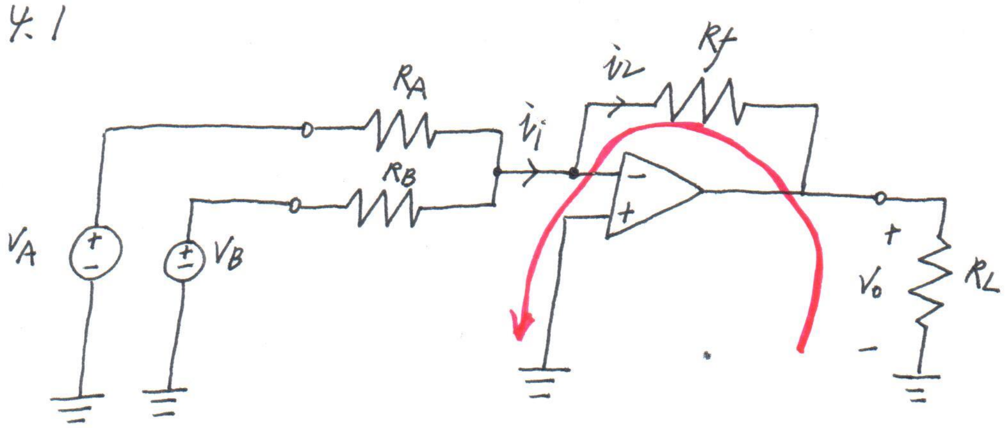
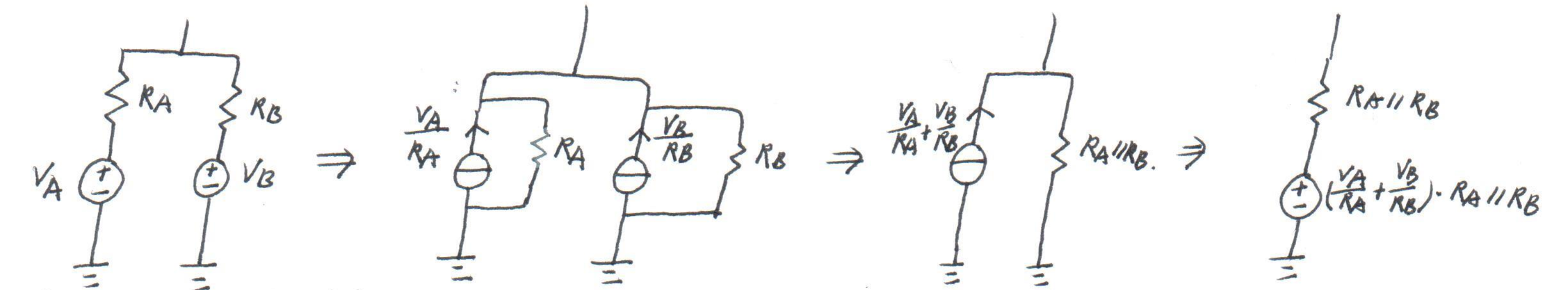
Chapter 4

4.1





(a) First, we verify that negative feedback is present

According to the summing-Point constraint:

$$i_1 = \left(\frac{V_A}{R_A} + \frac{V_B}{R_B}\right) \cdot R_A // R_B \div (R_A // R_B) = \frac{V_A}{R_A} + \frac{V_B}{R_B}$$

$$i_2 = i_1 = \frac{V_A}{R_A} + \frac{V_B}{R_B}$$

Writing a voltage equation around the loop that includes the output terminal, the resistor R_f, and op-amp input terminal:

$$V_o + i_2 R_f = 0$$

$$\therefore \quad V_o + \left(\frac{V_A}{R_A} + \frac{V_B}{R_B}\right) R_f = 0$$

$$V_o = -\left(\frac{R_f}{R_A}\right) V_A - \left(\frac{R_f}{R_B}\right) V_B$$

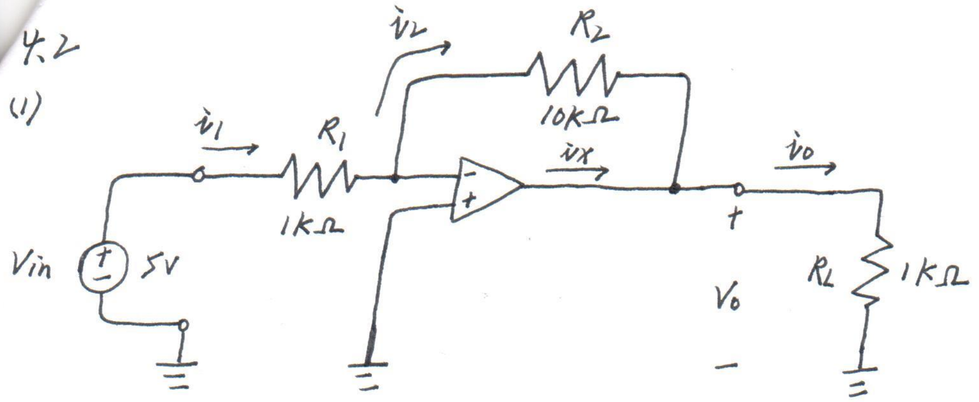
(b) The input resistance for V_A is equal to R_A.

(c) The input resistance for V_B is equal to R_B.

(d) The output resistance is zero.

4.2

(1)



First, we verify that negative feedback is present.

According to the summing-point constraint:

$$i_1 = \frac{V_{in}}{R_1} = \frac{5V}{1k\Omega} = 5mA$$

$$i_2 = i_1 = 5mA$$

Writing a voltage equation around the loop that includes the output terminals, the resistor R_2, and the op-amp input terminals:

$$V_o + R_2 i_2 = 0$$

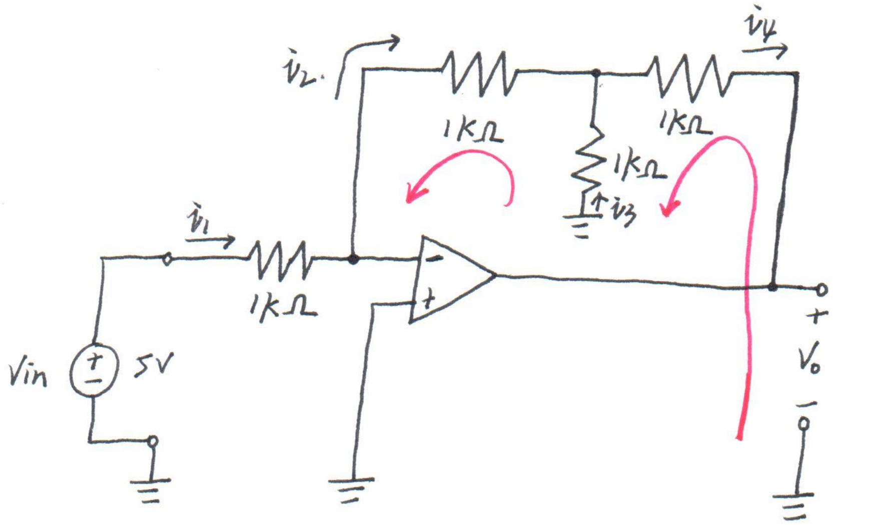
$$\therefore V_o = -R_2 i_2 = -10k\Omega \cdot 5mA = -50V$$

$$i_o = \frac{V_o}{R_L} = \frac{-50V}{1k\Omega} = -50mA$$

KCL:

$$i_2 + i_x = i_o \Rightarrow i_x = i_o - i_2 = (-50-5)mA = -55mA$$

4.2
(2)



First, we verify that negative feedback is present.

According to the summing-Point constraint:

$$i_1 = \frac{V_{in}}{1K\Omega} = \frac{5V}{1K\Omega} = 5mA$$

$i_2 = i_1 = 5mA$

KVL:

$i_2 \times 1K\Omega = i_3 \times 1k\Omega$

$\therefore i_3 = i_2 = 5mA$

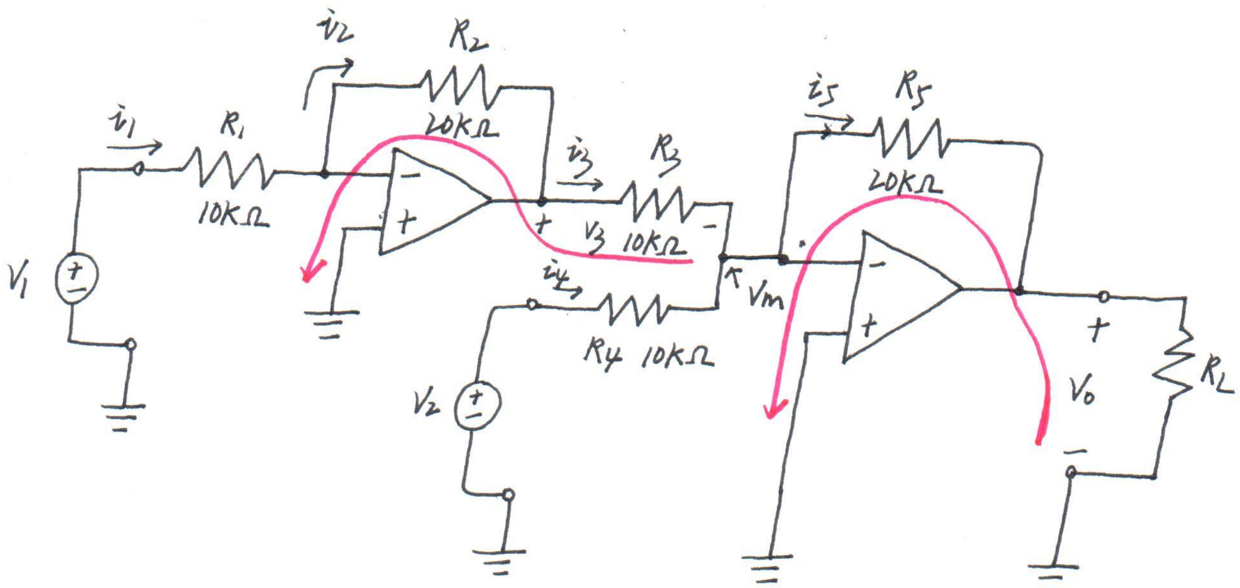
KCL:

$i_4 = i_2 + i_3 = (5+5)\,mA = 10mA$

KVL:

$V_o = -i_4 \times 1K\Omega - i_3 \times 1K\Omega = -15V$

4.3



First, we verify that negative feedback is present

According to the summing-Point constraint :

$$i_1 = \frac{V_1}{R_1} = \frac{V_1}{10k\Omega}$$

$$i_2 = i_1 = \frac{V_1}{10k\Omega}$$

$$V_m = 0$$

KVL:

$$\therefore \quad V_3 + R_2 i_2 = 0 \Rightarrow V_3 = -2V_1$$

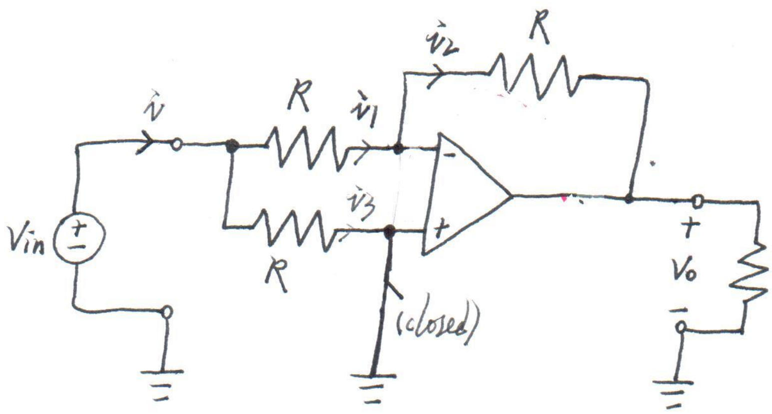
KCL:

$$i_5 = i_3 + i_4 = \frac{V_3}{R_3} + \frac{V_2}{R_4} = \frac{-2V_1}{10k\Omega} + \frac{V_2}{10k\Omega}$$

KVL:

$$V_o + R_5 i_5 = 0 \Rightarrow V_o = -\left(\frac{-2V_1}{10k\Omega} + \frac{V_2}{10k\Omega}\right) \times 20k\Omega = 4V_1 - 2V_2$$

4.4



(b) with the switch closed

∵ First, we verify that negative feedback is present.

According to the summing-point constraint:

$$i_1 = \frac{V_{in}}{R}$$

$$i_2 = i_1 = \frac{V_{in}}{R}$$

KVL:

$$i_2 R + V_o = 0$$

$$V_o = -\frac{V_{in}}{R} \cdot R = -V_{in}$$

$$\therefore A_v = \frac{V_o}{V_{in}} = -1$$

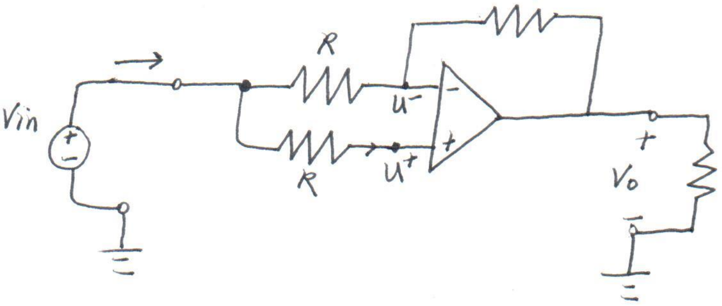
$$i_3 = \frac{V_{in}}{R}$$

KCL:

$$i = i_1 + i_3 = \frac{2V_{in}}{R}$$

$$R_{in} = \frac{V_{in}}{i} = \frac{R}{2}$$

(a) with the switch open:



$$\begin{cases} \dfrac{V_{in} - u^+}{R} = 0 \\ \dfrac{V_{in} - u^-}{R} = \dfrac{u^- - V_o}{R} \end{cases}$$

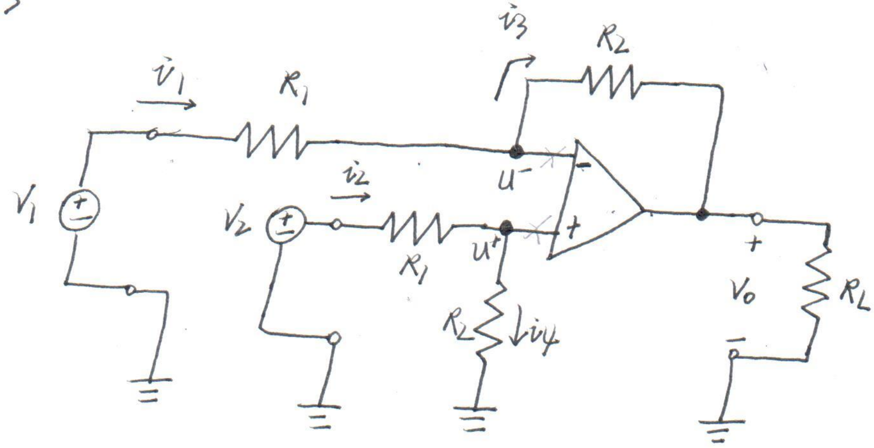
thus: $u^+ = u^- = V_{in}$

$$V_{in} = V_o$$

$$\therefore A_v = \frac{V_o}{V_{in}} = 1$$

$$Z_{in} = \frac{V_{in}}{0} = \infty \quad (\because V_{in} = u^-)$$

4.5



First, we verify that negative feedback is present.
According to the summing-point constraint:

$$\begin{cases} i_1 = i_3 \\ i_2 = i_4 \end{cases}$$

$$\therefore \begin{cases} \dfrac{V_1 - u^-}{R_1} = \dfrac{u^- - V_o}{R_2} & ① \\ \dfrac{V_2 - u^+}{R_1} = \dfrac{u^+}{R_2} & ② \end{cases} \Rightarrow u^+ = \frac{R_2}{R_1 + R_2} V_2$$

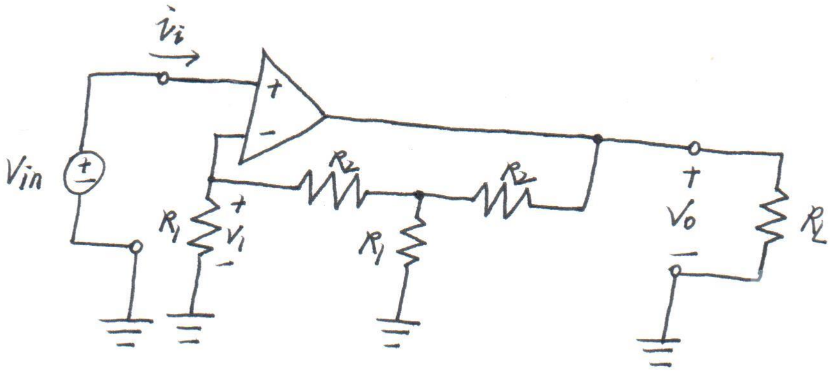
$\because$ $u^- = u^+$ (summing-point constraint)

$$\therefore u^- = u^+ = \frac{R_2}{R_1 + R_2} V_2$$

$$V_o = -\frac{R_2}{R_1}(V_1 - u^-) + u^-$$

$$= \frac{R_2}{R_1}(V_2 - V_1)$$

4.6



First, we verify that negative feedback is present

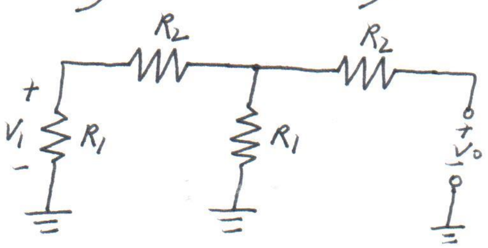
(a)

According to the summing-point constraint:

$i_i = 0$

$V_{in} = V_1$

According to the voltage-divider principle:



$$V_{in} = V_1 = V_o \frac{R_1^2}{R_1^2 + 3R_1R_2 + R_2^2}$$

$$A_v = \frac{V_o}{V_{in}} = 1 + \left(\frac{R_2}{R_1}\right)^2 + 3\left(\frac{R_2}{R_1}\right)$$

(b)

For $R_1 = 1k\Omega$ and $R_2 = 10k\Omega$

$A_v = 131$

(c)

$R_{in} = \frac{V_{in}}{i_1} = \infty$ (theoretically)

(d)

$R_o = 0\Omega$