"Operational amp" :-

I $a = 10^3 \frac{V}{V}$

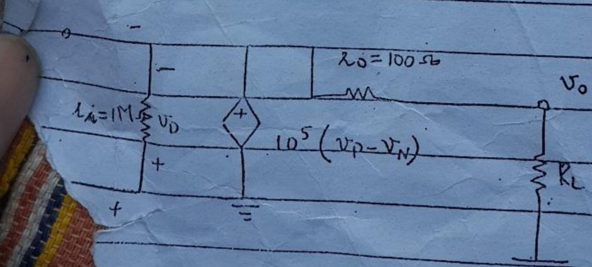
(a) $v_N = ?$ $v_P = 0$ $v_o = 3\,V$

$v_o = a(v_P - v_N)$ ——— (1)

$\frac{v_o}{a} = v_P - v_N \Rightarrow v_N = -\frac{v_o}{a}$

$\boxed{v_N = -3 \times 10^{-3}\,V}$

(b), (c) (d) do yourself.



$v_P - v_N$

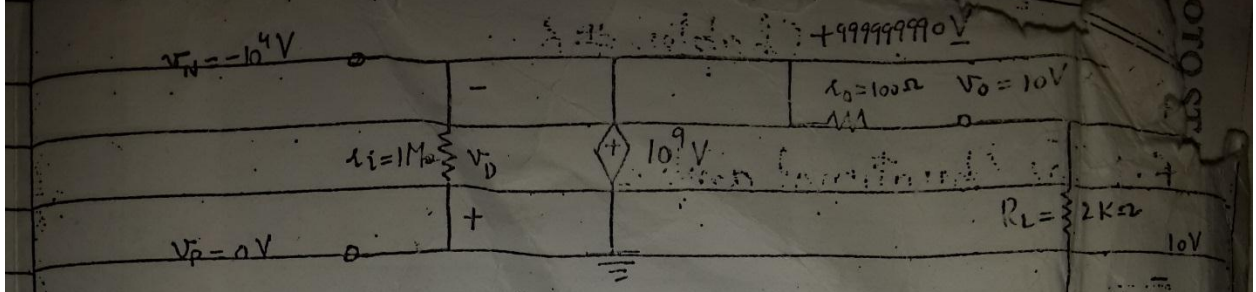
$v_P - v_N)$

$(0 - v_N)$

$- \frac{10}{10^5} = -10^{-4}$

$[...]\,V$

$A_v = -R_2$ ... -4 V



$v_D = v_{ri} = v_p - v_N = 0 - (-10^4) = 10^4$ V

	$v_{ri} = 10^4$V	$(\overset{-}{+})$
	$i_{ri} = 0.01$ A	$(\uparrow)$

$v_{ro} = 10^9 - v_o = 10^9 - 10 = 999,999,990$ V

$i_{ro} = \frac{999,999,990}{100} = 9,999,999.9$ A

$v_{ro} = 999,999,990$V	$(+ \quad -)$
$i_{ro} = 9,999,999.9$ A	$(\longrightarrow)$

3

6.2 Basic Op Amp Configuration :-

6.3 (a) $R_1 = 10K\ \Omega$

$R_2 = 20K\ \Omega$

For non-inverting amplifier :

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

$$= 1 + \frac{20K}{10K}$$

$$\boxed{A = 3\ \frac{V}{V}}$$

(b) $R_3 = 10K\ \Omega$

Case I: In series with R_1

$$R_1' = R_1 + R_3 = 10K + 10K = 20K$$

$$A = 1 + \frac{R_2}{R_1} = 1 + \frac{20K}{20K} = 1 + 1 = 2$$

$$\boxed{A = 2\ \frac{V}{V}}$$

Case II: In parallel with R_1

$$R_1' = \left(R_1^{-1} + R_3^{-1}\right)^{-1} = \left(10K^{-1} + 10K^{-1}\right)^{-1}$$

$$R_1' = 5K$$

$$A = 1 + \frac{R_2}{R_1'} = 1 + \frac{20K}{5K} = 1 + 4$$

$$\boxed{A = 5\ \frac{V}{V}}$$

6.4 do yourself:

By $A = -\frac{R_2}{R_1}$

$A_{sec} = -1V$

$A_{pri} = -4V$

6.5 (a) $A = 5\ \frac{V}{V}$ (for non-inverting)

$R_1 + R_2 = 100\ K\Omega$ ①

$A = 1 + \frac{R_2}{R_1}$; $5 = 1 + \frac{R_2}{R_1}$, $4 = \frac{R_2}{R_1}$

$R_2 = 4R_1$ ②

put in ①

$R_1 + 4R_1 = 100\ K\Omega$

$5R_1 = 100\ K\Omega$

$\boxed{R_1 = 20K\Omega}$

$\boxed{R_2 = 80K\Omega}$

(b) $A = -5\ \frac{V}{V}$ (for inverting)

$R_1 + R_2 = 100\ K\Omega$ ①

$A = -\frac{R_2}{R_1}$

$+5 = +\frac{R_2}{R_1}$

$R_2 = 5R_1$ ② put in ①

$6R_1 = 100\ K\Omega$

$\boxed{R_1 = \frac{50}{3}\ K\Omega}$ $\boxed{R_2 = \frac{250}{3}\ K\Omega}$

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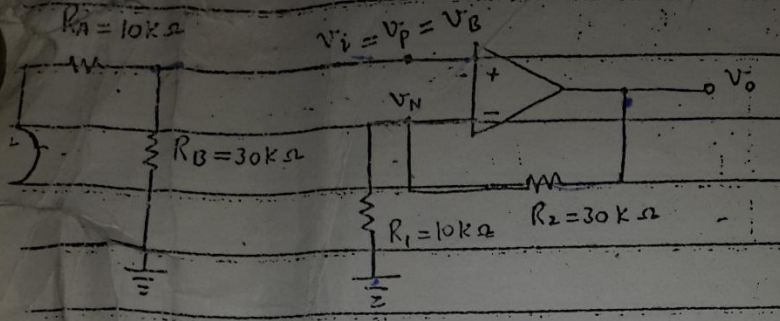


$$\boxed{A = 4\ \frac{V}{V}}$$

$$V_B = \frac{R_B}{R_A + R_B} \times 1 = \frac{30k}{10k + 30k} = \frac{3}{4}\ V$$

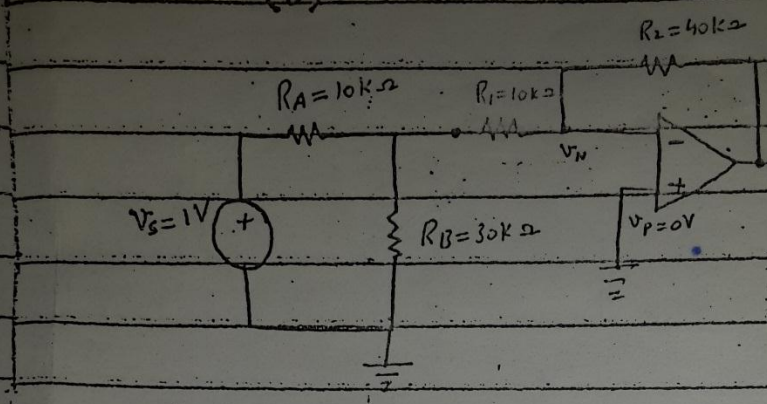
$$V_i = V_p = V_B = \frac{3}{4}\ V \quad , \quad \boxed{V_p = \frac{3}{4}\ V}$$

$$A = \frac{V_o}{V_i} = 1 + \frac{R_2}{R_1}$$

$$4 = \frac{V_o}{3/4} \Rightarrow V_o = 4 \times \frac{3}{4} = 3$$

$$\boxed{V_o = 3\ V}$$

(b)



$$A = -4 \frac{V}{V}$$

$$v_B = \frac{R_B}{R_A + R_B} \times v_s = \frac{30K}{10K + 30K} \times 1 = \frac{3}{4} V$$

$$v_B = \frac{3}{4} V$$

$$v_B = v_i \qquad v_i = \frac{3}{4} V$$

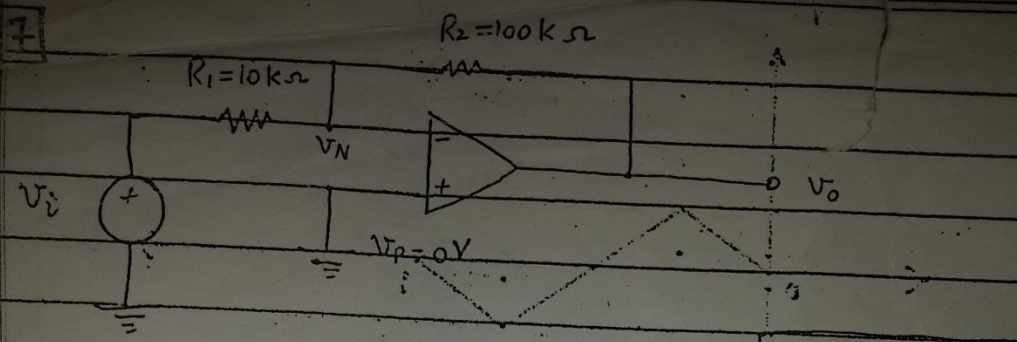
$$A = \frac{v_o}{v_i} = -\frac{R_2}{R_1}$$

$$-4 = \frac{v_o}{v_i} \quad , \quad -4 = \frac{v_o}{3/4} \Rightarrow v_o = -4 \times \frac{3}{4}$$

$$v_o = -3V$$

⇒ In case (b) the output is inverted.

7



$f = 1$ kHz
$T = 1$ msec

$V_o = a(V_p - V_N)$

$V_o = 10^3 (0 - V_N)$

$\boxed{V_o = -10^3 V_N}$ ①

at V_N:

$$\frac{V_N - V_i}{10k\Omega} + \frac{V_N - V_o}{100k\Omega} + 0 = 0$$

$$10V_N - 10V_i + V_N - V_o = 0$$

$$10V_N - 10V_i + V_N - (-10^3 V_N) = 0$$

$$11V_N - 10V_i + 10^3 V_N$$

$$1011 V_N = 10 V_i$$

$$\boxed{V_N = 9.891\,m\, V_i}$$ ②

put in ①

$$\boxed{V_o = -9.891\, V_i}$$ ③

Extreme values of	V_i	1 V	−1 V
	V_o	−9.891 V	9.891 V
	V_N	9.891 mV	−9.891 mV

$V_o = a(V_p - V_N)$ ... (i)

$V_p = 0$ ... (ii)

$V_N = \left(\frac{V_o + 100}{101}\right)$ ... (iii)

$V_o = 10^3 \left(0 - \left(\frac{V_o + 100}{101}\right)\right)$

$V_o = \frac{-1000}{101}(V_o + 100)$

$V_o = \frac{-1000}{101} V_o - \frac{10,0,000}{101} V_i$

$V_o \left(1 + \frac{1000}{101}\right) = \frac{-100,000}{101} V_i$

6.8

$V_o \left(\frac{101 + 1000}{101}\right) = \frac{-100,000}{101} V_i$

$V_I = 0.1V$

$V_o \frac{1101}{101} = \frac{-100,000}{101} V_i$

$\frac{V_o}{V_i} = \frac{-100,000}{1101}$

$\frac{V_o}{V_i} = -90.83$

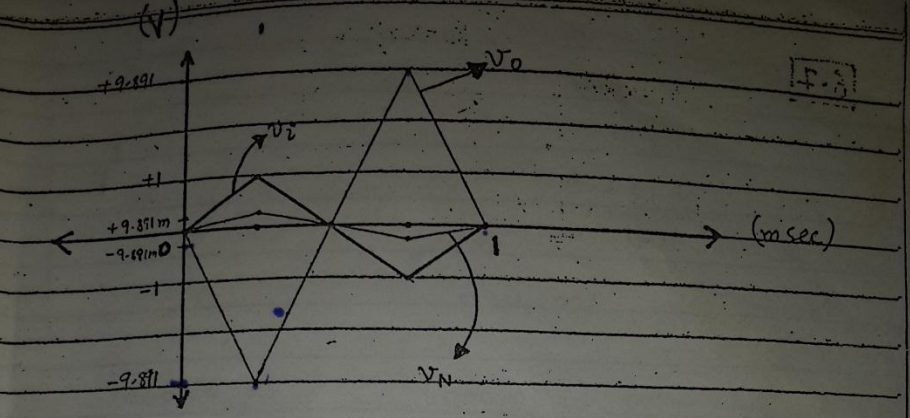
$$\boxed{A = \frac{V_o}{V_i} = -90.83}$$

$A_{ideal} = \frac{-R_2}{R_1} = \frac{-|1|}{10K} = \frac{-1000K\Omega}{10K\Omega}$

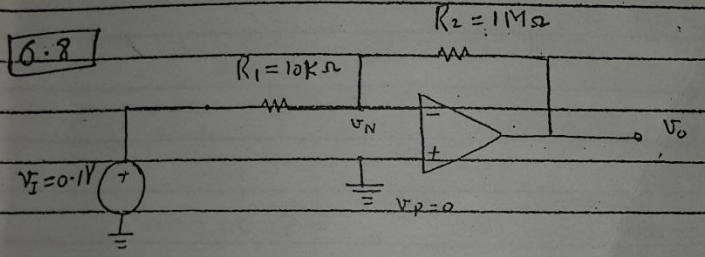
$$\boxed{A_{ideal} = -100}$$

$\%$ deviation $= \frac{A_{ideal} - A}{A_{ideal}} \times 100 = 9.17\%$

$$\boxed{\% \text{ deviation} = 9.17\ \%}$$



Q.7



Q.8

$A = ?$ (i) $a = 10^3 \frac{V}{V}$

$V_p = 0\ V$

$V_N =$

$$\frac{V_N - V_i}{10K} + \frac{V_N - V_o}{1M} = 0$$

$$100\left(V_N - \overbrace{(0.1)}^{V_i}\right) + (V_N - V_o) = 0$$

$$101\ V_N = V_o + 10V_i$$

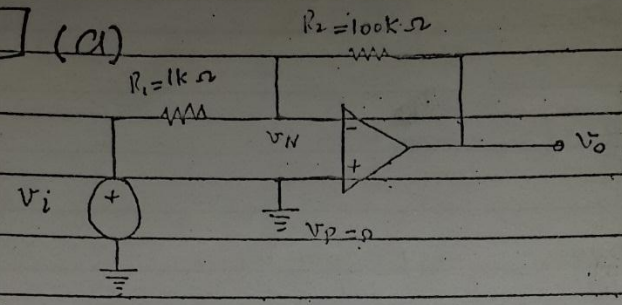
$$V_N = \frac{V_o + 10V_i}{101}$$

$V_p = 0\ V$

(ii) $a = 10^9$

(iii) $a = 10^5$ do yourself

6.9 (a)



at v_N:

$$\frac{v_N - v_i}{1k} + \frac{v_N - v_o}{100k} = 0$$

$$100 v_N - 100 v_i + v_N - v_o = 0$$

$$101 v_N = v_o + 100 v_i$$

$$v_N = \frac{v_o + 100 v_i}{101}$$

$$v_p = 0$$

$$v_o = a(v_p - v_N)$$

$$\because v_p = 0 \quad v_N = \frac{v_o + 100 v_i}{101}$$

$$v_o = \frac{-a}{101}(v_o + 100 v_i)$$

$$v_o = -\frac{a}{101} v_o - \frac{a 100}{101} v_i$$

$$v_o\left(\frac{101 + a}{101}\right) = -\frac{100}{101} a v_i$$

$$\frac{V_o}{V_i} = \frac{-100\,a}{(101+a)}$$

$$A = \frac{-100\,a}{101+a}$$

Now $a_1 = 200,000$

$$A_1 = \frac{-100\,(200,000)}{101 + 200,000} = \frac{-20,000,000}{200,101}$$

$$\boxed{A_1 = -99.95}$$

$a_2 = 50,000$

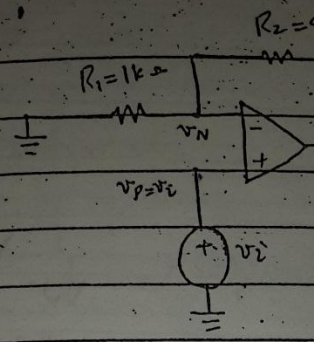
$$A_2 = \frac{-100\,(50,000)}{101 + 50,000} = \frac{-5,000,000}{50,101}$$

$$\boxed{A_2 = -99.80}$$

$$\Rightarrow \%\ \text{change} = \frac{A_2 - A_1}{A_1} \times 100 = -0.15\ \%$$

* -ve means decrease

(b)



at v_N:

$$\frac{v_N - 0}{1K} + \frac{v_N - v_o}{99K} = 0$$

$$99 v_N + v_N - v_o = 0$$

$$100 v_N = v_o$$

$$\boxed{v_N = \frac{v_o}{100}}$$

$$\boxed{v_p = v_i}$$

$$v_o = a(v_p - v_N)$$

$$v_o = a\left(v_i - \frac{v_o}{100}\right)$$

$$v_o + \frac{a v_o}{100} = a v_i$$

$$v_o\left(\frac{100 + a}{100}\right) = a v_i$$

$$\frac{v_o}{v_i} = \frac{a100}{a+100}$$

$$\boxed{A = \frac{a100}{a+100}}$$

13.

$a_1 = 200,000$

$$A_1 = \frac{200,000 \times 100}{200,000 + 100} = 99.95$$

$$\boxed{A_1 = 99.95}$$

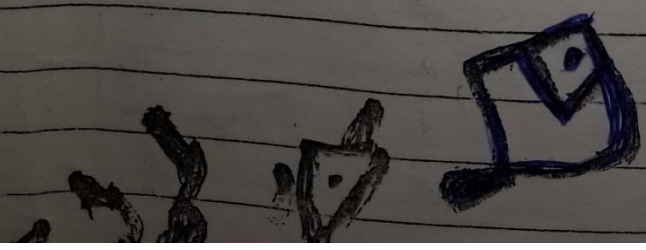
$a_2 = 50,000$

$$A_2 = \frac{50,000 \times 100}{50,000 + 100} = 99.80$$

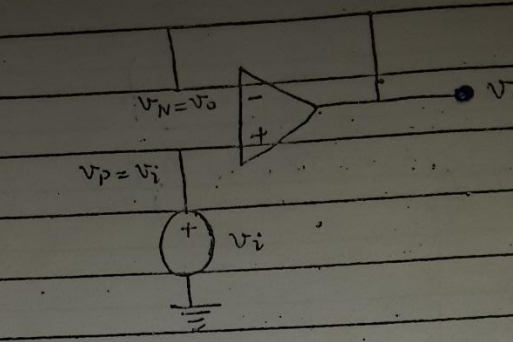
$$\boxed{A_2 = 99.80}$$

$$\% \text{ change} = \frac{A_2 - A_1}{A_1} \times 100 = -0.15\ \%$$

* -ve means decrease.



(c)



$$v_o = a(v_p - v_N)$$

$$v_o = a(v_i - v_o)$$

$$v_o = av_i - av_o$$

$$v_o(1+a) = av_i$$

$$\frac{v_o}{v_i} = \frac{a}{1+a}$$

$$\boxed{A = \frac{a}{1+a}}$$

when $a_1 = 200,000$

$$A_1 = \frac{200,000}{200,001} = 0.999995$$

$$\boxed{A_1 = 0.999995}$$

when $a_2 = 50,000$

$$A_2 = \frac{50,000}{50,001} = 0.99998$$

$$\boxed{A_2 = 0.99998}$$

$\Rightarrow$ % change $= \frac{A_2 - A_1}{A_1} \times 100 = -0.0015$ %

-ve means decrease

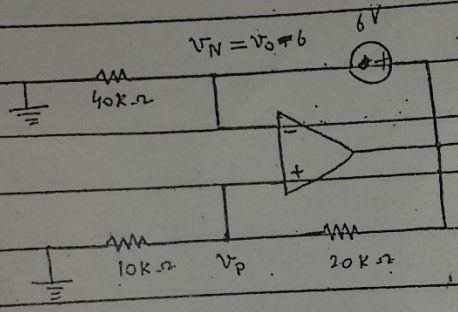
6.3 Ideal Op-Amp Circuit Analysis:-

$V_N = V_0 - 6$

$V_0 - V_N = +6$

$V_0 - 6$

6.10



$$V_p = \frac{10K}{10K + 20K} \times V_0 = \frac{1}{3} V_0 \quad \text{---(1)}$$

$$V_N = V_0 - 6 \quad \text{---(2)}$$

$V_p = V_N$

$\frac{1}{3} V_0 = V_0 - 6$

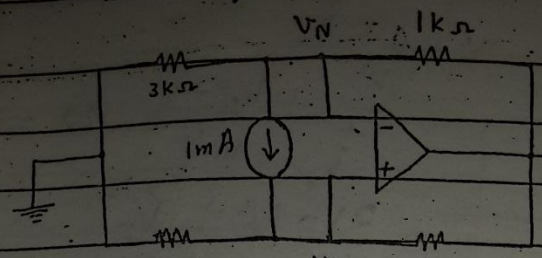
$V_0 = 3V_0 - 18$

$2V_0 = 18$

$V_0 = 9\ V$	$V_p = V_N = 3\ V$

16 V.I

6.11



at V_N:

$$\frac{V_N - 0}{3k} + 1m + \frac{V_N - V_o}{1k} = 0$$

$$V_N + 3 + 3V_N - 3V_o = 0$$

$$4V_N + 3 - 3V_o = 0$$

$$4V_N - 3V_o - 3$$

$$V_N = \frac{3}{4}(V_o - 1) \quad \text{---------- (1)}$$

at V_p:

$$\frac{V_p - 0}{2K} + \frac{V_p - V_o}{4K} = 1m$$

$$2V_p + V_p - V_o = 4$$

$$3V_p - V_o = 4$$

$$V_p = \frac{V_o + 4}{3} \quad \text{---------- (2)}$$

$$V_N = V_p \quad \text{---------- (3)}$$

$$\frac{3}{4}(V_o - 1) = \frac{1}{3}(V_o + 4)$$

$$9(V_o - 1) = 4(V_o + 4)$$

$$9V_o - 9 = 4V_o + 16$$

$$5V_o = 25$$

$$V_o = 5\ V$$

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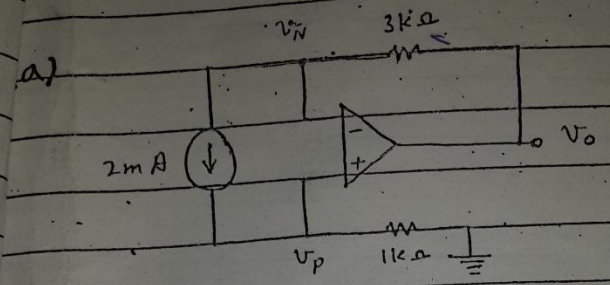
V_o

$V_N = V_p = 3\,V$

a)



I_N :

$$0 = 2m + \frac{V_N - V_o}{3K}$$

$$0 = 6 + V_N - V_o$$

$$V_N = V_o - 6 \quad \text{---------- (1)}$$

At V_p :

$$2m = \frac{V_p - 0}{1K}$$

$$V_p = 2\,V \quad \text{---------- (2)}$$

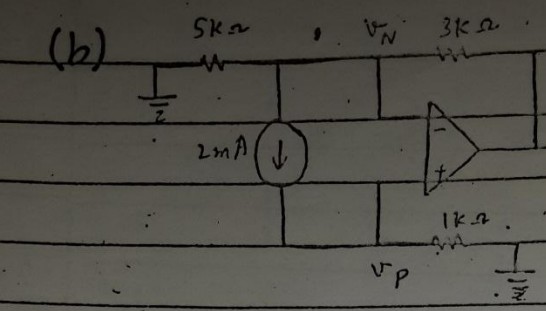
As :-

$V_p = V_N = 2\,V$ put in (1)

$$2 = V_o - 6$$

$$V_o = 8\,V$$

(b)



at V_N:

$$0 = 2m + \frac{V_N - 0}{5K} + \frac{V_N - V_o}{3K}$$

$$0 = 30 + 3V_N + 5V_N - 5V_o$$

$$0 = 30 + 8V_N - 5V_o$$

$$\boxed{V_N = \frac{5V_o - 30}{8}} \quad \text{---------- (1)}$$

at V_p:

$$2m = \frac{V_p - 0}{1k}$$

$$2 = V_p$$

$$\boxed{V_p = 2V} \quad \text{---------- (2)}$$

as $\boxed{V_p = V_N = 2V}$ ---------- (3) put in (1)

$$16 = 5V_o - 30$$

$$16 + 30 = 5V_o$$

$$46 = 5V_o$$

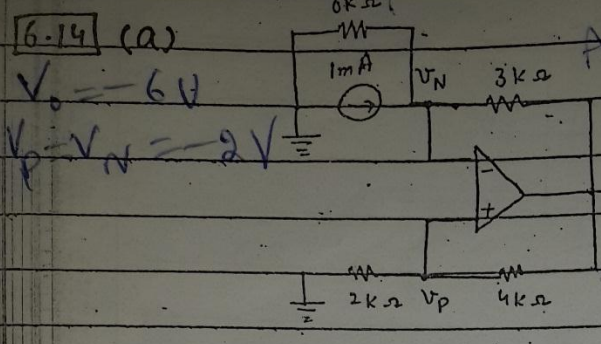
$$\boxed{V_o = \frac{46}{5} V}$$

6.13

6.14 (a)

$V_o = -6\ V$

$V_p = V_N = -2\ V$



At V_N: $\frac{V_N - 1}{6} + \frac{V_N - V_o}{3} = 0$

$V_N = \frac{2V_o + 6}{3}$

At V_p: $\frac{V_p}{2} + \frac{V_p - V_o}{4} = 0$

$V_p = \frac{V_o}{3}$

$\frac{2V_o + 6}{3} = \frac{V_o}{3}$

$-1 + \frac{V_N - V_o}{3} = 0$

$V_N = V_o + 3$ — ①

$\frac{1}{2} + \frac{V_p}{2} + \frac{V_p - V_o}{4} = 0$

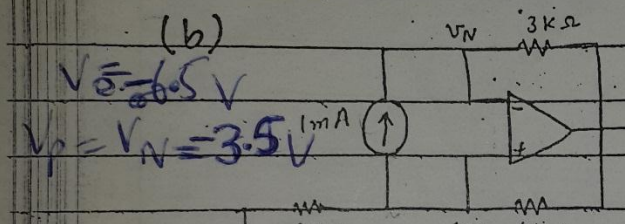
$V_p = V_o - 4$

$V_o - 6 = V_o - 4$

(b)

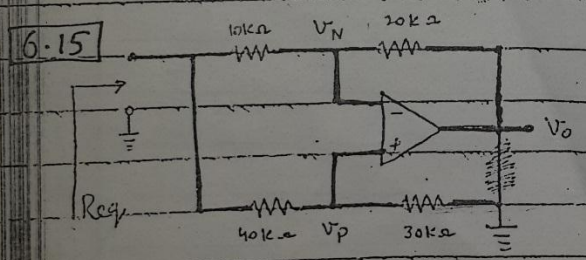
$V_o = -6.5\ V$

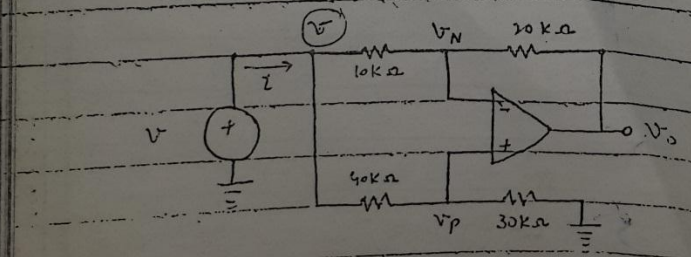
$V_p = V_N = -3.5\ V$



do yourself.

6.15





at v_N:

$$\frac{v_N - v_o}{20k} + \frac{v_N - v}{10k} = 0$$

$$v_N - v_o + 2v_N - 2v = 0$$

$$3v_N - 2v - v_o = 0$$

$$v_N = \frac{2v + v_o}{3} \quad \text{——} \ (1)$$

at v_p:

$$\frac{v_p - 0}{30k} + \frac{v_p - v}{40k} = 0$$

$$4v_p + 3v_p - 3v = 0$$

$$7v_p = 3v$$

$$v_p = \frac{3}{7}v \quad \text{——} \ (2)$$

at v:

$$i = \frac{v - v_N}{10k} + \frac{v - v_p}{40k}$$

$$40k\,i = 4v - 4v_N + v - v_p$$

$$40k\,i = 5v - 4v_N - v_p \quad \text{——} \ (3)$$

as $v_N = v_p$

$$v_o = -\left(\frac{[illegible]}{7}\right)v \quad \text{——} \ (4)$$

as $v_N = v_p = \frac{3}{7}v$ put in (3)

$40k\,i = 5V - \frac{3}{7}(4V) = \frac{3}{7}V$

$40k\,i = 5V - \frac{15}{7}V$

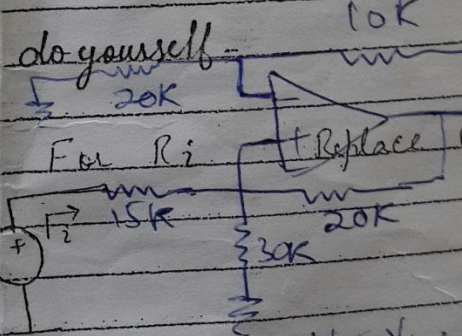
$= \frac{35V - 15V}{7}$

$40k\,i = \frac{20}{7}V$

$\frac{V}{i} = \frac{40k \times 7}{20}$

$R_{eq} = 14k\,\Omega$

[b] do yourself



$V_o = 4$

$V_p = V - \frac{4}{3}$

at V_N:

at V_p:

at V:

$40k\,i$

$40k\,i$

$\frac{V_N}{20} + \frac{V_N - V_o}{10} = 0$

$V_N = \frac{2V_o}{3}$ ①

$\frac{V_p - V}{15} + \frac{V_p}{30} + \frac{V_p - V_o}{20} = 0$

$V_p = \frac{4V + 3V_o}{9}$ ②

$V_N = V_p$

$\frac{2V_o}{3} = \frac{4V + 3V_o}{9}$

$\frac{3}{9}V_o = \frac{4}{3}V$

At V: $\frac{V - V_p}{15} = I$

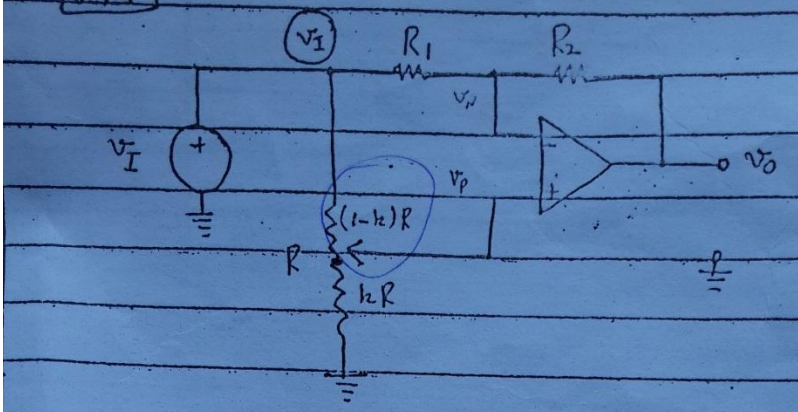
② $\Rightarrow V_p = \frac{4V + 3(\frac{4}{3}V)}{9}$

$V_p = \frac{8}{9}V$

$\Rightarrow \frac{V - \frac{8}{9}V}{9} = 15\,I$

$\rightarrow \frac{V}{I} = 1.5k\,\Omega$

6.17



$R_1 = R_2 = 10k\Omega$

at V_N =

$$\frac{V_N - V_I}{R_1} + \frac{V_N - V_o}{R_2} = 0$$

$$\frac{V_N - V_I}{10K} + \frac{V_N - V_o}{10K} = 0$$

$$V_N - V_I + V_N - V_o = 0$$

$$2V_N = V_I + V_o$$

$$V_N = \frac{V_I + V_o}{2} \quad \text{---------- (1)}$$

at V_p :

$$\frac{V_p - V_I}{(1-k)R} + \frac{V_p - 0}{kR} = 0$$

$$\frac{k(V_p - V_I) + (1-k)(V_p)}{(1-k)kR} = 0$$

$$k(V_p - V_I) + V_p(1-k) = 0$$

$$kV_p - kV_I + V_p - kV_p = 0$$

$$kV_I = V_p \quad \text{---------- (2)}$$

23 :-

as $V_p = V_N$ from ① & ②

$$kV_I = \frac{V_I + V_o}{2}$$

$$2kV_I = V_I + V_o$$

$$V_o = 2kV_I - V_I$$

$$V_o = (2k-1)V_I$$

$$\frac{V_o}{V_I} = 2k - 1$$

$$\boxed{A = 2k - 1}$$

⇒ when whipper at top means $k = 1$

$$\boxed{A = +1}$$

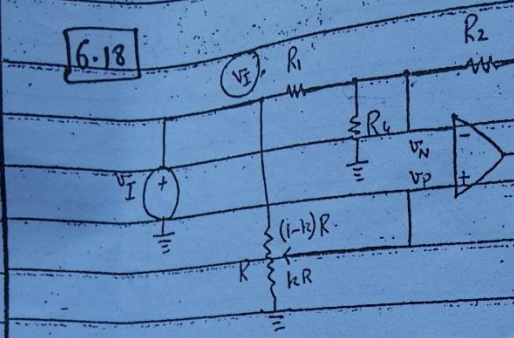
⇒ " at mid " $k = \frac{1}{2}$

$$\boxed{A = 0}$$

⇒ " at bottom " $k = 0$

$$\boxed{A = -1}$$

6.18



at V_N:

$$\frac{V_N - 0}{R_4} + \frac{V_N - V_o}{R_2} + \frac{V_N - V_I}{R_1} = 0$$

$$R_1R_2V_N + R_1R_4(V_N - V_o) + R_2R_4(V_N - V_I) = 0$$

$$R_1R_2V_N + R_1R_4V_N - R_1R_4V_o + R_2R_4V_N - R_2R_4V_I = 0$$

$$(R_1R_2 + R_1R_4 + R_2R_4)V_N = R_1R_4V_o + R_2R_4V_I$$

$$V_N = \frac{R_1R_4V_o + R_2R_4V_I}{(R_1R_2 + R_1R_4 + R_2R_4)} \quad \text{---(1)}$$

at V_P:

$$\frac{V_P - V_I}{(1-k)R} + \frac{V_P - 0}{kR} = 0$$

$$k(V_P - V_I) + (1-k)V_P = 0$$

$$kV_P - kV_I + V_P - kV_P = 0$$

$$V_P = kV_I \quad \text{---(2)}$$

6.18

$V_N = V_P$

$$\frac{R_1 R_4 V_o + R_2 R_4 V_I}{(R_1 R_2 + R_1 R_4 + R_2 R_4)} = k V_I$$

$R_1 = R_2 = 10k\Omega$

$$\frac{R_1 R_4}{(R_2 + R_1 R_4 + R_2 R_4)} V_o = V_I \left(k = \frac{R_2 R_4}{R_1 R_2 + R_1 R_4 + R_2 R_4} \right)$$

$$\frac{V_o}{V_I} = \left(\frac{k(R_1 R_2 + R_1 R_4 + R_2 R_4) - R_2 R_4}{R_1 R_2 + R_1 R_4 + R_2 R_4} \right) \left(\frac{R_1 R_2 + R_1 R_4 + R_2 R_4}{R_1 R_4} \right)$$

$$\boxed{A = \frac{k(R_1 R_2 + R_1 R_4 + R_2 R_4)}{R_1 R_4} = \frac{R_2}{R_1}} \quad (3)$$

$-100 \leq A \leq +100$

(at bottom as $V_N > V_P$) (at top as $V_P \geq V_N$)

at bottom when $k = 0$ & $A = -100$, put in (3)

$$-100 = 0 - \frac{R_2}{R_1}$$

$$\boxed{R_2 = 100 R_1} \quad (4)$$

at top when $k = 1$ & $A = 100$, put in (3)

$$100 = \frac{R_1 R_2 + R_1 R_4 + R_2 R_4}{R_1 R_4} - \frac{R_2}{R_1}$$

$$100 = \frac{R_2}{R_4} + 1 + \frac{R_2}{R_1} - \frac{R_2}{R_1}$$

$$100 - 1 = \frac{R_2}{R_4}$$

$$\boxed{R_2 = 99 R_4} \quad (5)$$

⇒ at halfway $k = \frac{1}{2}$ & $A = 0$ from (3)

$$0 = \frac{R_1 R_2 + R_1 R_4 + R_2 R_4}{2 R_1 R_4} - \frac{R_2}{R_1}$$

$$0 = \frac{1}{2}\frac{R_2}{R_4} + \frac{1}{2} + \frac{1}{2}\frac{R_2}{R_1} - \frac{R_2}{R_1}$$

$$0 = \frac{1}{2}\frac{R_2}{R_4} + \frac{1}{2} - \frac{1}{2}\frac{R_2}{R_1}$$

$$0 = \frac{R_2}{R_4} + 1 - \frac{R_2}{R_1}$$

$$0 = \frac{R_1 R_2 + R_1 R_4 - R_2 R_4}{R_1 R_4}$$

$$\boxed{R_1 R_2 + R_1 R_4 - R_2 R_4 = 0} \quad (6)$$

from (4) & (5)

$$100 R_1 = 99 R_4$$

$$\boxed{R_1 = \frac{99}{100} R_4} \quad (7)$$

we have the relations:-

$$R_2 = 100\, R_1 \quad \text{---(4)}$$

$$R_4 = \frac{1}{99} R_2 \quad \text{---(5)}$$

If we take $R_1 = 1k\Omega$ then

$R_1 = 1k\Omega$
$R_2 = 100k\Omega$
$R_4 = 1.01k\Omega$

$\Rightarrow$ whichever out halfway put $k = \frac{1}{2}$ in (3)

$$A = \frac{\frac{1}{2}\left((1)(100) + (1)(1.01) + (100)(101)\right)}{(1)(1.01)} - \frac{(100)}{(1)}$$

$$= 100. - 100$$

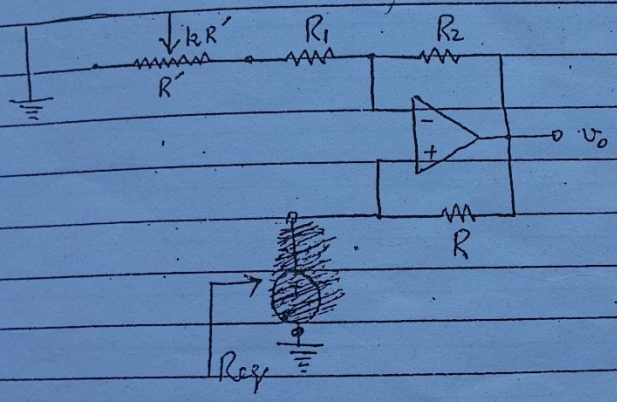
$$\boxed{A = 0 \ \frac{V}{V}}$$

6.19

As we know

$$R_{eq} = -\frac{R_1}{R_2} R$$ so we should change R_1.

So



Now we have

$$R_{eq} = -\frac{(R_1 + kR')}{R_2} R$$

$$\boxed{R_{eq} = -\frac{(R_1 + k(100))}{R_2} R}$$ $R' = 100k\Omega$ (given) (1)

$\Rightarrow$ By given conditions

when $R_{eq} = -1k\Omega$ then $k = 0$ put in (1)

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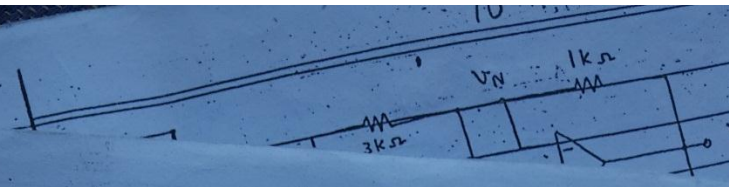

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$$= \neq \frac{(R_1 + 0)\, R}{R_2}$$

$$1 = \frac{R_1 R}{R_2}$$

$$\boxed{R_2 = R_1 R} \quad \text{---} \quad (2)$$

6.19

when $R_{eq} = -10K\Omega$ then $k=1$ put in

$$\neq 10 = \neq \frac{(R_1 + 100)\, R}{R_2}$$

$$10 R_2 = (R_1 + 100) R \quad \text{---} \quad (3)$$

from (2)

$$10 R_1 R = (R_1 + 100) R$$

$$9 R_1 = 100$$

$$R_1 = \frac{100}{9} = 11.\phi 1$$

$$\boxed{R_1 = 11.11\ k\Omega} \quad \text{---} \quad (4)$$

put in (2)

$$\boxed{R_2 = 11.11\, R} \quad \text{---} \quad (5)$$

$R_2 = 11 \cdot 11\ R$ ——— (5)

assume	$R = 1\,k\Omega$	then
	$R_2 = 11 \cdot 11\ k\Omega$	

Check :-

put in (1) :-

$$Req = -\left(\frac{11 \cdot 11 + 100k}{11 \cdot 11}\right) k\Omega$$

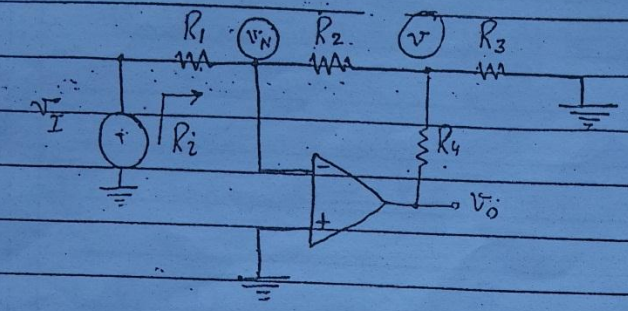
when $k = 0$

$Req = -1\,k\Omega$

when $k = 1$

$Req = -10\,k\Omega$

6.20 (a) ~~Refer to the given~~



at v_N:

$$\frac{v_N - v_I}{R_1} + \frac{v_N - v}{R_2} = 0 \quad \text{---(1)}$$

at v:

$$\frac{v - v_N}{R_2} + \frac{v - v_o}{R_4} + \frac{v - 0}{R_3} = 0 \quad \text{---(2)}$$

from (1)

$$R_2 v_N - R_2 v_I + R_1 v_N - R_1 v = 0$$

$$(R_1 + R_2) v_N - R_2 v_I - R_1 v = 0$$

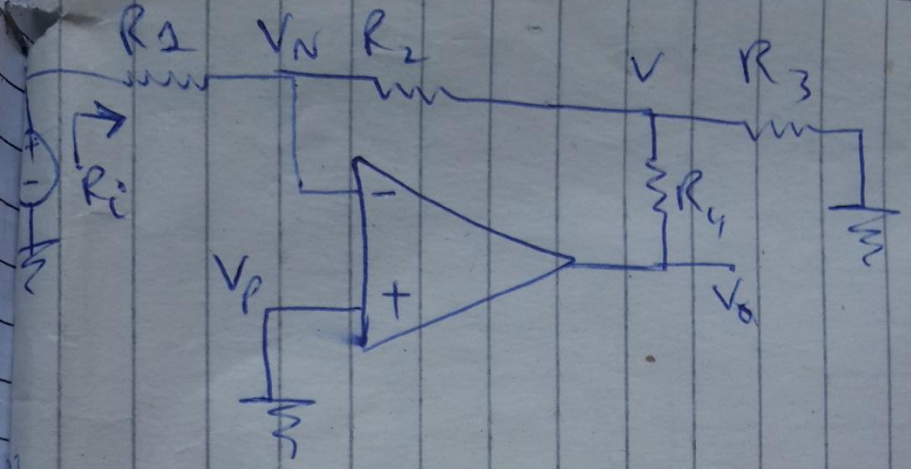
$$v = \frac{(R_1 + R_2) v_N - R_2 v_I}{R_1} \quad \text{---(3)}$$

from (2)

$$0 = R_3 R_4 v - R_3 R_4 v_N + R_2 R_3 v - R_2 R_3 v_o + R_2 R_4 v$$

$$R_3 R_4 v_N = (R_2 R_4 + R_2 R_3 + R_2 R_4) v - R_2 R_3 v_o$$

from (3) put the value of v



$$\frac{V_N - V_i}{R_1} + \frac{V_N - V}{R_2} = 0$$

$$\frac{(V_N - V_i) + R_1 (V_N - V)}{R_1 R_2} = 0$$

$$+R_1) V_N - V_i R_2 - V R_1 = 0$$

$$V_N = \frac{V_i R_2 + V R_1}{R_1 + R_2} \quad \text{---(1)}$$

$$\frac{V - V_o}{R_4} + \frac{V}{R_3} + \frac{V - V_N}{R_2} = 0$$

$$\frac{3R_2(V - V_o) + R_2 R_4 (V) + R_3 R_4 (V - V_N)}{R_4 R_3 R_2} = 0$$

$$3R_2 V - R_3 R_2 V_o + R_2 R_4 V + R_3 R_4 V - R_3 R_4 V_N = 0$$

$$V(R_2R_3+R_2R_4+R_3R_4) = R_3R_2V_0 + R_3R_4V_N \quad \text{--- (2)}$$

$V_P = 0$

$V_N = V_P$

(1) $\Rightarrow \dfrac{V_iR_2 + VR_1}{R_1+R_2} = 0$

$$V = \frac{-V_iR_2}{R_1}$$

(2) $\Rightarrow \dfrac{-V_iR_2}{R_1}(R_2R_3+R_2R_4+R_3R_4) = R_3R_2V_0$

$$\frac{V_0}{V_i} = \frac{-R_2}{R_1}\left(R_2R_3+R_2R_4+R_3R_4\right)\cdot\frac{1}{R_2R_3}$$

$$= \frac{-R_2}{R_1}\left[\frac{R_2R_3}{R_2R_3} + \frac{R_2R_4}{R_2R_3} + \frac{R_3R_4}{R_2R_3}\right]$$

$$= -\frac{R_2}{R_1}\left[1 + \frac{R_4}{R_3} + \frac{R_4}{R_2}\right]$$

$$\boxed{\frac{V_0}{V_i} = -\frac{R_2}{R_1}(R)}$$

At V_i: $\dfrac{V_i}{I} = \dfrac{V_i - V_N}{R_1}$

$V_N = 0$

$I = \dfrac{V_i}{R_1}$

$\therefore R_i = R_1$

$$\boxed{R_i = \frac{V_i}{I}}$$

$$R_3R_4V_N = (R_3R_4 + R_2R_3 + R_2R_4)\left[\frac{(R_1+R_2)V_N - R_2V_I}{R_1}\right] - R_2R_3V_o$$

$$R_3R_4V_N = \frac{(R_3R_4+R_2R_3+R_2R_4)(R_1+R_2)}{R_1}V_N - \frac{(R_3R_4+R_2R_3+R_2R_4)R_2}{R_1}V_I - R_2R_3V_o$$

$$\frac{(R_3R_4+R_2R_3+R_2R_4)R_2}{R_1}V_I + R_2R_3V_o = \frac{(R_3R_4+R_2R_3+R_2R_4)(R_1+R_2)}{R_1}V_N - R_3R_4V_N$$

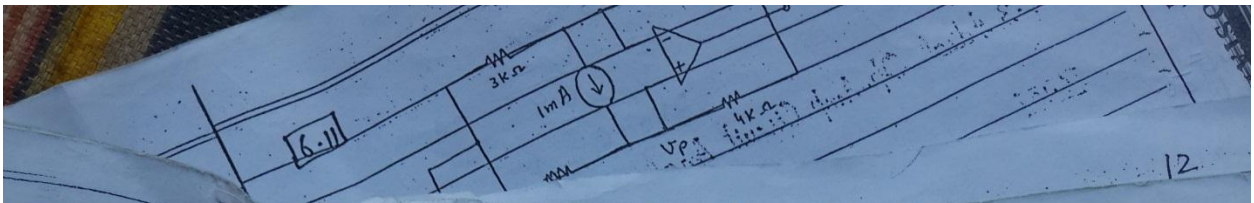
$$(R_3R_4+R_2R_3+R_2R_4)R_2V_I + R_1R_2R_3V_o = \left[(R_3R_4+R_2R_3+R_2R_4)(R_1+R_2) - R_1R_3R_4\right]V_N$$

$$V_N = \frac{(R_3R_4+R_2R_3+R_2R_4)R_2V_I + R_1R_2R_3V_o}{\left[(R_3R_4+R_2R_3+R_2R_4)(R_1+R_2) - R_1R_3R_4\right]} \quad (4)$$

at virtual: $V_p = 0$

a) $V_p = V_N = 0$ put in (4) we get

$0 =$ //



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$$+ R_2R_3 + R_2R_4)\,R_2V_I + R_1R_2R_3\,V_o$$

$$R_2R_3)\,V_o = -(R_2R_3R_4 + R_2^2R_3 + R_2^2R_4)\,V_I$$

$$\frac{V_o}{V_I} = -\left[\frac{R_2R_3R_4 + R_2^2R_3 + R_2^2R_4}{R_1R_2R_3}\right]$$

$$= -\left[\frac{R_4}{R_1} + \frac{R_2}{R_1} + \frac{R_2R_4}{R_1R_3}\right]$$

$$\frac{V_o}{V_I} = -\frac{R_2}{R_1}\left[\frac{R_4}{R_2} + 1 + \frac{R_4}{R_3}\right] \quad \text{---(5)}$$

As given $k = 1 + \frac{R_4}{R_2} + \frac{R_4}{R_3}$

So

$$\frac{V_o}{V_I} = -\frac{R_2}{R_1}k$$

$$\boxed{A = -k\frac{R_2}{R_1}} \quad \text{---(6)}$$

$$\boxed{R_i = R_1} \quad \text{---(7)}$$

→ at V_I i

$$i = \frac{V_i - V_N}{R_1}$$

$V_N = V_p = 0$

$$i = \frac{V_i}{R_1}$$

$$R_1 = \frac{V_I}{i} = R_i$$

$$\boxed{R_i = R_1}$$

(b) $R_i = 100k\Omega$

$A = -200$

$$A = -\frac{R_2}{R_1}\left(1 + \frac{R_4}{R_2} + \frac{R_4}{R_3}\right) \quad (5)$$

$$R_i = R_1 \quad (7)$$

$R_1 = R_i = 100k\Omega$

$\boxed{R_1 = 100k\Omega}$ put in (5) ∴ $A = -200$

$$-200 = -\frac{R_2}{100k}\left(1 + \frac{R_4}{R_2} + \frac{R_4}{R_3}\right)$$

$$200 = \frac{R_2}{100k} + \frac{R_4}{100k} + \frac{R_2 R_4}{100k R_3}$$

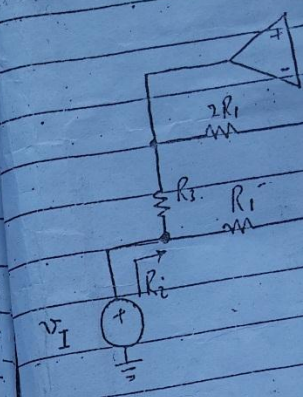
$$\boxed{20{,}000k = R_2 + R_4 + \frac{R_4 R_2}{R_3}} \quad (8)$$

Assuming $\boxed{R_2 = 10k\Omega,\ R_4 = 20k\Omega,\ R_3 = 0.01k\Omega}$ we get $A \simeq -200$

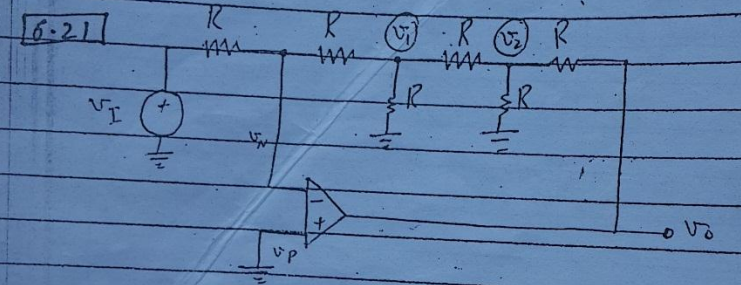
Check:-

$$A = -\frac{100k}{100k}\left(1 + \frac{20k}{10k} + \frac{20k}{0.01k}\right)$$

$$\boxed{A = -200.3\ \frac{V}{V}}$$



6.21



at v_N:

$$\frac{v_N - v_I}{R} + \frac{v_N - v_1}{R} = 0$$

$$v_N - v_I + v_N - v_1 = 0$$

$$-v_1 = v_I - 2v_N \quad \text{---- (1)}$$

at v_1:

$$\frac{v_1 - v_N}{R} + \frac{v_1 - 0}{R} + \frac{v_1 - v_2}{R} = 0$$

$$v_1 - v_N + v_1 + v_1 - v_2 = 0$$

$$3v_1 = v_N + v_2 \quad \text{---- (2)}$$

at v_2:

$$\frac{v_2 - v_1}{R} + \frac{v_2 - 0}{R} + \frac{v_2 - v_o}{R} = 0$$

(b)

A =

R_i =

R_1

f_{3dB} = A

2π =

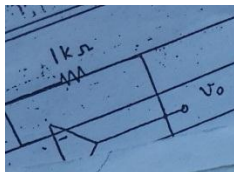
20,000 K

Assuming

Check:-

A_2

A =



$$V_2 = V_1 + V_2 + V_2 - V_o = 0$$

$$3V_2 = V_1 + V_o \quad \text{---(3)}$$

As $V_p - V_N = 0$ put in (1) & (2), then it becomes

$$-V_1 = V_I \quad \text{---(1')}$$

$$3V_1 = V_2 \quad \text{---(2')}$$

$$3V_2 = V_1 + V_o \quad \text{---(3)}$$

put $V_2 = 3V_1$ in (3)

$$3(3V_1) = V_1 + V_o$$

$$9V_1 - V_1 = V_o$$

$$8V_1 = V_o \quad \text{---(3')}$$

put $V_1 = -V_I$ in (3')

$$8(-V_I) = V_o$$

$$\boxed{\frac{V_o}{V_I} = -8 \frac{V}{V}}$$

$$\boxed{A_v = -8 \frac{V}{V}}$$

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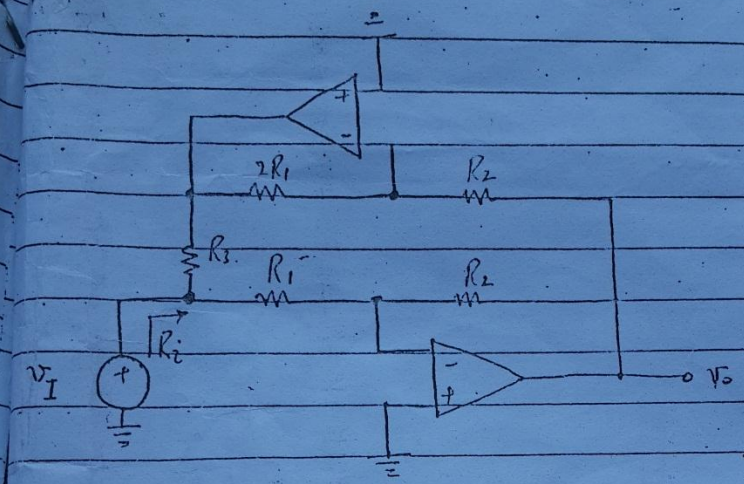

At V_N

$$\frac{V_N - V_i}{R} + \frac{V_N - V_1}{R} = 0$$

$\because V_P = V_N = 0$

$$\boxed{V_1 = -V_i}$$

At V_1

$$\frac{V_1 - V_N}{R} + \frac{V_1}{R} + \frac{V_1 - V_2}{R} = 0$$

$$V_1 + V_1 + V_1 - V_2 = 0$$

$$\boxed{V_2 = 3V_1}$$

$$\frac{V_2 - V_1}{R} + \frac{V_2}{R} + \frac{V_2 - V_o}{R} = 0$$

$$3V_2 - V_1 - V_o = 0$$

$$3(3V_1) - V_1 - V_o = 0$$

$$8V_1 - V_o = 0$$

$$-8(V_i) = V_o$$

$$\boxed{\frac{V_o}{V_i} = -8\ V/V}$$