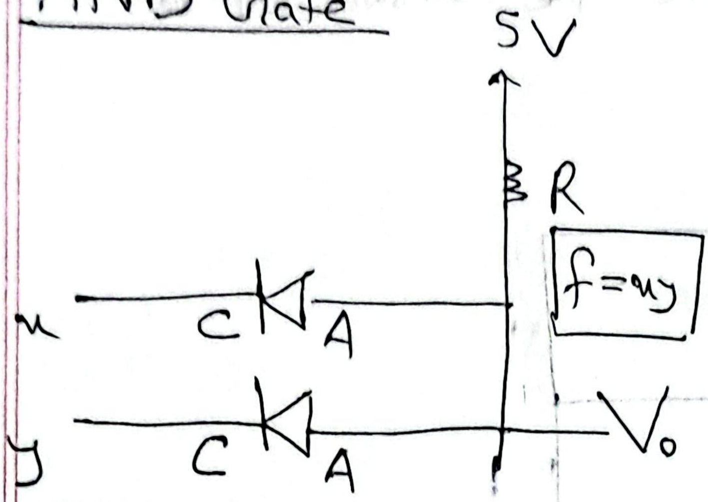
• If $f = x+y+z$ then the answer will be $\max(x,y,z)$.

5)



• x, y, z can not be on at the same time. Only the diode with the maximum voltage will remain on. (7V for this case).

AND Gate



x	y	V_o
0	0	0
5	0	0
0	5	0
5	5	5

- Anode will always have 5V voltage
- When x is 0, $V = 5 - 0$

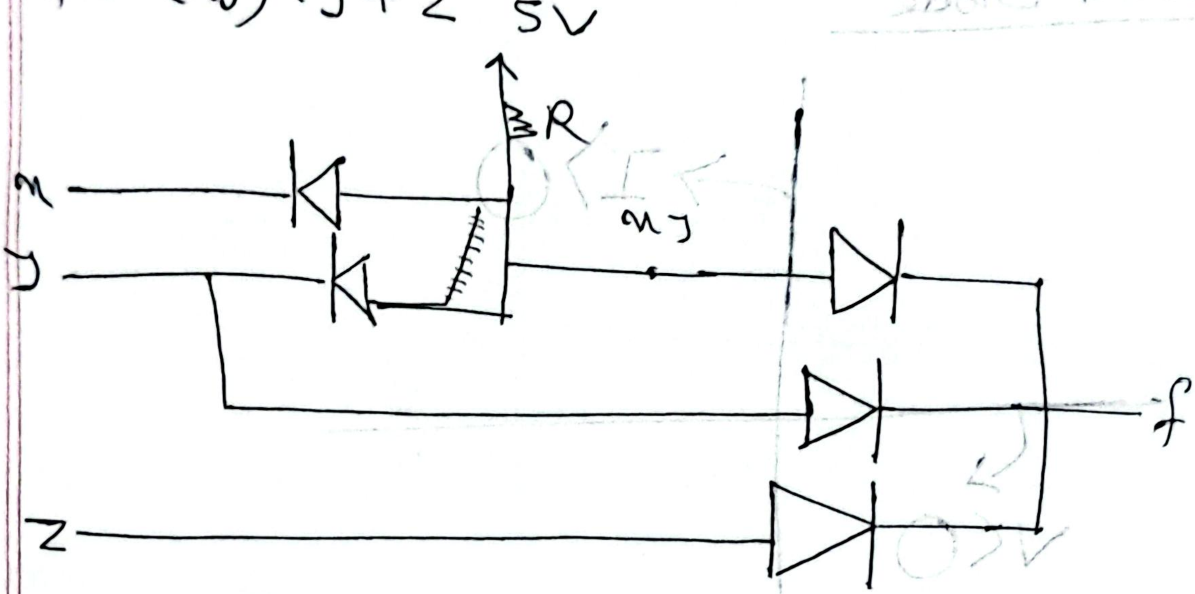
$$= 5 > 0 \text{ (Diode on)}$$

When x is 5, $V = 5 - 5$

$$= 0 \text{ (Diode off)}$$

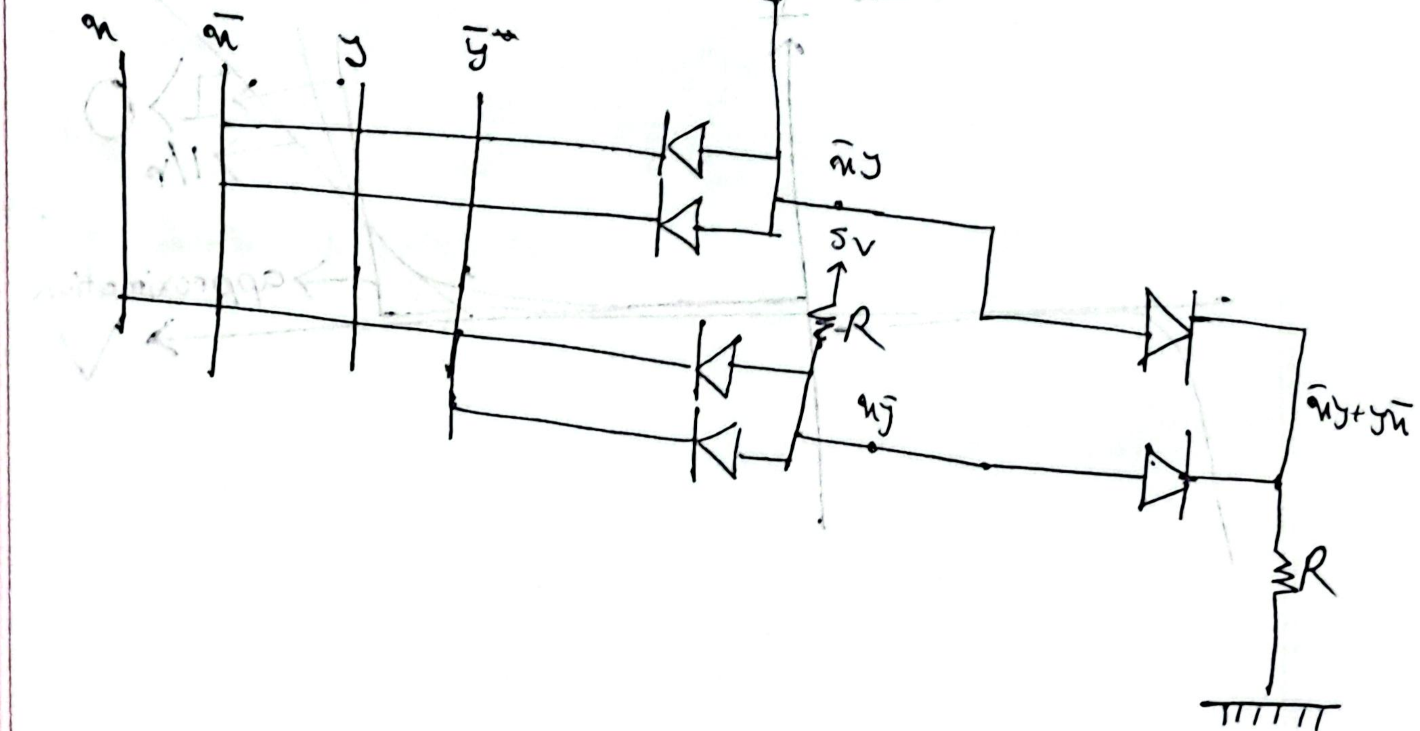
6) Design the circuit :

$f = (xy) + y + z$



$f = y(x+1) + z$

7) $f = \bar{x}y + x\bar{y}$



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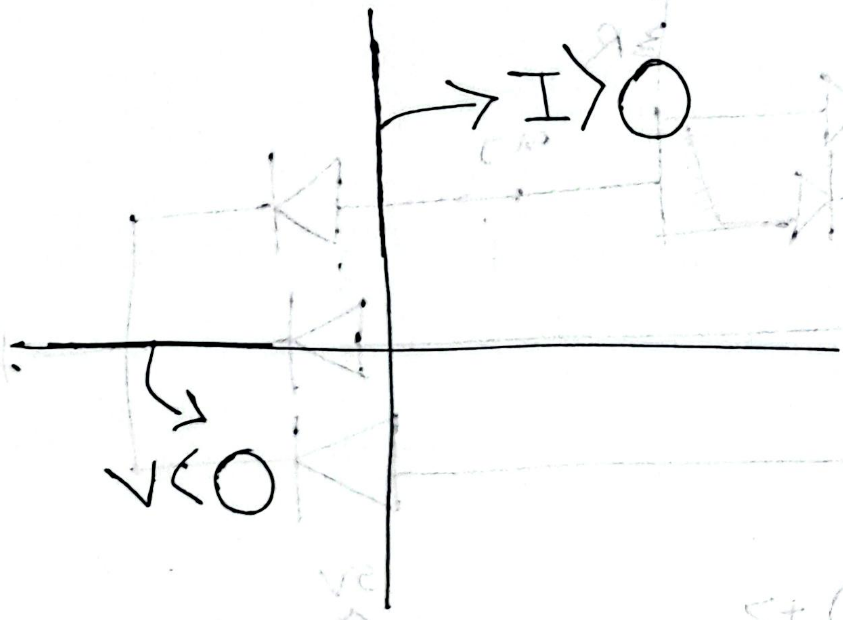
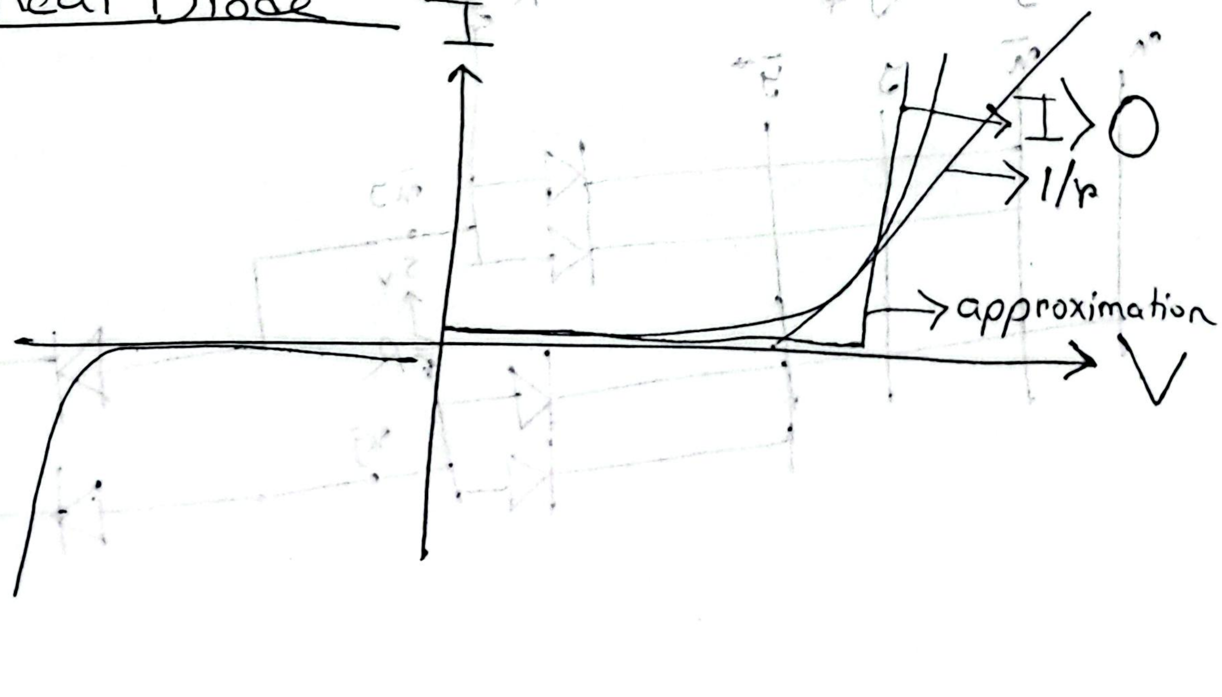
Lecture-7

Ideal Diode

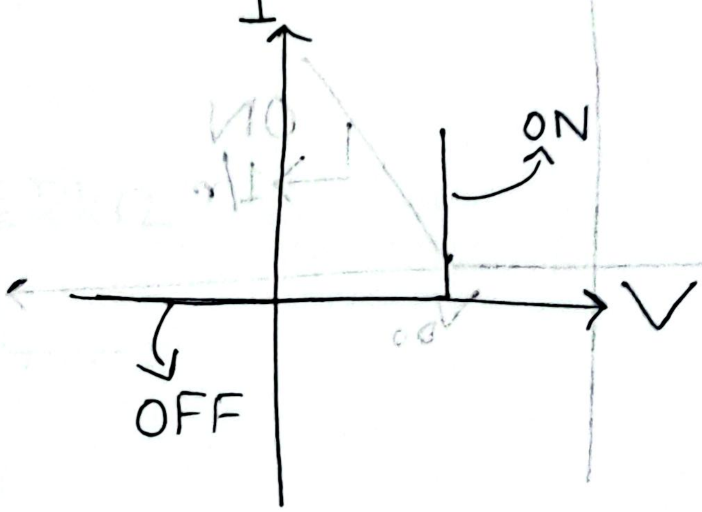


Real Diode



Approximation of Real Diode

1) Constant voltage drop model (CVD Model)



If diode is on, diode can be replaced by,

$V_{DO} = 0.7 (Si)$ or $0.2 (Ge)$

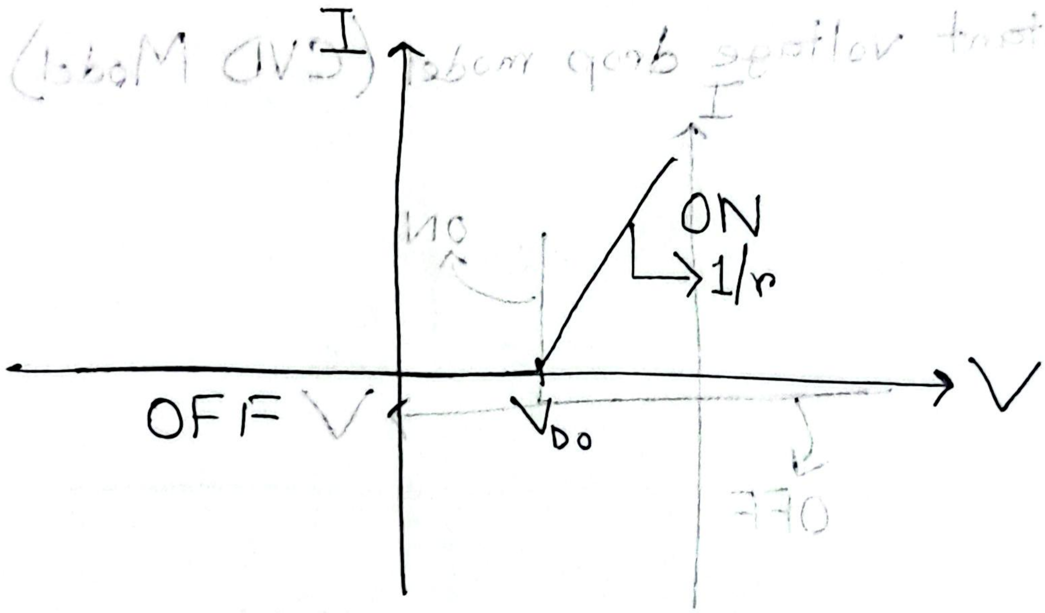
If diode is ON then,

$I > 0$

If diode is off then,

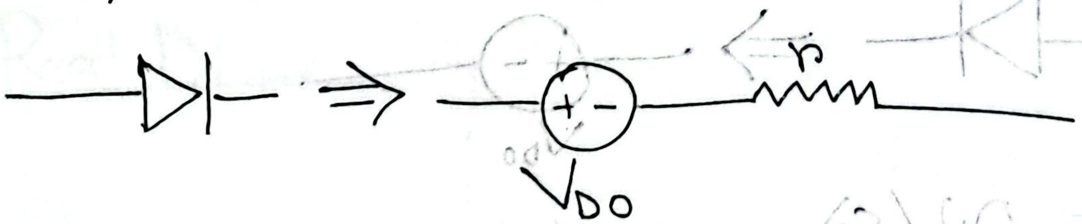
$V < V_{DO}$

ii) Constant voltage drop+resistance (CVD+r model)



If ON,

$V > V_{DO}$ and $I > 0$



If OFF,

$V < V_{DO}$

Find I,

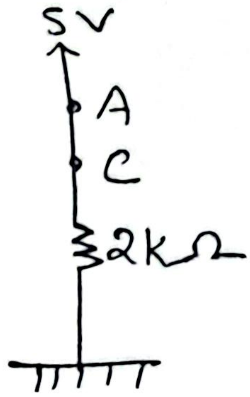
i) For an ideal diode model

ii) For CVD model with $V_{D0} = 0.7V$

iii) For CVD+r model with $V_{D0} = 0.7V$ and $r = 10\Omega$

i) For ideal

$V_D = 5 - 0$
$= 5$

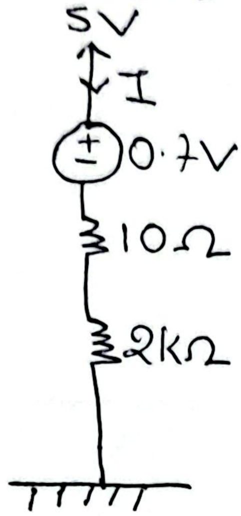


$I = 2.5mA$

ii) For CVD model

$$I = \frac{5 - 0.7}{2}$$
$$= 2.15mA$$

iii) For CVD+r model,

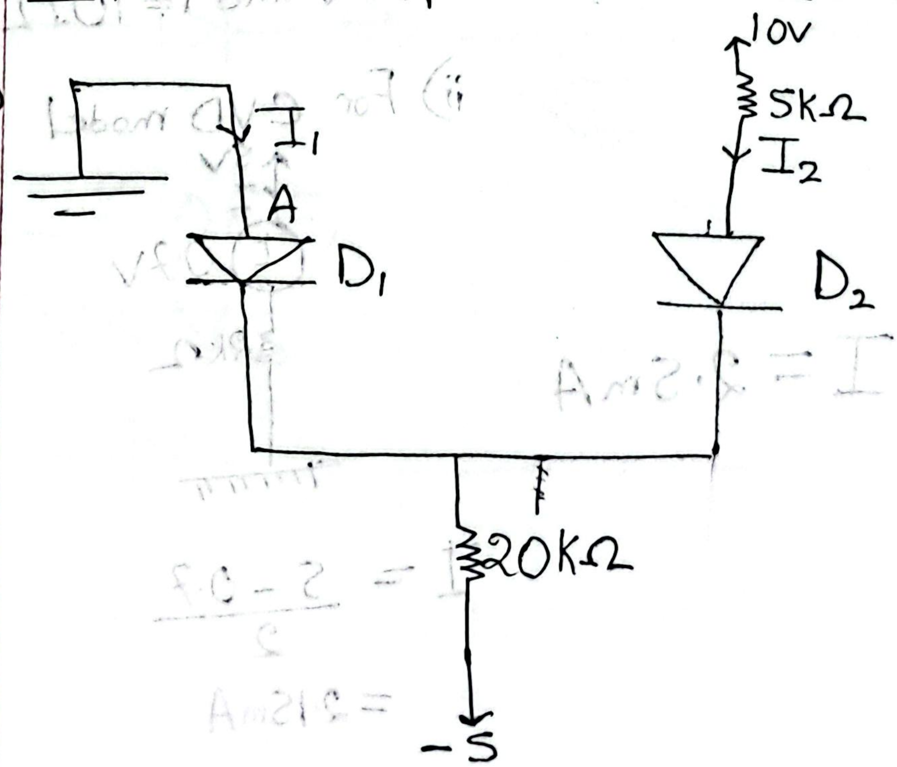


$$I = \frac{(5-0.7-0)V}{2100\Omega}$$

$$I = 2.14mA$$

- If r is not specified then use CVD Model.

2)



- For both D1 and D2 we donot know the value of voltage of cathode and due to this we cannot determine whether a diode is ~~on or~~ ON or OFF

- For this reason we will use,

Methods of Assumed State (MAS)

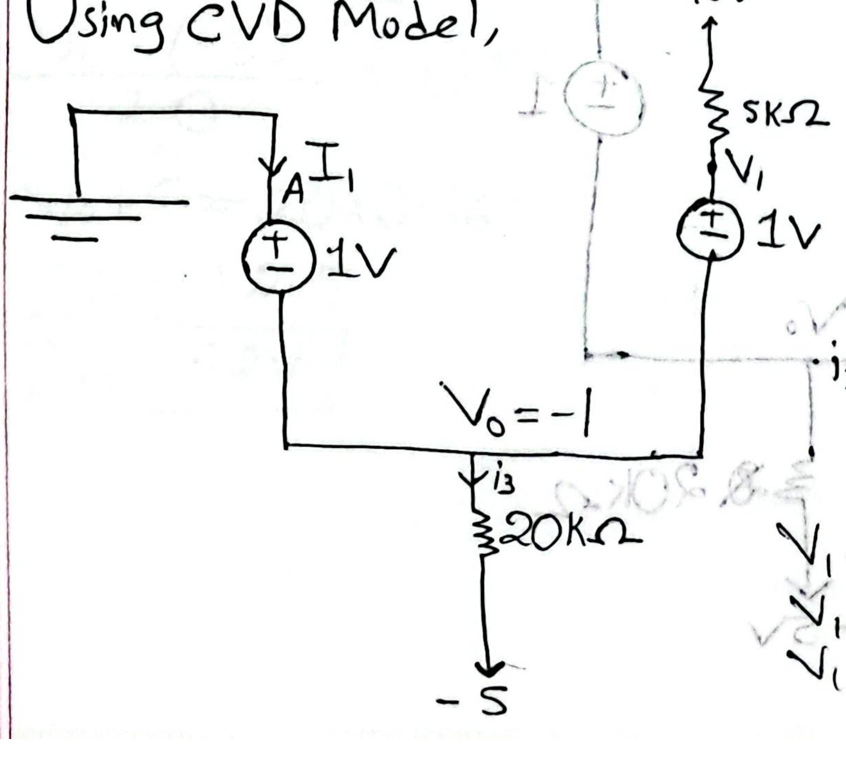
I) Assume — ON / OFF

II) Calculation — ON, I_D / OFF, $V_A - V_C$

III) Verify — ON, $I_D > 0$ / OFF, $V_D < V_o$

Assumption-1: Assume D_1 and D_2 are both open

Using CVD Model,



$1 = 0 - V_o$

$1 = -V_o$

$V_o = -1V$

~~∴ For D_1~~

$i_3 = \frac{-1-(-5)}{20}$

$i_3 = 0.2mA$

$V_1 - (-1) = 1$

$V_1 + 1 = 1$

$V_1 = 0V$

$$i_2 = \frac{10-0}{5}$$

$i_2 = 2mA$

Applying KCL at V_o,

$i_1 + i_2 = i_3$

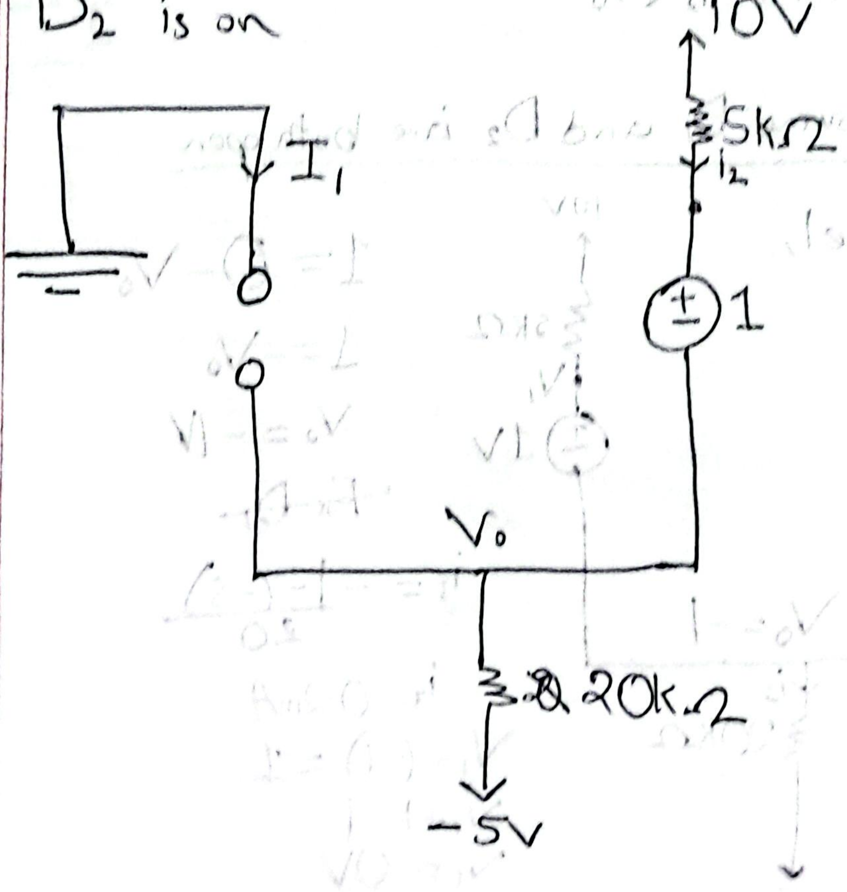
$i_1 + 2 = 0.2$

$i_1 = -1.8mA$

Since $i_1 < 0$,

D_1 and D_2 both cannot be on,

Since $i_1 < 0$ we will assume that D_1 is off and D_2 is on



Since D_1 is off,

$I_1 = 0V$

Applying KCL at V_0,

$i_1 + i_2 = i_3$

$0 + i_2 = i_3$

$\therefore i_2 = i_3$

Apply KVL in the circuit,

$10 - (-5) = 5i_2 + 1 + 20i_3$

$15 = 5i_2 + 1 + 20i_2$

$14 = 25i_2$

$$\boxed{\begin{aligned} i_2 &= 0.56mA \\ i_3 &= 0.56mA \end{aligned}}$$

$$\frac{V_0 - (-5)}{20} = 0.56$$

$V_0 + 5 = 20 \times 0.56$

$V_0 = 11.2 - 5$

$$\boxed{V_0 = 6.2V}$$

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Lecture-8

No notes

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Lecture-9

No notes