$\boxed{1}$

$\boxed{\text{VI}}$

We are taking this (-) because adder has (-) in the formula

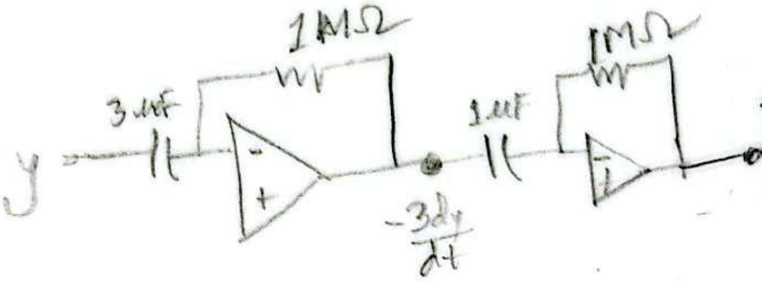
$$f = -\left[\boxed{\int\left(-6x + 3\frac{d^2y}{dt^2}\right)dt} + \boxed{3\frac{dz}{dt}}\right]$$

This (-) because integration formula has (-)

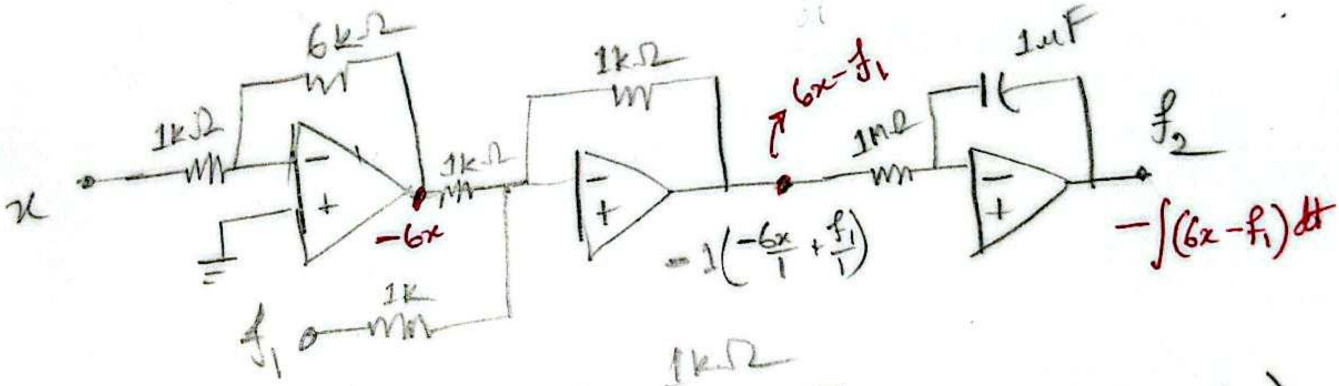
$$-\int\boxed{\left(6x - 3\frac{d^2y}{dt^2}\right)}dt$$

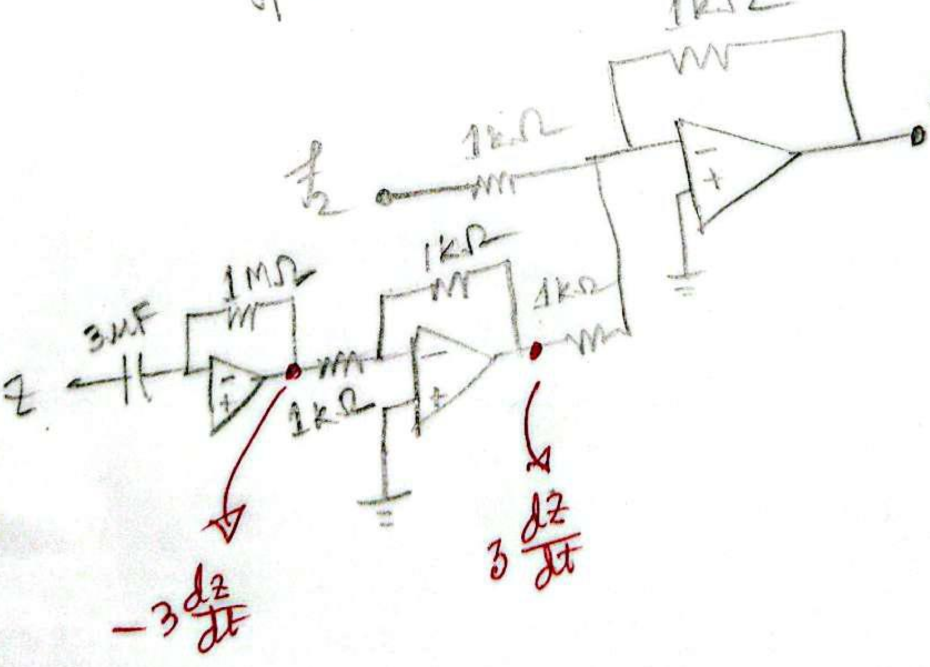
This minus(-) because adder formula has (-)

$$-\left(-6x + 3\frac{d^2y}{dt^2}\right)$$



$$f_1 = -\frac{d}{dt}\left(-\frac{3dy}{dt}\right) = \frac{3d^2y}{d^2t}$$





$$f = -\left(f_2 + \frac{3dz}{dt}\right)$$

2

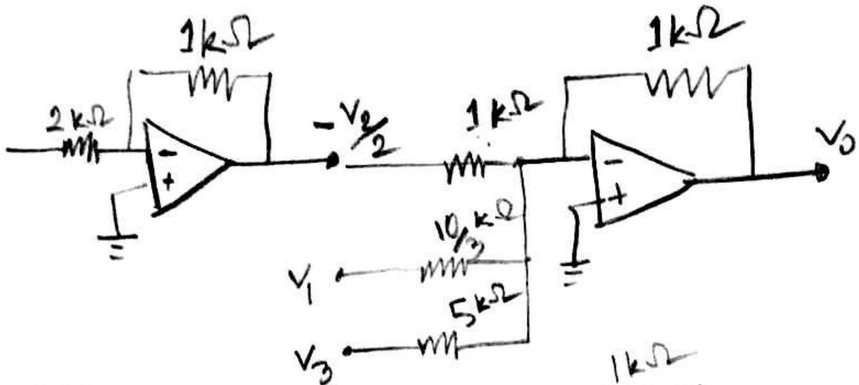
i.

$$-V_0 = \frac{V_3}{5} - \frac{V_1}{5} + \frac{V_1}{2} - \frac{V_2}{2}$$

Inv. Adder Formula

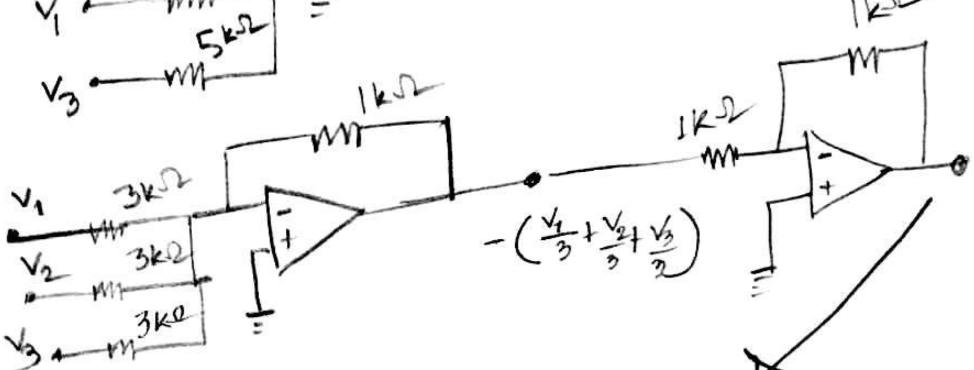
$$V_0 = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

$$\Rightarrow V_0 = -\left(\frac{3V_1}{10} + \frac{V_3}{5} - \frac{V_2}{2}\right)$$



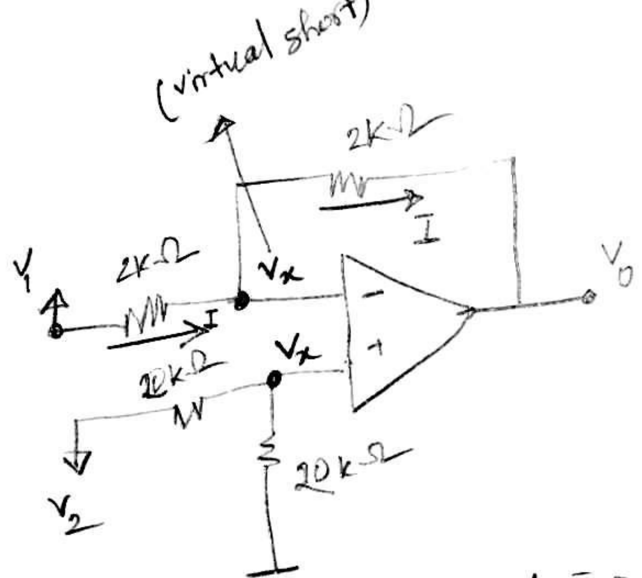
ii

$$\text{average} = \frac{V_1 + V_2 + V_3}{2}$$



$$V_0 = \frac{V_1}{3} + \frac{V_2}{3} + \frac{V_3}{3}$$
$$= \frac{V_1 + V_2 + V_3}{3}$$

3



$$V_x = \frac{20}{20+20} \times V_2 \quad [\text{VDR}]$$
$$= \frac{V_2}{2}$$

$$I = \frac{V_1 - V_x}{2} = \frac{V_x - V_0}{2}$$

$$\Rightarrow \frac{V_1 - \frac{V_2}{2}}{2} = \frac{\frac{V_2}{2} - V_0}{2}$$

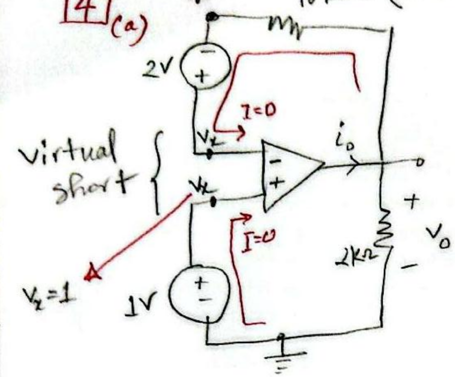
$$\Rightarrow \frac{V_1}{2} - \frac{V_2}{4} = \frac{V_2}{4} - \frac{V_0}{2}$$

$$\Rightarrow V_0 = \boxed{V_1 - V_2}$$

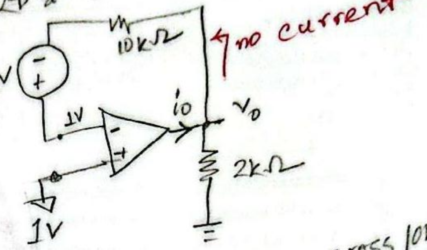
difference

4 (a)

10kΩ (No voltage drop here as I=0)



$1-V_a=2 \Rightarrow V_a=-1V$



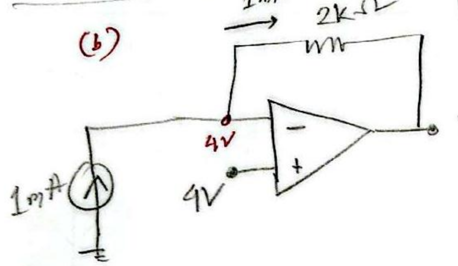
$V_o = V_a$ [as no V.drop across 10k]

$= -1V$

i_o will flow through 2kΩ

$i_o = \frac{V_o - 0}{2} = -\frac{1}{2} = -0.5\,mA$

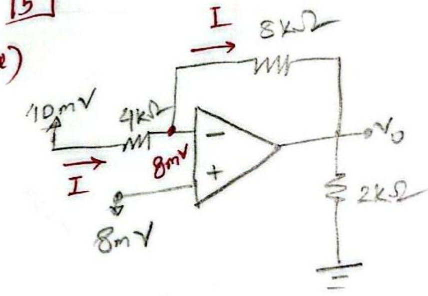
(b)



$1 = \frac{4-V_o}{2} \Rightarrow V_o = 2V$

5

(a)



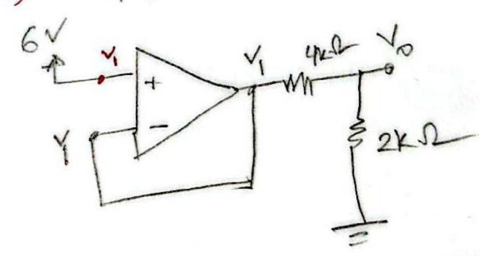
$I = \frac{10-8}{4} = \frac{8-V_o}{8}$

$\Rightarrow \frac{1}{2} = \frac{8-V_o}{8}$

$\Rightarrow V_o = 4mV$

(b)

$V_1 = 6V$



$V_o = \frac{2}{2+4} \times V_1$

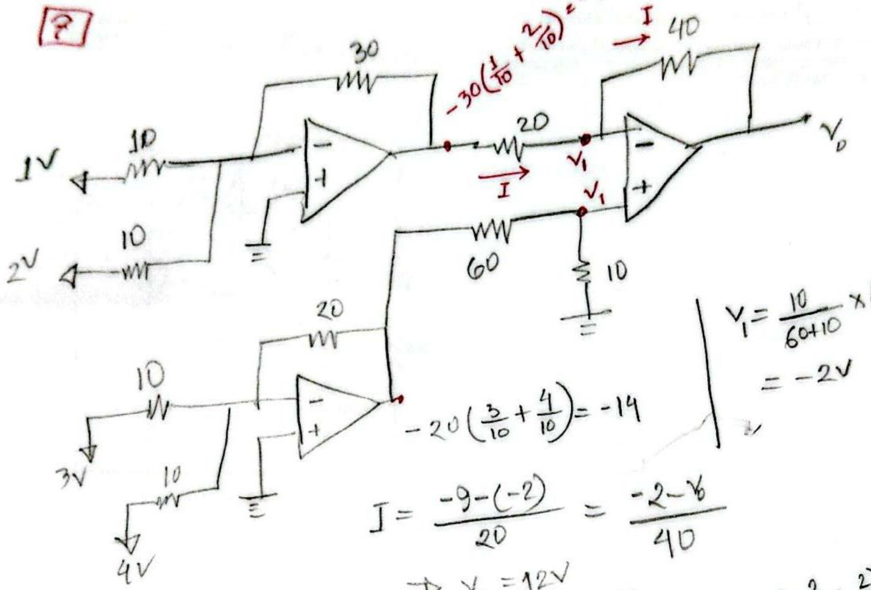
$= 2V$

6

$$\underset{-16.5}{V_o} = -50\left(\frac{-3}{10} + \frac{V_2}{20} + \frac{5}{50}\right)$$

$V_2 = 10.6$

7

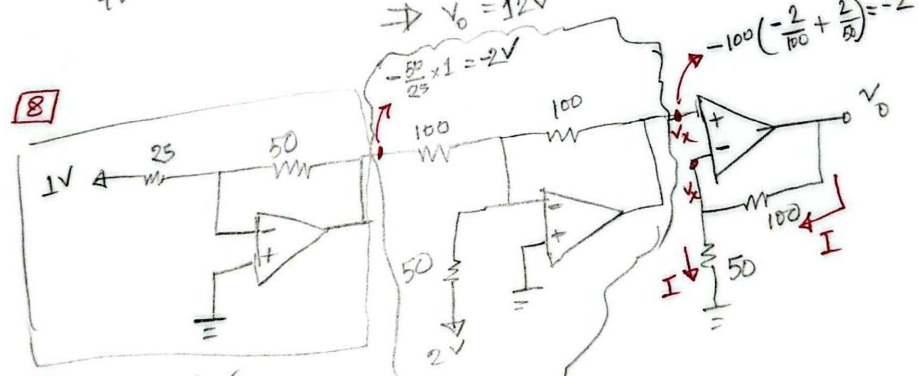


$$V_1 = \frac{10}{60+10} \times (-14) = -2V$$

$$I = \frac{-9-(-2)}{20} = \frac{-2-V_o}{40}$$

$\Rightarrow V_o = 12V$

8



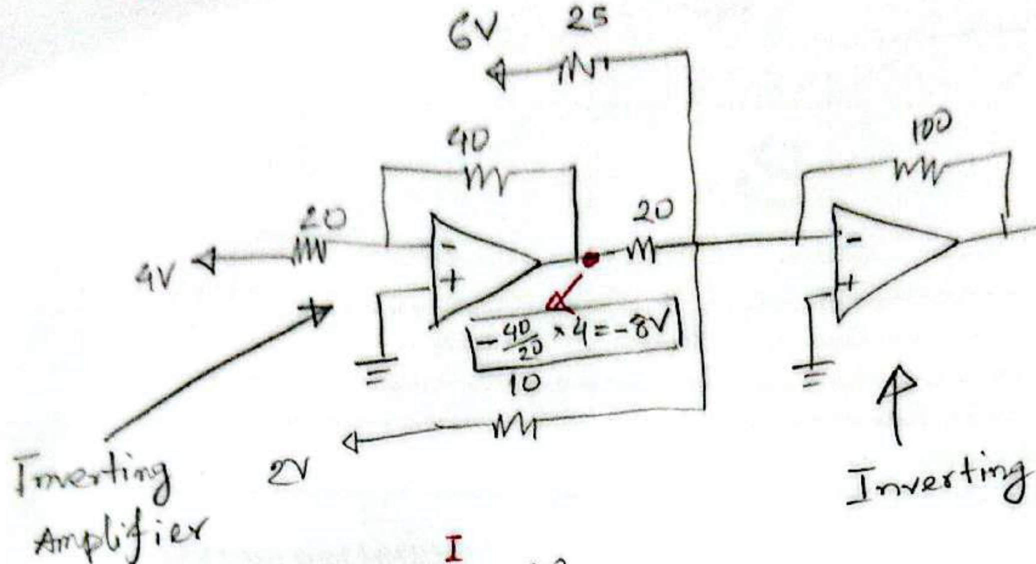
Inverting amplifier

Inverting Summer

$$I = \frac{V_x - 0}{50} = \frac{V_o - V_x}{100}$$

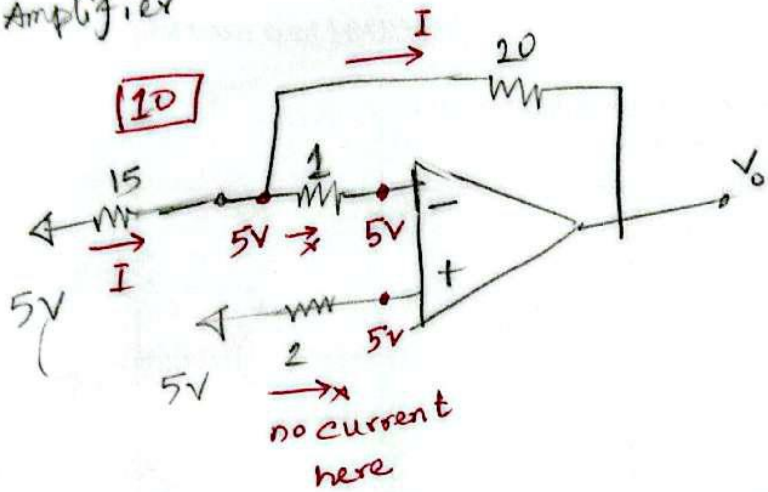
$$\Rightarrow \frac{-2}{50} = \frac{V_o-(-2)}{100} \Rightarrow V_o = -6$$

9



$$V_0 = -100\left(\frac{6}{25} + \frac{-8}{20} + \frac{2}{10}\right)$$
$$= -4V$$

10



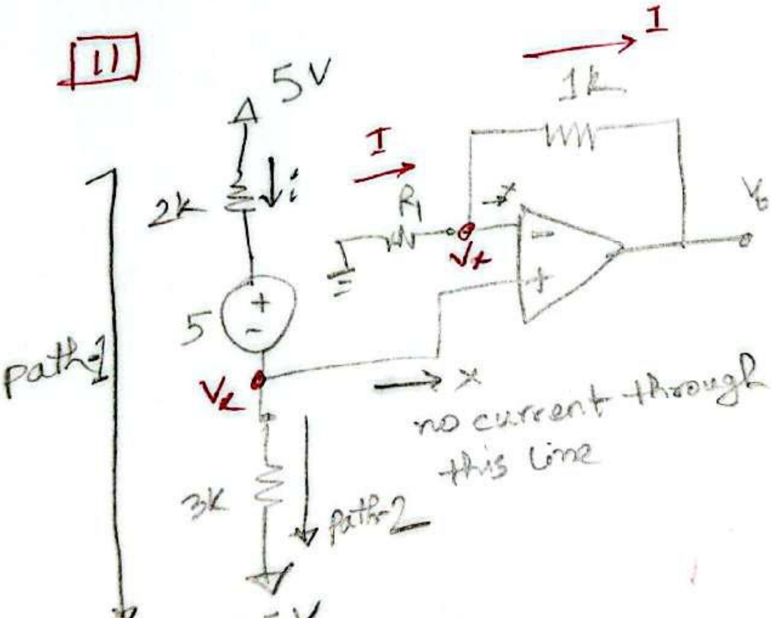
$$I = \frac{5-5}{15} = \frac{5-V_0}{20}$$

$$\Rightarrow \frac{0}{15} = \frac{5-V_0}{20}$$

$$\Rightarrow V_0 = 5V$$

[no current passes through 1kΩ & 2kΩ, so no voltage drop]

11



KVL through the path 1:

$$2i + 5 + 3i = 5 - (-5)$$
$$\Rightarrow i = 1\ mA$$

KVL through path-2:

$$3i = V_x - (-5)$$
$$\Rightarrow 3 \times 1 = V_x + 5$$
$$\Rightarrow V_x = -2V$$

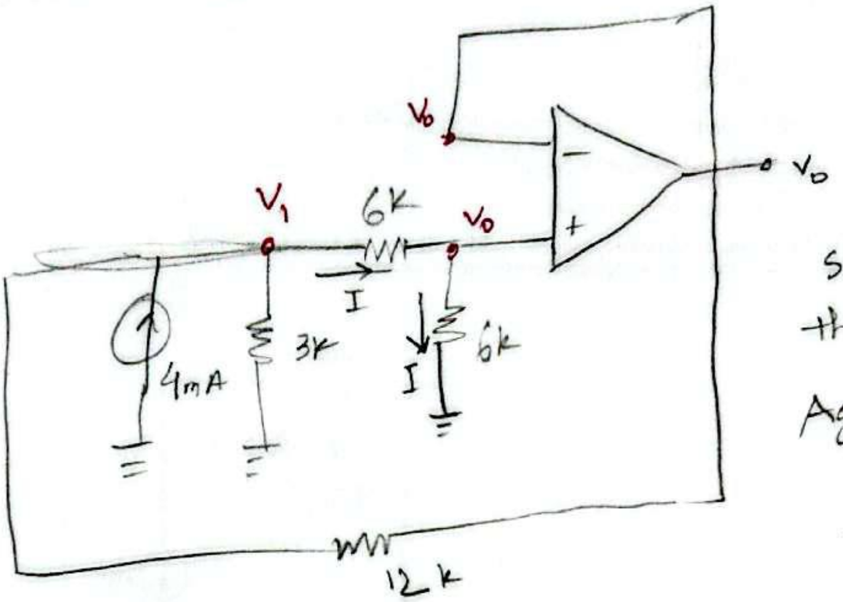
$$I = \frac{0 - V_x}{R_1} = \frac{V_x - V_0}{1}$$

$$\Rightarrow \frac{-(-2)}{R_1} = \frac{-2-(-4)}{1}$$

$$\Rightarrow R_1 = 1k\Omega$$

[N:B: $\int u\,dx = \psi + C$ → Integration constant

~~12~~ ~~12~~ $\boxed{13}$



$$I = \frac{V_0 - 0}{6} = \frac{V_0}{6}$$

Same, I will flow through the other 6K

$$\text{Again, } I = \frac{V_1 - V_0}{6}$$

$$\Rightarrow \frac{V_0}{6} = \frac{V_1 - V_0}{6}$$

$$\Rightarrow V_1 = 2V_0$$

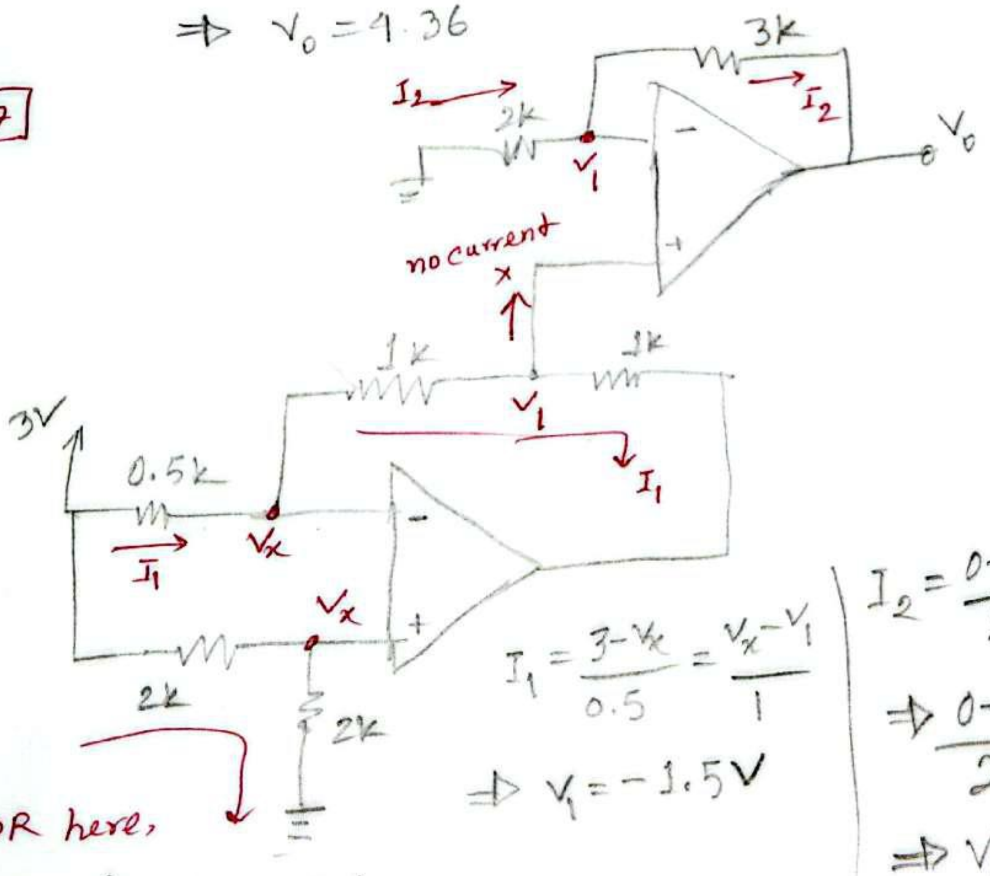
KCL @ node 1 (V_1):

$$4 = \frac{V_1 - 0}{3} + \frac{V_1 - V_0}{6} + \frac{V_1 - V_0}{12}$$

$$\Rightarrow 4 = \frac{2V_0}{3} + \frac{V_0}{6} + \frac{V_0}{12}$$

$$\Rightarrow V_0 = 4.36$$

$\boxed{17}$



$$I_1 = \frac{3 - V_x}{0.5} = \frac{V_x - V_1}{1}$$

$$\Rightarrow V_1 = -1.5V$$

$$I_2 = \frac{0 - V_1}{2} = \frac{V_1 - V_0}{3}$$

$$\Rightarrow \frac{0 - (-1.5)}{2} = \frac{-1.5 - V_0}{3}$$

$$\Rightarrow V_0 = -3.75$$

VDR here,

$$V_x = \frac{2}{2+2} \times 3 = 1.5V$$

[19] Integrator ckt:

N.B: $z = \int y\,dx = Y + C$ → Integration constant. C is the value of z at the start of the incident

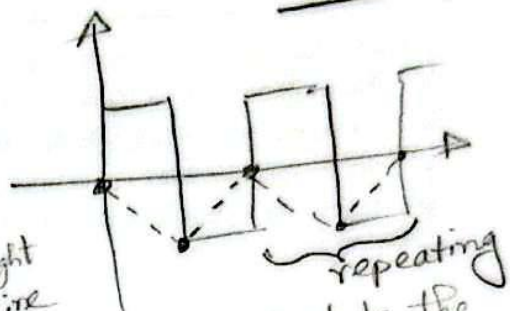
$$V_o = -\frac{1}{RC}\int V_i\,dt + V_{initial}$$

$$= -\frac{1}{5\times 0.1}\int V_i\,dt + V_{initial}$$

$$= -2\int V_i\,dt + V_{initial} \rightarrow y = mx$$

V_o - - -

V_i ——



from 0 to 0.5 ms, $V_i = 1$

for any time $0 \le t \le 0.5$: $V_o = -2\int_0^t 1\,dt + V_{initial}$ (we let $V_{initial} = 0$)

$$= -2[t]_0^t = -2(t-0) = -2t$$ eq of a straight line

At $t=0$, $V_o = 0$

At $t = 0.5\text{ms}$, $V_o = -1\text{V}$

[We calculate the corner values and join them through a straight line]

from 0.5 to 1 ms, $V_i = -1$

for any time $0.5 \le t \le 1$: $V_o = -2\int_{0.5}^t (-1)\,dt + V_{initial}$

for this time period $V_{initial}$ is -1 as V_o was -1 just at the start of this period → $y = mx + c$

$$= 2[t]_{0.5}^t - 1$$

$$= 2(t-0.5)$$ also eq of a straight line

At $t = 0.5\text{ms}$, $V_o = -1$

At $t = 1\text{ms}$, $V_o = 0$

join them through a straight line

** The pattern will repeat.

[20]

$$V_o = -\frac{1}{10\times 0.1}\int V_i\,dt + V_{initial} \Rightarrow V_o = -\int V_i\,dt + V_{initial}$$

from 0 to 0.05 ms, $V_i = -4$

for any time in $0 \le t \le 0.05$,

$$V_o = -\int_0^t (-4)\,dt + \overset{\nearrow 0}{V_{initial}}$$

$$= 4[t]_0^t = 4t$$ [$t=0$, $V_o = 0$; $t = 0.05$, $V_o = 0.2$]

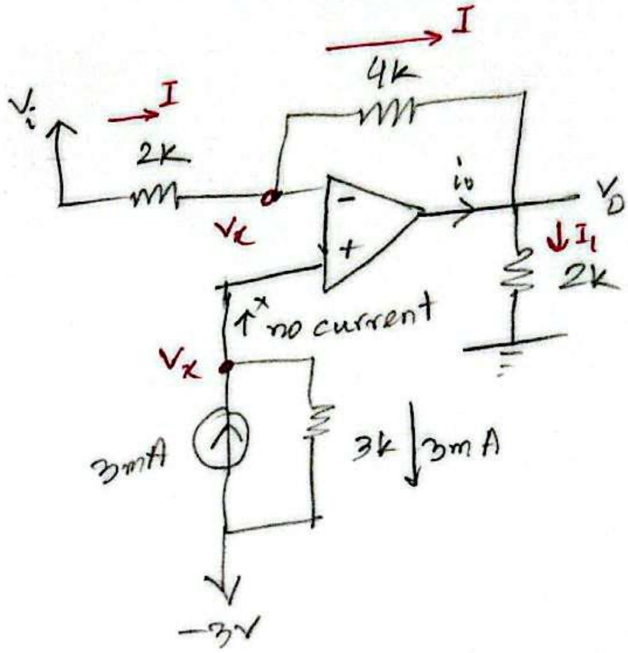
for any time in $0.05 \le t \le 0.1$ [$V_i = 4$]

$$V_o = -\int_{0.05}^t 4\,dt + V_{initial}$$

$$= -4(t-0.05) + 0.2$$

[~~at $t=0$, V_o=~~ $t = 0.05$, $V_o = 0.2$; $t = 0.1$, $V_o = 0$]

$\boxed{22}$



$$\frac{V_x-(-3)}{3} = 3$$

$$\Rightarrow V_x = 6$$

$$I = \frac{V_i - V_x}{2} = \frac{V_x - V_0}{4}$$

$$\Rightarrow \frac{V_i - 6}{2} = \frac{6 - V_0}{4}$$

$$\Rightarrow 2V_i - 12 = 6 - V_0$$

$$\Rightarrow V_0 = -2V_i + 18$$

KCL @ V_0, $I + i_0 = I_1$

$$i_0 = I_1 - I$$

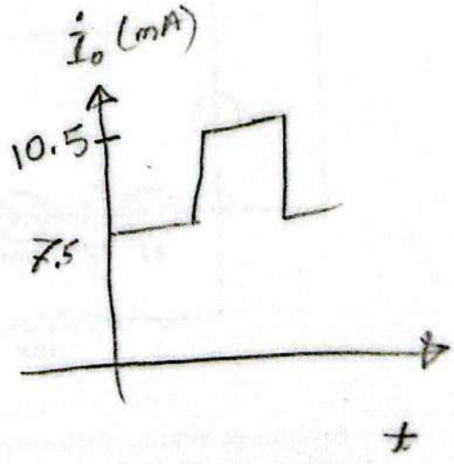
$$= \frac{V_0}{2} - \frac{V_i - 6}{2}$$

$$= \frac{-2V_i + 18}{2} - \frac{V_i - 6}{2}$$

$$= -V_i + 9 - \frac{V_i}{2} + 3$$

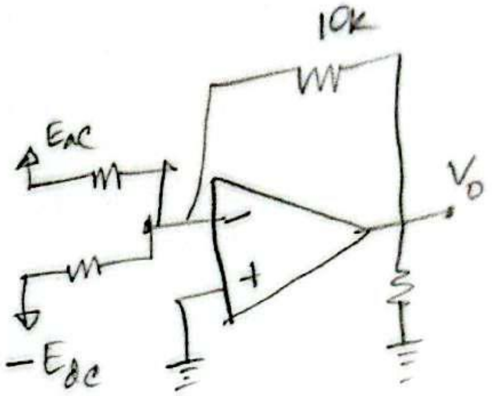
$$= -\frac{3V_i}{2} + 12$$

$V_i = 3$, $i_0 = 7.5$ | $V_i = 1$, $i_0 = 10.5$



23 The op amp is acting as an inverting summer

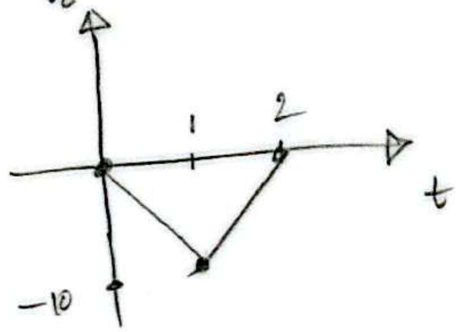
$$V_o = -10\left(\frac{E_{ac}}{10} + \frac{-E_{dc}}{10}\right)$$



$$= -E_{ac} + E_{dc}$$

$$= -E_{ac} - 5$$

** If you think, V_o is inverted E_{ac}, then add -5

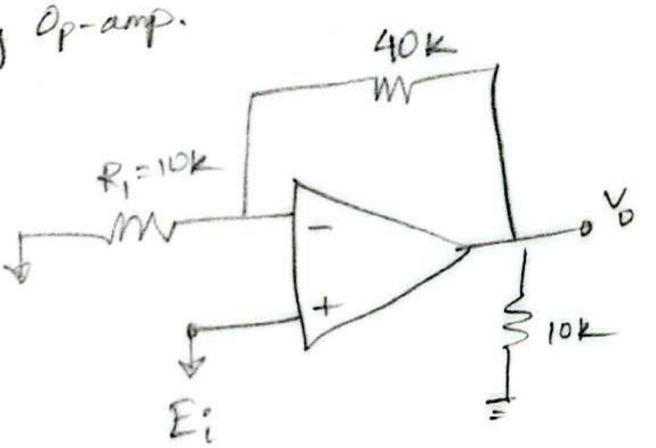


$t=0,\ E_{ac} = -5,\ V_o = 0$

$t=1,\ E_{ac} = 5,\ V_o = -10$

$t=2,\ E_{ac} = -5,\ V_o = 0$

24 This is non-inverting Op-amp.



$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_i$$

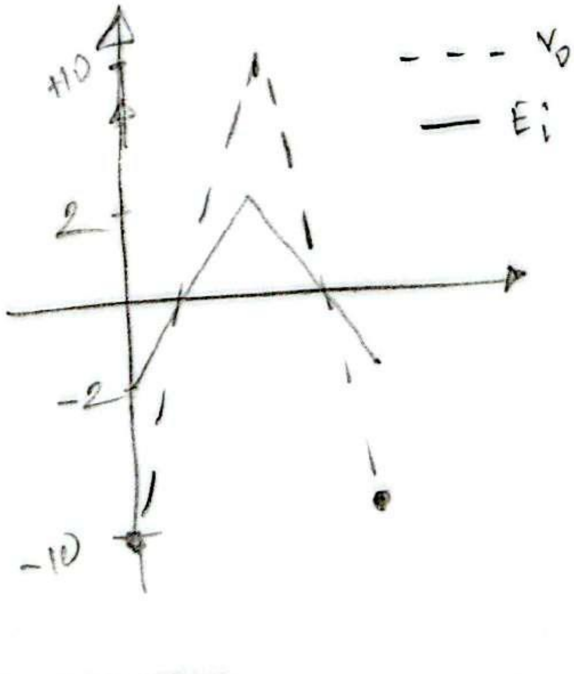
$$= \left(1 + \frac{40}{10}\right) E_i$$

$$= 5 E_i$$

$t=0 \rightarrow E_i = -2,\ V_o = -10$

$t=5 \rightarrow E_i = 2,\ V_o = +10$

$t=10 \rightarrow E_i = -2,\ V_o = -10$



25

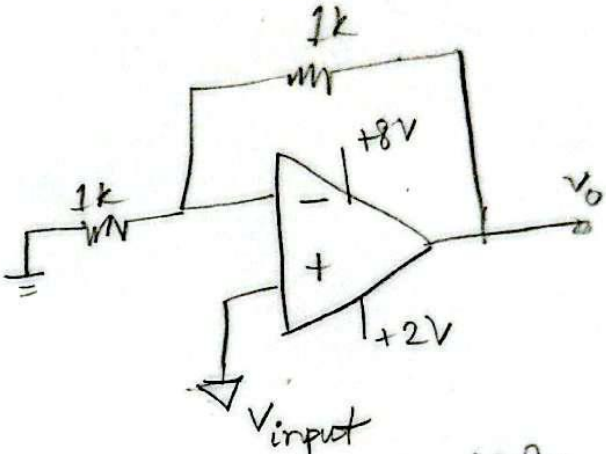
Gain = slope

(a) positive slope = positive gain

$\therefore$ non-inverting amplifier

take two points $\rightarrow$ (1,2), (4,8)

$$\text{slope} = \frac{8-2}{4-1} = 2$$



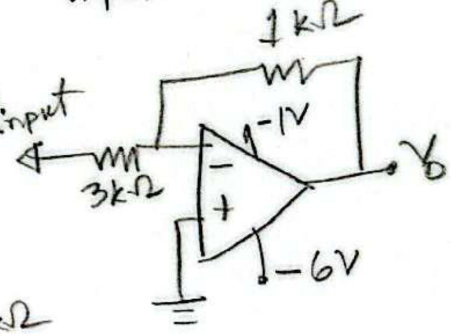
$$\text{Gain} = 1 + \frac{R_f}{R_1} = 2$$

$$\Rightarrow \frac{R_f}{R_1} = 1$$

$R_f = R_1 = 1k\Omega$

$V_{sat}^{+} = 8V$, $V_{sat}^{-} = 2V$

(b) $\text{slope} = \frac{-6-(-1)}{18-3} = \frac{-5}{15} = -\frac{1}{3}$



negative slope $\rightarrow$ inverting op-amp

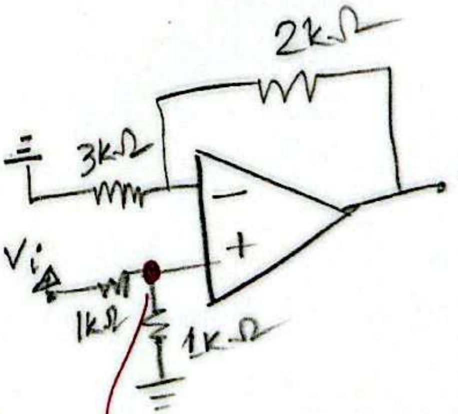
$-\frac{R_f}{R_1} = -\frac{1}{3} \Rightarrow R_f = 1k\Omega, R_1 = 3k\Omega$

26

$$\text{slope} = \frac{5-(-2)}{6-(-2.4)} = \frac{7}{8.4} = \frac{5}{6}$$

slope positive $\rightarrow$ non-inverting

but gain < 1. $\boxed{\text{formula: } \left(1+\frac{R_2}{R_1}\right)}$



So, we need voltage division as we have to use only one op-amp.

Let's say, we will halve the input then amplify $\left(2 \times \frac{5}{6}\right) = \frac{5}{3}$

$$V_+ = \frac{1}{1+1} \times V_i = V_i/2$$

$$\left(1+\frac{R_2}{R_1}\right) = \frac{5}{3} \Rightarrow \frac{R_2}{R_1} = \frac{2}{3}$$