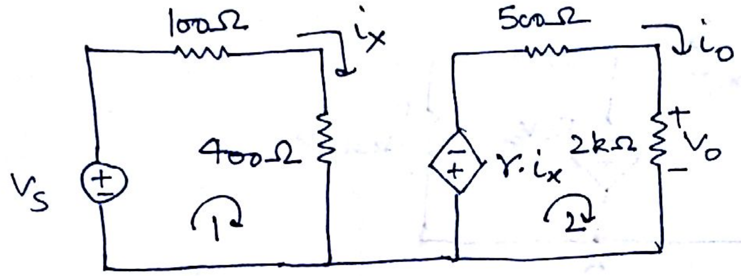
4.1)



$r = 5k\Omega$.

KVL in 1 : $i_x = \dfrac{V_s}{100+400} = 2V_s \text{ mA}$

KVL in 2 : $i_o = \dfrac{-r \cdot i_x}{500+2000} = \dfrac{-5\times10^3 i_x}{2500} = -2i_x$

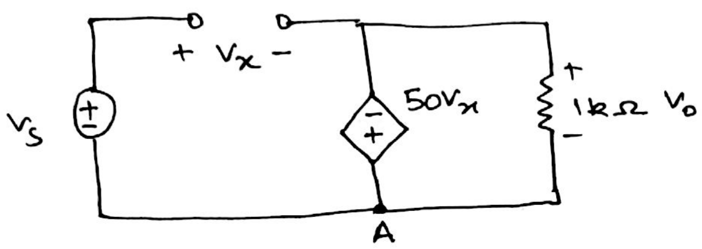
Using voltage division:

$$V_o = i_o \times 2000 = -2i_x \times 2000 = -4i_x \text{ kV}$$

$$\therefore \frac{V_o}{V_s} = \frac{-4i_x \times 10^3}{V_s} = \frac{-4\times10^3 \times 2V_s \times 10^{-3}}{V_s} = -8$$

$$\frac{i_o}{i_x} = \frac{-2i_x}{i_x} = -2.$$

4.5)



Assume A is grounded

then $V_x = V_s - (-50V_x)$

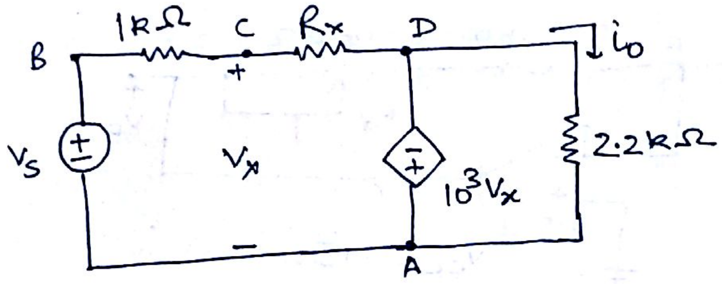
$\Rightarrow V_x = \dfrac{-V_s}{49}$

Also, $V_o = -50V_x = -50 \times \left(\dfrac{-V_s}{49}\right)$

$= \dfrac{50}{49} V_s.$

$\therefore \dfrac{V_o}{V_s} = \dfrac{50}{49}$

4.8)



Let A be grounded.

(a) Then $V_B = V_S$

$V_C = V_x$.

$V_D = -10^3 V_x$

Also, $2.2\times10^3 \times i_o = -10^3 V_x$.

$$i_o = -\frac{1}{2.2} V_x$$

Node voltage equation at C.

$$\frac{V_C - V_B}{1\times10^3} \mp \frac{V_C - V_D}{R_x} = 0$$

$$\Rightarrow \frac{V_x - V_S}{10^3} = -\frac{V_x - (-10^3 V_x)}{R_x}.$$

$$\Rightarrow V_x R_x - V_S R_x = -10^3(1+10^3)V_x$$

$$\Rightarrow V_x\left(1 + \frac{10^3(1+10^3)}{R_x}\right) = V_S$$

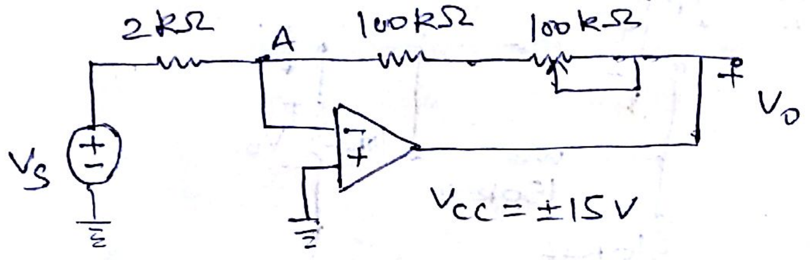
$$\therefore V_x = \frac{V_S}{\left(1+\frac{10^3(1+10^3)}{R_x}\right)}$$

$$\therefore \frac{i_o}{V_S} = \frac{-1}{2.2} \times \frac{1}{\left(1+\frac{10^3(1+10^3)}{R_x}\right)}$$

b) $\frac{i_o}{V_S} = -0.227 \Rightarrow -\frac{1}{2.2} \times \frac{1}{\left(1+\frac{10^3(1+10^3)}{R_x}\right)}$

$$\Rightarrow 0.227 \times 2.2 \simeq \frac{1}{1+\frac{10^6}{R_x}} \Rightarrow R_x \simeq 10^6 \Omega.$$

4.28)



Let variable resistor be R_v,

such that $0 \leq R_v \leq 100k\Omega$.

$V_A = 0V$.

This is an inverting amplifier with

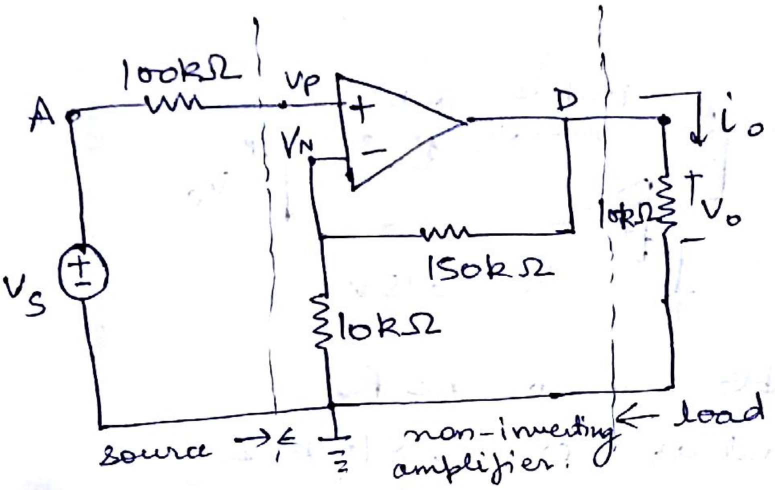
$$V_o = -\left(\frac{100k\Omega + R_v}{2k\Omega}\right) V_s.$$

$$\therefore K = \frac{V_o}{V_s} = -\frac{100\times10^5 + R_v}{2\times10^3}$$

as $0 \leq R_v \leq 100k\Omega$.

$$\therefore \boxed{-100 \leq K = \frac{V_o}{V_s} \leq -50}$$

4.30)

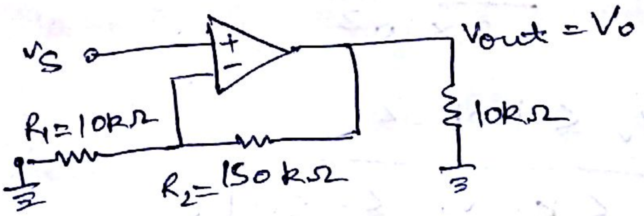


a) This is a non-inverting op amp with a load.

Also, the load won't change the output voltage of the op amp.

$$V_P = V_N = V_S.$$

eqt. circuit :



$$V_O = \left(1 + \frac{R_2}{R_1}\right) V_S = 16\, V_S$$ (as from class).

b) $V_S = 1V, 3V.$

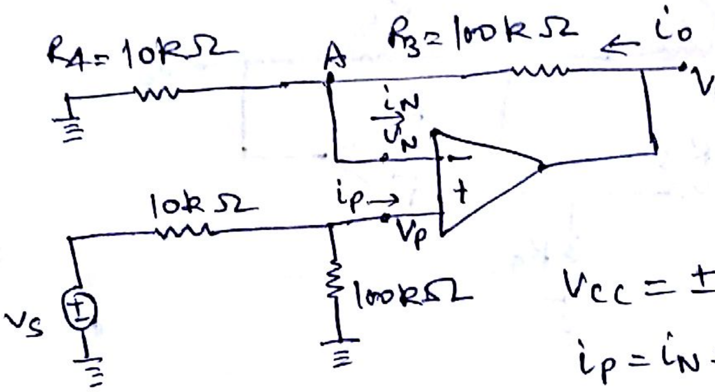
$$i_o = \frac{V_o}{10 \times 10^3}$$

$V_o(V_S = 1V) = 16V < V_{cc} \rightarrow \boxed{i_o = 1.6mA}$

$V_o(V_S = 3V) = 48V > V_{cc}$ op-amp gets saturated

$\therefore V_o = 24V \rightarrow \boxed{i_o = 2.4mA}$

4.31)



$V_{cc} = \pm 18V$.

$i_p = i_N = 0$.

a) Using voltage division & observing that it is a non-inverting op amp, we get.

$$V_p = \frac{100\times10^3}{100\times10^3+10\times10^3} \times V_s = \frac{10}{11}V_s.$$

$$V_N = V_p$$

Also, $K_s = \frac{V_p}{V_s} = \frac{10}{11}$

$$K_{AMP} = \frac{V_o}{V_p} = \frac{R_3+R_4}{R_4} = \frac{100\times10^3+10\times10^3}{10\times10^3} = 11$$

$$\therefore K_{circuit} = \frac{V_o}{V_s} = \frac{V_p}{V_s}\times\frac{V_o}{V_p} = K_s \times K_{AMP}$$

$$= \frac{10}{11}\times 11 = 10$$

$\therefore \boxed{V_o = 10V_s}$

b) $V_s = 0.5V, 2V$

$$i_o = \frac{V_o - V_A}{100\times10^3} = \frac{10V_s - \frac{10}{11}V_s}{100\times10^3}$$

$V_o(V_s = 0.5V) = 10\times0.5V = 5V.$

$\therefore \boxed{i_o = 45.45\,\mu A}$

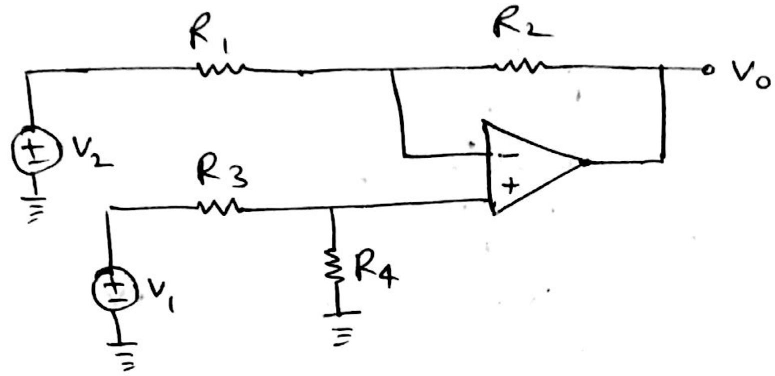
Alternatively, since $i_N = 0$.

$\therefore i_o = \frac{V_o}{(R_3+R_4)}$

$V_o(V_s = 2V) = 10\times2V = 20V > V_{cc}$ so op amp gets saturated $\therefore V_o = 18V$

$$\boxed{i_o = \frac{18 - \frac{10}{11}\times2}{100\times10^3} = 161.8\,\mu A.}$$

4.33) a)



a) This is a ~~differtial~~ differential amplifier.

as derived in class.

when V_1 is turned off.

$$V_{o1} = -\frac{R_2}{R_1} V_2$$

when V_2 is turned off, it is a voltage divider at input with a noninverting amplifier.

$$V_{o2} = \frac{R_4}{R_3+R_4} \times \frac{R_1+R_2}{R_1} \times V_1$$

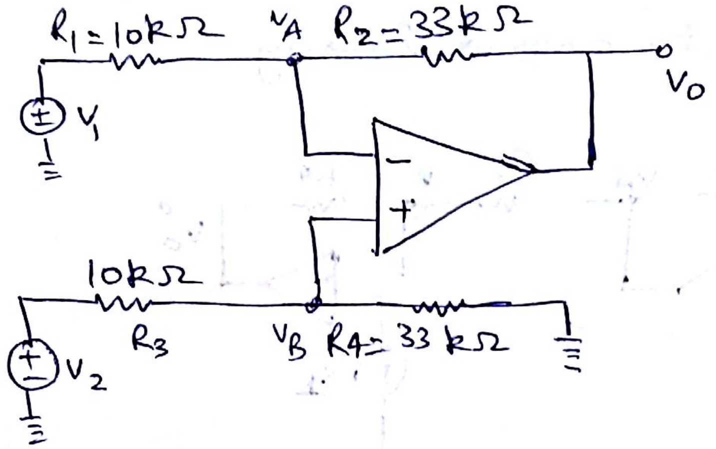
$$\therefore V_o = V_{o1} + V_{o2}$$

$$= -\left(\frac{R_2}{R_1}\right)V_2 + \left(\frac{R_4}{R_3+R_4}\right)\left(\frac{R_1+R_2}{R_1}\right)V_1$$

for $R_1 = 10\,k\Omega$, $R_2 = 30\,k\Omega$, $R_3 = 20\,k\Omega$, $R_4 = 20\,k\Omega$.

$$\Rightarrow \boxed{V_o = 2V_1 - 3V_2}$$

4.36)



This is a differential amplifier.

We can also use superposition principle.. for v_o in terms of v_1 & v_2

(1) Turn v_2 off: inverting amplifier.

$$V_{o1} = -\frac{R_2}{R_1} V_1 = -3.3\, V_1$$

(2) Turn V_1 off: noninverting amplifier.

$$V_{o2} = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right) V_2$$

$$= \frac{33}{43} \times 4.3 \times V_2.$$

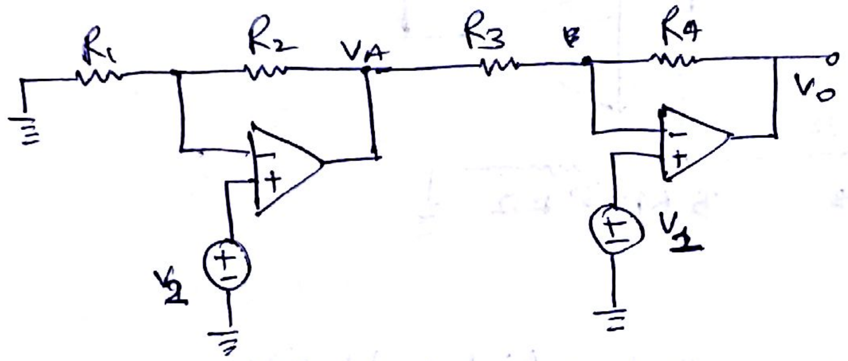
$$\therefore V_o = V_{o1} + V_{o2} = -3.3 V_1 + \frac{4.3 \times 33}{43} V_2$$

$$= 3.3(V_2 - V_1)$$

differential amplier.

can be calculated directly.

b) Both inputs must be into high input resistance amplifiers to avoid loading.



It is interconnection of noninverting & inverting amplifier, with V_2 applied at noninverting input.

VA is output of the non-inverting amplifier.

$$V_A = \left(\frac{R_1+R_2}{R_1}\right) V_1.$$

as derived in class.

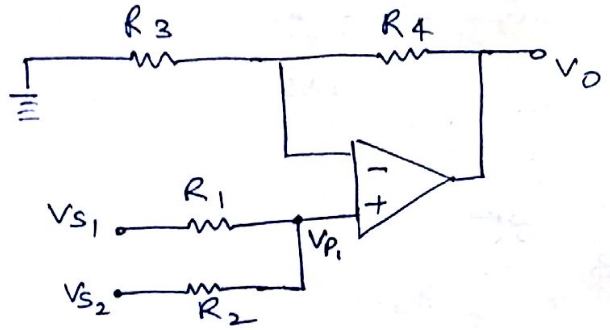
$$V_o = V_{o1} + V_{o2}$$

$$= \left[\frac{R_3+R_4}{R_3}\right] V_1 - \left(\frac{R_4}{R_3}\right)\left(\frac{R_1+R_2}{R_1}\right) V_2.$$

$R_1 = 10k\Omega$, $R_2 = R_3 = R_4 = 20k\Omega$.

$$\Rightarrow \boxed{V_o = 2V_1 - 3V_2}$$

4.38)



Using superposition,

(i) first set $V_{S_2} = 0$.

it is a non-inverting amplifier with voltage divider at input. ($V_{S_2}=0$).

$$\therefore V_{P_1} = \frac{R_2}{R_1+R_2} V_{S_1}.$$

$$V_{o_1} = \frac{R_3+R_4}{R_3} V_{P_1} = \frac{R_3+R_4}{R_3} \times \frac{R_2}{R_1+R_2} \times V_{S_1}$$

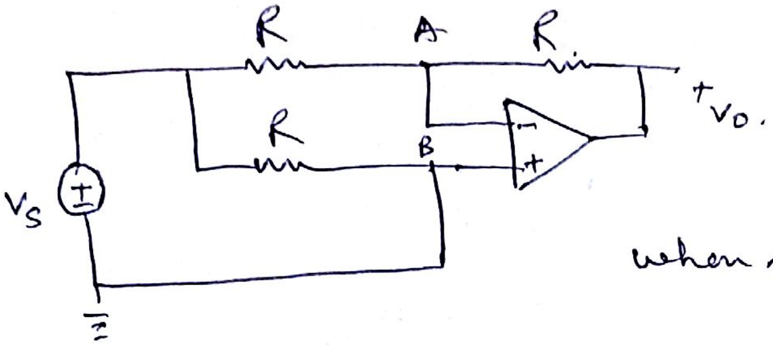
(ii) similary set $V_{S_1} = 0$.

By symmetry of problem.

$$V_{o_2} = \frac{R_3+R_4}{R_3} \times \frac{R_1}{R_1+R_2} V_{S_2}.$$

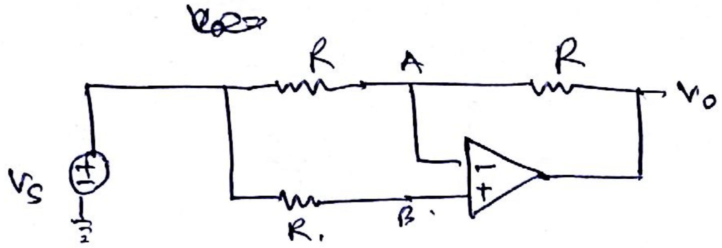
$$\therefore \boxed{V_o = V_{o1} + V_{o2} = \frac{R_3+R_4}{R_3} \times \frac{1}{R_1+R_2} (R_2 V_{S1} + R_1 V_{S2})}$$

4.39)



when switch is closed.

This is an inverting op-amp.



This is a ~~non-inverting~~ differential op-amp (with infinite resistance to ground at input).

Hence, claim is false.

<u>Alternate</u>!

when switch is closed.

$V_B = 0 \Rightarrow V_A = V_B = 0.$

$V_o = -V_s.$

when switch is open.

$V_B = V_s \Rightarrow V_A = V_s.$

$\Rightarrow V_o = V_s.$