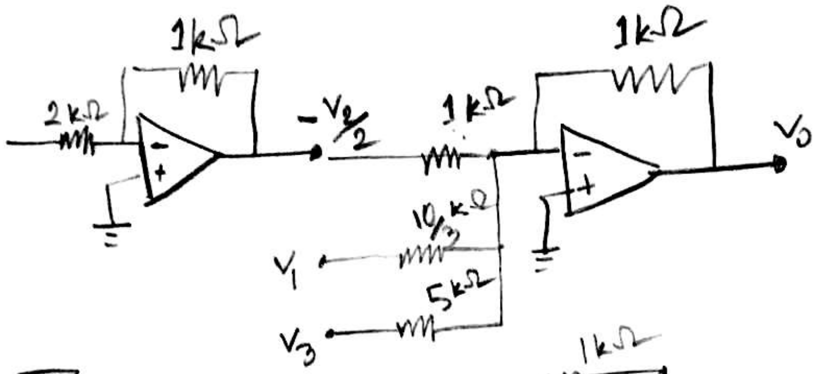
2

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

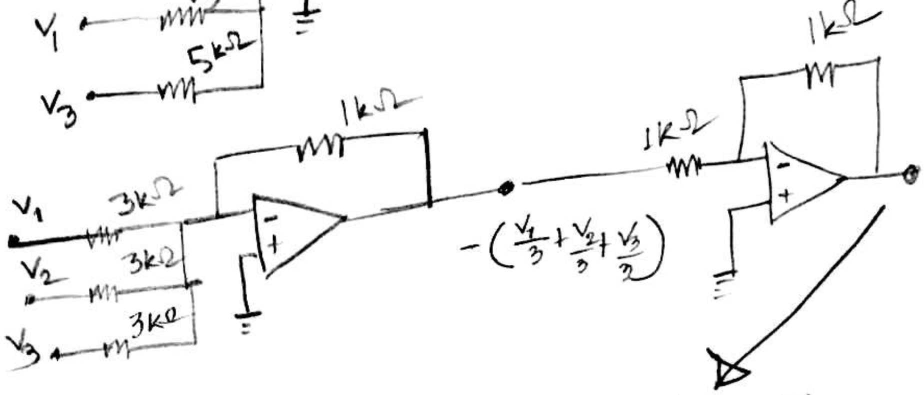
Inv. Adder Formula

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

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



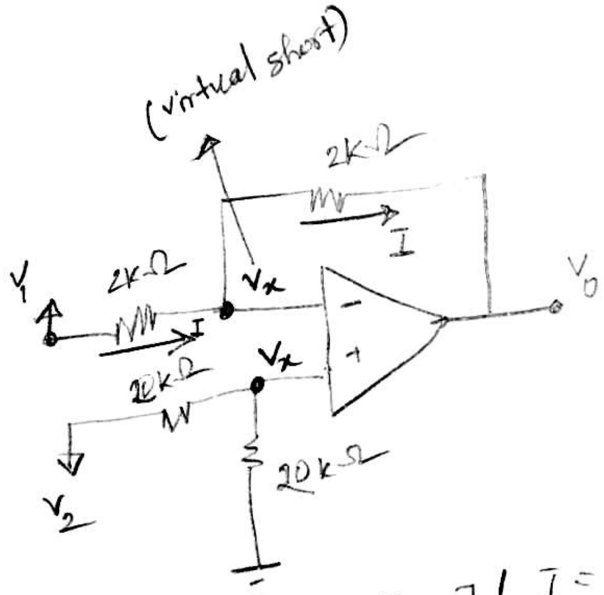
ii. average $= \frac{V_1+V_2+V_3}{2}$



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

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

3



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

$= \frac{V_2}{2}$

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

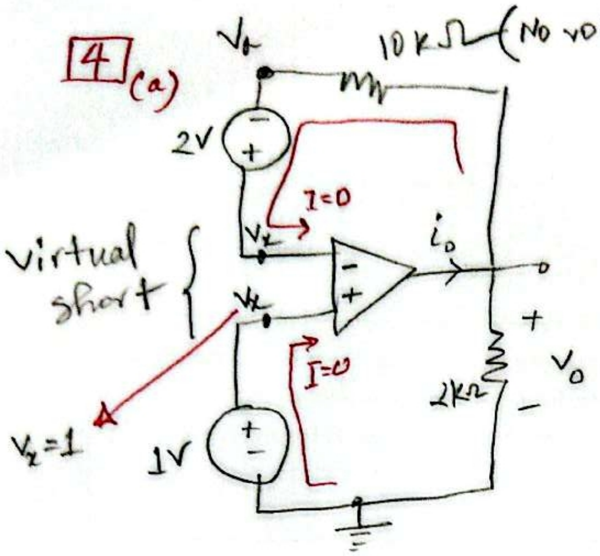
$\Rightarrow \frac{V_1 - \frac{V_2}{2}}{2} = \frac{\frac{V_2}{2} - V_0}{2}$

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

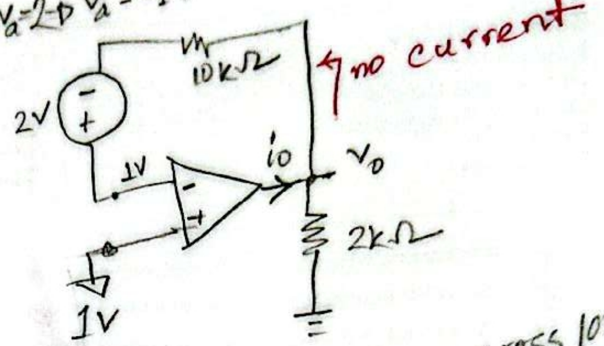
$\Rightarrow V_0 = \boxed{V_1 - V_2}$ difference

4 (a)

10 kΩ (No voltage drop here as I=0)



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



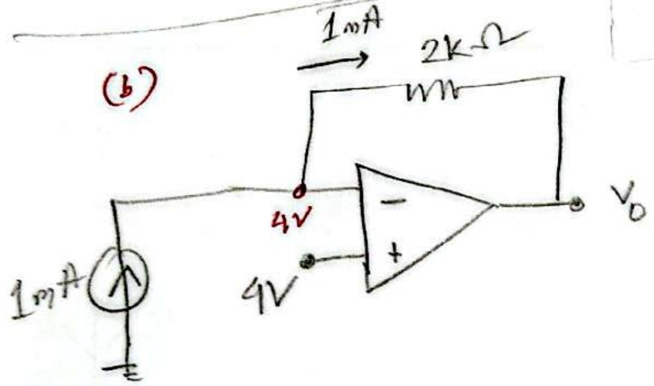
$V_o = V_a$ [as no V.drop across 10k]

$= -1\,V$

i_o will flow through 2kΩ

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

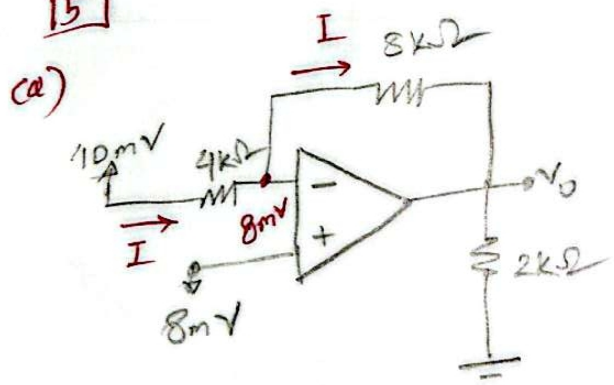
(b)



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

15

(a)



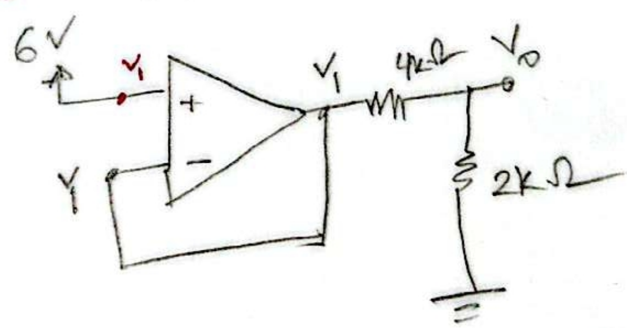
$$I = \frac{10-8}{4} = \frac{8-V_o}{8}$$

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

$$\Rightarrow V_o = 4mV$$

(b)

$V_1 = 6V$



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

$$= 2V$$

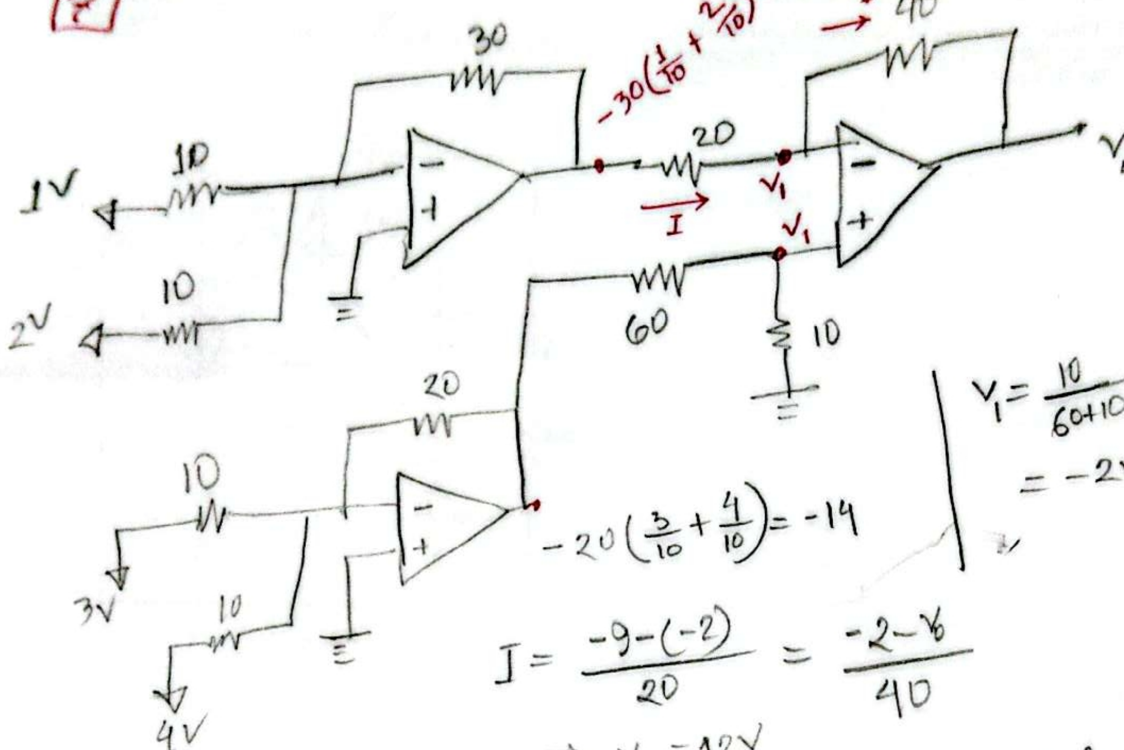
$\boxed{6}$

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

-16.5

$$V_2 = 10.6$$

$\boxed{7}$



$$-30\left(\frac{1}{10}+\frac{2}{10}\right) = -9$$

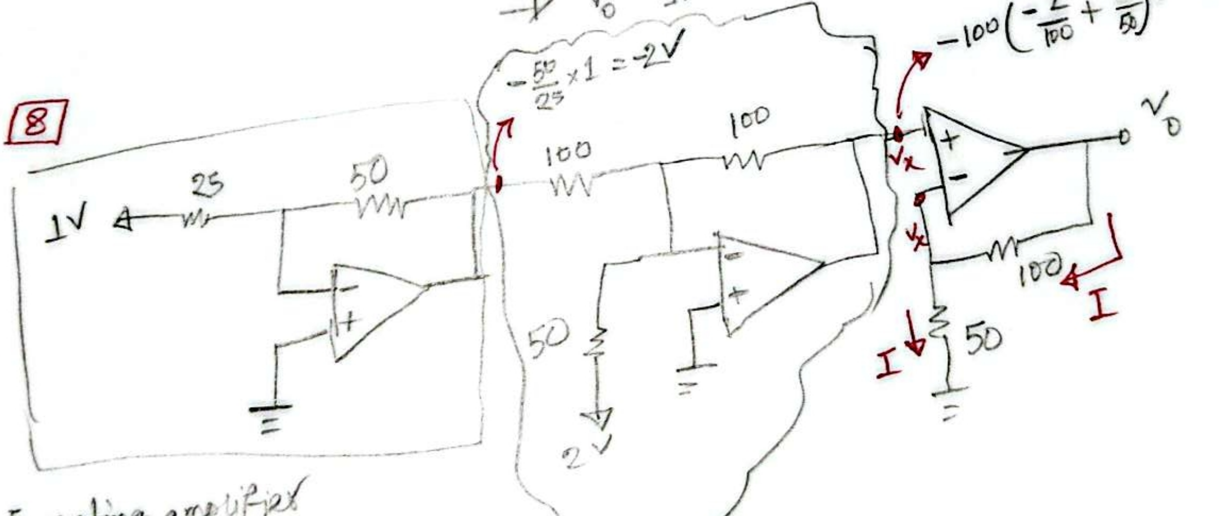
$$-20\left(\frac{3}{10}+\frac{4}{10}\right) = -14$$

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

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

$$\Rightarrow V_o = 12V$$

$\boxed{8}$



$$-\frac{50}{25} \times 1 = -2V$$

$$-100\left(-\frac{2}{100} + \frac{2}{50}\right) = -2$$

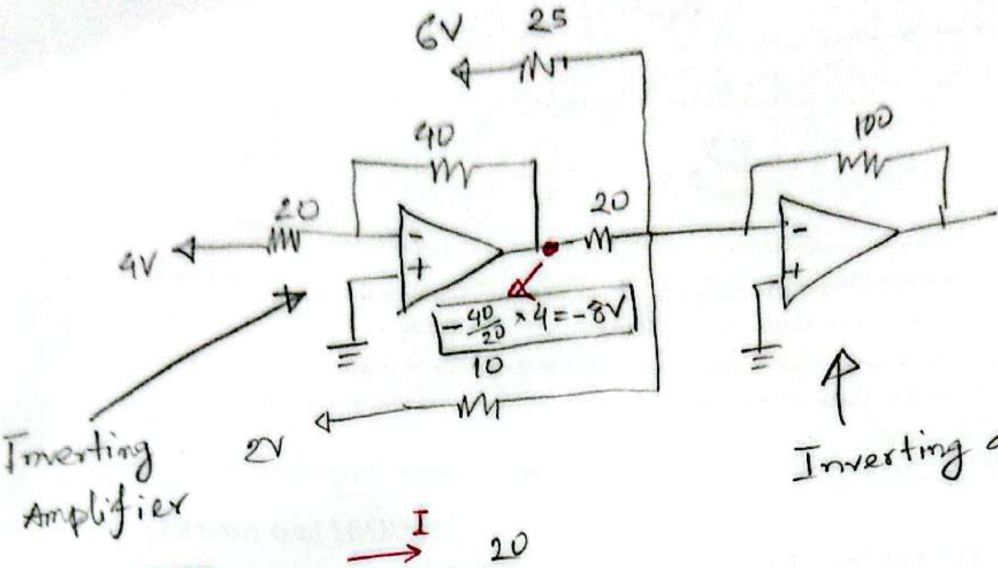
Inverting amplifier

Inverting Summer

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

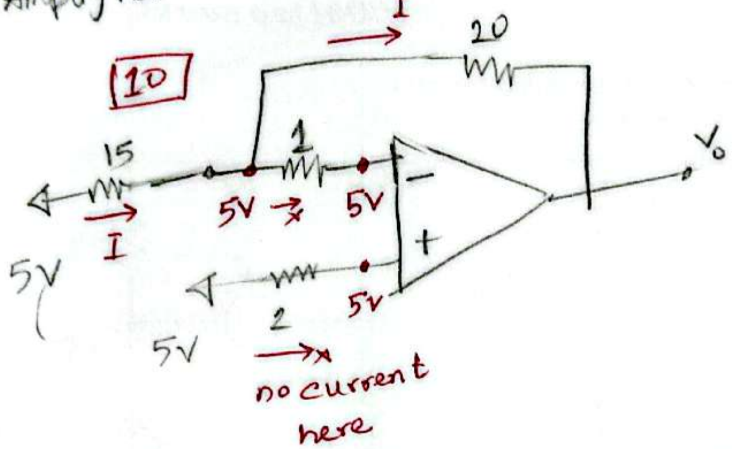
$$\Rightarrow \frac{-2}{50} = \frac{V_o - (-2)}{100} \Rightarrow V_o = -6$$

9



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

10



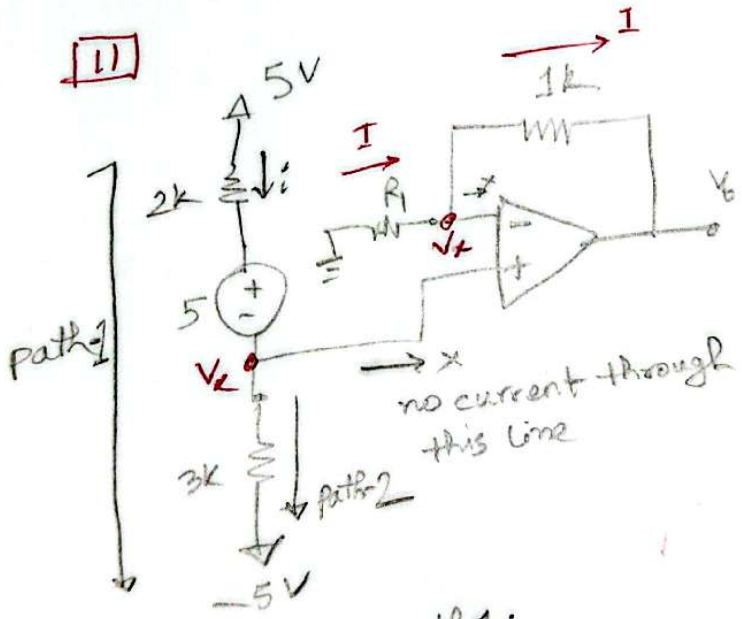
$$I = \frac{5-5}{15} = \frac{5-v_0}{20}$$

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

$$\Rightarrow v_0 = 5V$$

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

11



KVL through the path 1:

$$2i + 5 + 3i = 5 - (-5)$$

$$\Rightarrow i = 1 \text{ mA}$$

KVL through path-2:

$$3i = V_x - (-5)$$

$$\Rightarrow 3 \times 1 = V_x + 5$$

$$\Rightarrow V_x = -2V$$

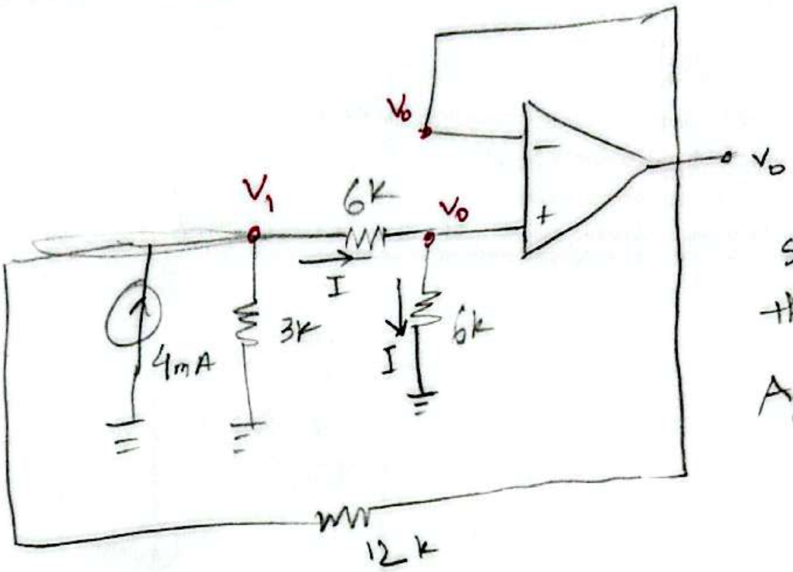
$$I = \frac{0 - V_x}{R_1} = \frac{V_x - V_0}{1}$$

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

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

[N.B: $\int f(x)\,dx = \psi + C$ → Integration constant

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



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

Same, I will flow through the other 6K

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

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

$$\Rightarrow V_1 = 2V_0$$

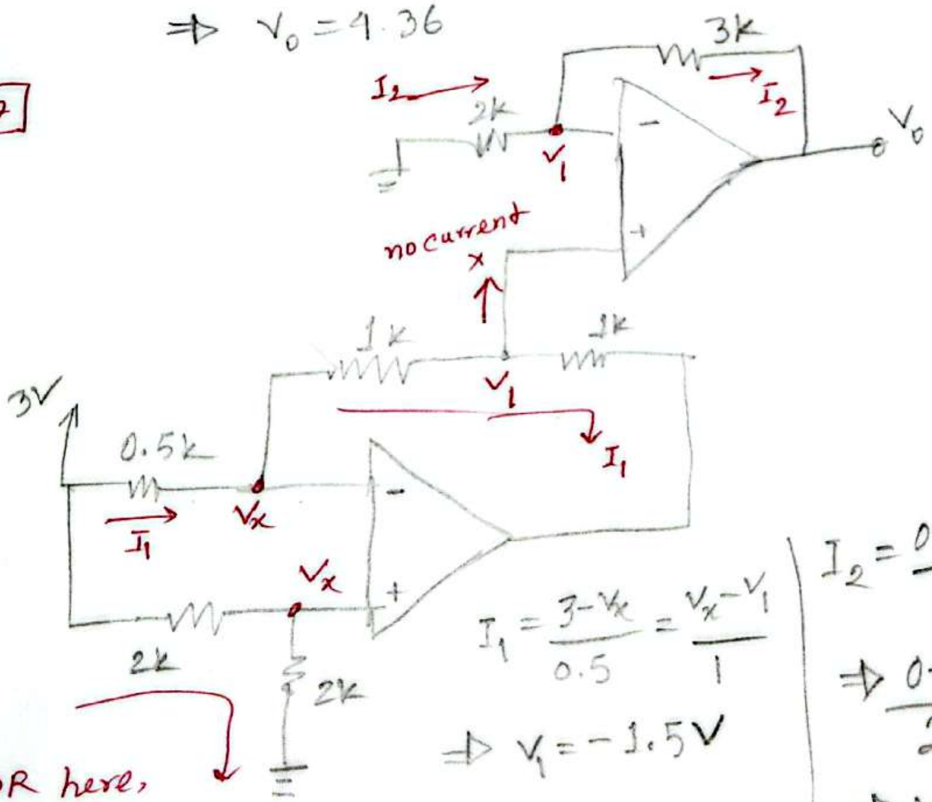
KCL @ node 1 (V_1):

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

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

$$\Rightarrow V_o = 4.36$$

$\boxed{17}$



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

$$\Rightarrow V_1 = -1.5V$$

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

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

$$\Rightarrow V_0 = -3.75$$

VDR here,

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

[19] Integrator Ckt:

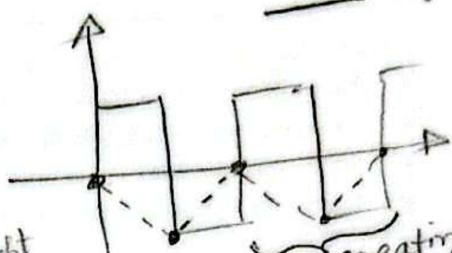
N.B: $z = \int y\,dx = Y + c$ → Integration constant
c is the value of z at the start of the incident

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

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

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

- - - V_o
—— V_i



repeating

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 → $y = mx$

At $t=0$, $V_o = 0$
At $t = 0.5ms$, $V_o = -1V$

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

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

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

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

$$= 2(t-0.5) - 1$$

also eq of a straight line → $y = mx + c$

At $t = 0.5ms$, $V_o = -1$
At $t = 1ms$, $V_o = 0$
} Join them through a straight line

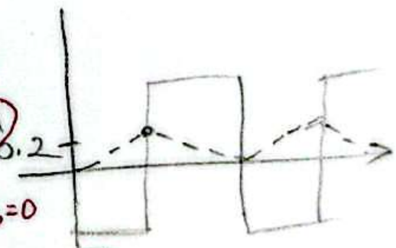
** The pattern will repeat.

[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 $0 \le t \le 0.05$



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

$V_{initial} \to 0$

$$= 4\,[t]_0^t = 4t$$

[$t=0$, $V_o=0$
$t=0.05$, $V_o=0.2$]

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

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

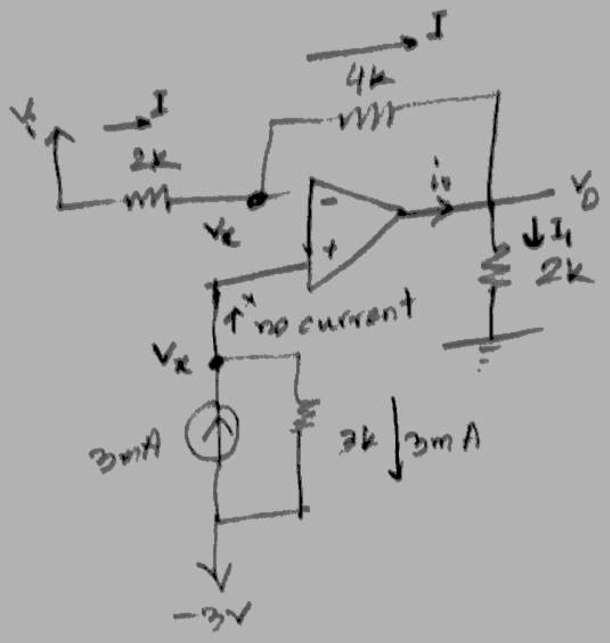
$$= -4(t-0.05) + 0.2$$

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

$\boxed{22}$

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

$$\Rightarrow V_x = 6$$



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

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

$$\Rightarrow$$

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

KCL @ V_o, $I + i_o = I_1$

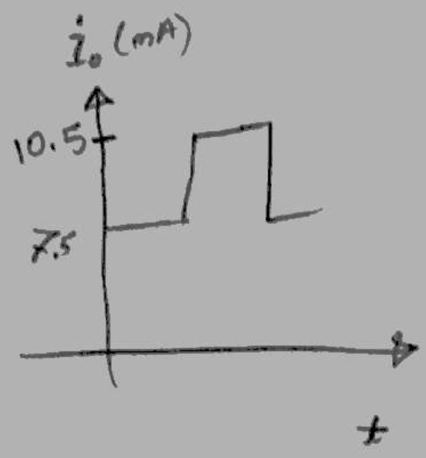
$$i_o = I_1 - I$$

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

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

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

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



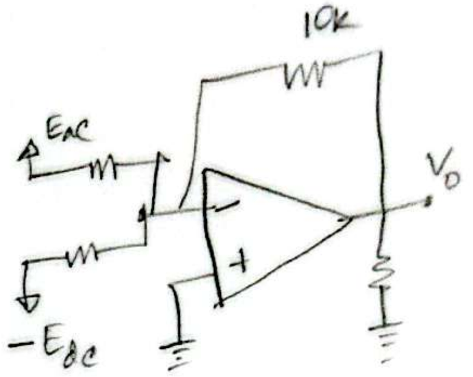
$V_i = 3$, $i_o = 7.5$ $\boxed{V_i = 1, i_o = 10}$

23 The op amp is acting as an inverting summer

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

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

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

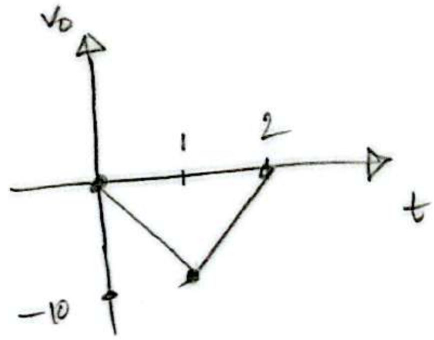


** If you think, V_o is inverted E_{ac}, then add -5

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

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

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

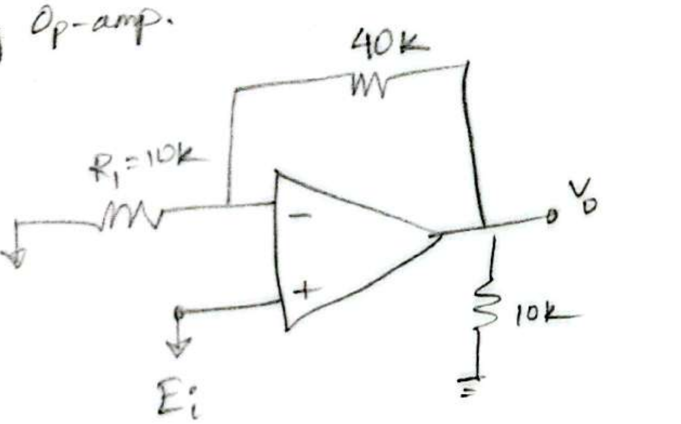


24 This is non-inverting Op-amp.

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

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

$$= 5 E_i$$



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

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

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