2.24

For notational convenience, let the middle node be node B. KCL at node B yields

$$6\text{ mA} - \frac{20}{5\text{ k}\Omega} - 4\text{ mA} + i_x = 0,$$

so $i_x = 2$ mA. The voltage drop v_x follows immediately as

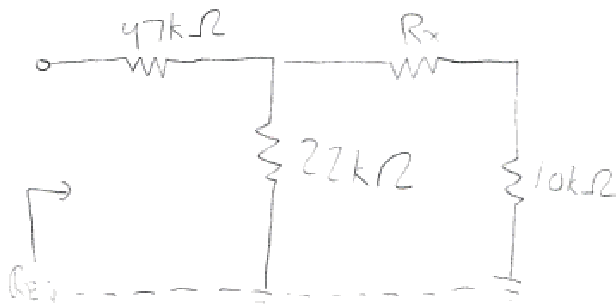
$$\begin{aligned} v_x &= 8\text{ k}\Omega \times i_x, \\ &= 16\text{ V}. \end{aligned}$$

To find v_A, note that by Ohm's law,

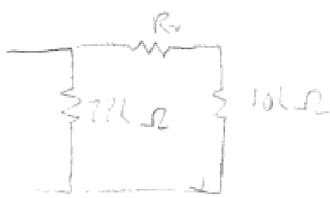
$$\frac{v_B - v_A}{2\text{ k}\Omega} = 6\text{ mA}, \tag{1}$$

where v_B may be solved by noting that $v_B = 12 + v_x = 28$ V (fyi, this is an application of KVL). Substituting into (1), we have that $v_A = 16$ V.

2-36



Find R_x so $R_{Eq} = 60k\Omega$



Must equal 13kΩ

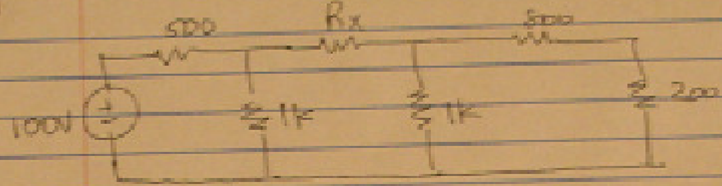
$22k \| X = 13k$

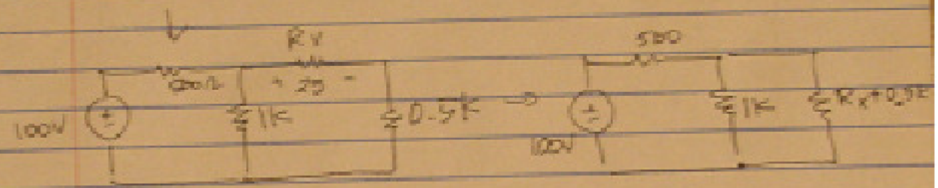
$$\frac{1}{22k} + \frac{1}{X} = \frac{1}{13k}$$

$x = 31{,}78k\Omega$

$R_x + 10k = 31{,}78k$

$\boxed{R_x = 21{,}78k\Omega}$





$$R_p = \frac{(1k)(R_x+0.5k)}{1k+R_x+0.5k} = \frac{R_x+0.5k}{1.5k+R_x}$$

Use voltage divider

$$V_p = (100)\frac{\left(\frac{R_x+0.5k}{1.5k+R_x}\right)}{\left(0.5k + \frac{R_x+0.5k}{1.5k+R_x}\right)}$$

$$V_p = \frac{(100)(R_x+0.5k)k}{0.5k(1.5k)+R_x(0.5k)+R_x+0.5k}$$

$$= \frac{100(R_x+0.5k)}{0.75k+\frac{R_x}{2}+R_x+0.5k} = \frac{100(R_x+0.5k)}{1.25k+\frac{3}{2}R_x}$$

$$V_{R_x} = \frac{100(R_x+0.5k)}{1.25k+1.5R_x}\left(\frac{R_x}{R_x+0.5k}\right) = 25$$

Rx=0.5k

3.11

Part a

The mesh equation follows directly by inspection as

$$\begin{bmatrix} R_A + R_B & -R_B & -R_A \\ -R_B & R_B + R_C + R_D & -R_C \\ -R_A & -R_C & R_A + R_C + R_E \end{bmatrix} \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \begin{bmatrix} v_S \\ 0 \\ 0 \end{bmatrix}.$$

Part b

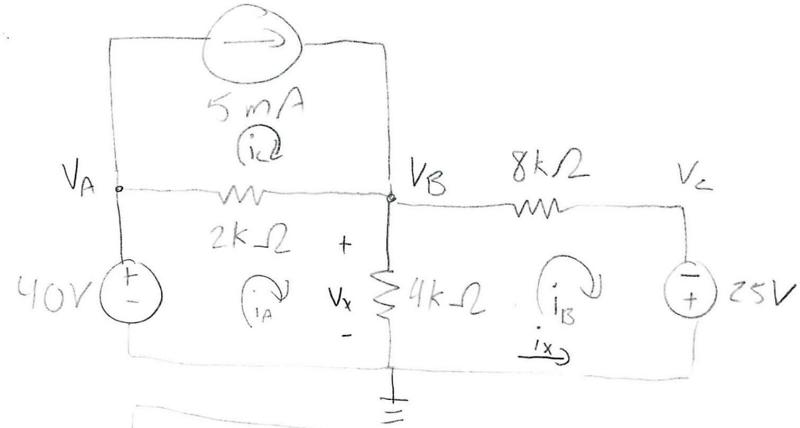
The nodal equation follows by inspection after grounding the bottom node. There is no good reason to ground any other node as doing so would only make the problem more difficult, hence, other answers under different reference nodes will not receive full credit. The center node is denoted node A and the center-right node is denoted node B. The nodal equation is

$$\begin{bmatrix} \frac{1}{R_A} + \frac{1}{R_B} + \frac{1}{R_C} & -\frac{1}{R_C} \\ -\frac{1}{R_C} & \frac{1}{R_C} + \frac{1}{R_D} + \frac{1}{R_E} \end{bmatrix} \begin{bmatrix} v_A \\ v_B \end{bmatrix} = \begin{bmatrix} \frac{v_S}{R_A} \\ \frac{v_S}{R_E} \end{bmatrix}$$

Parts d and e

As some students may not know of or have access to symbolic solvers, and as punching stuff into MATLAB does not contribute significantly to understanding circuits, these parts should not be graded, though I leave this to the grader's discretion. For reference, the MATLAB script and answers are separately attached.

3.15



a) mesh c: $i_c = 5mA$

mesh a: $40 - 2k(i_A - 5mA) - 4k(i_A - i_B) = 0$

mesh b: $25 - 4k(i_B - i_A) - 8k(i_B) = 0$

b) $V_A = 40V$

$V_c = -25V$

node B: $\frac{V_A - V_B}{2k} + 5mA + \frac{V_C - V_B}{8k} + \frac{0 - V_B}{4k} = 0$

c) Node Voltage is easier because there is only 1 unknown. Mesh-current has 2 unknowns.

d)

$$8k\left(\frac{40 - V_B}{2k} + 5mA + \frac{-25 - V_B}{8k} - \frac{V_B}{4k}\right) = 0$$

$$160 - 4V_B + 40 - 25 - V_B - 2V_B = 0$$

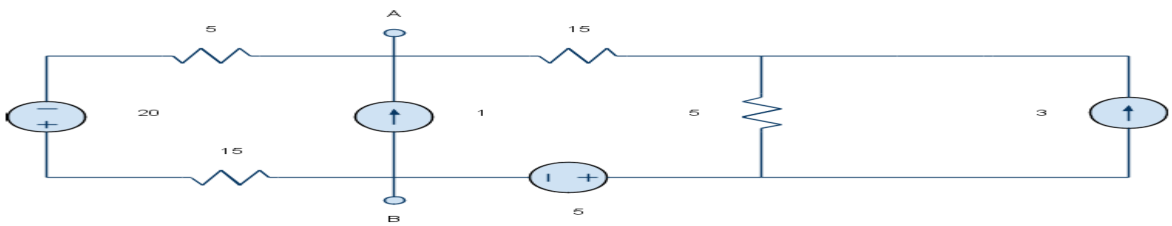
$$175 = 7V_B$$

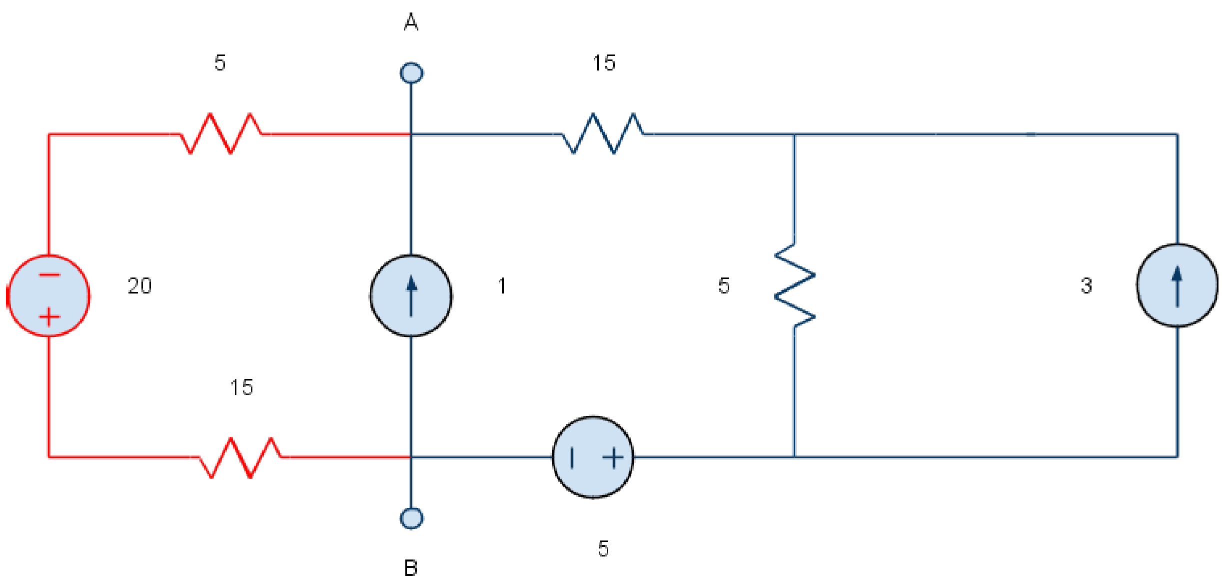
$$V_B = 25V \quad V_B = V_x = 25V$$

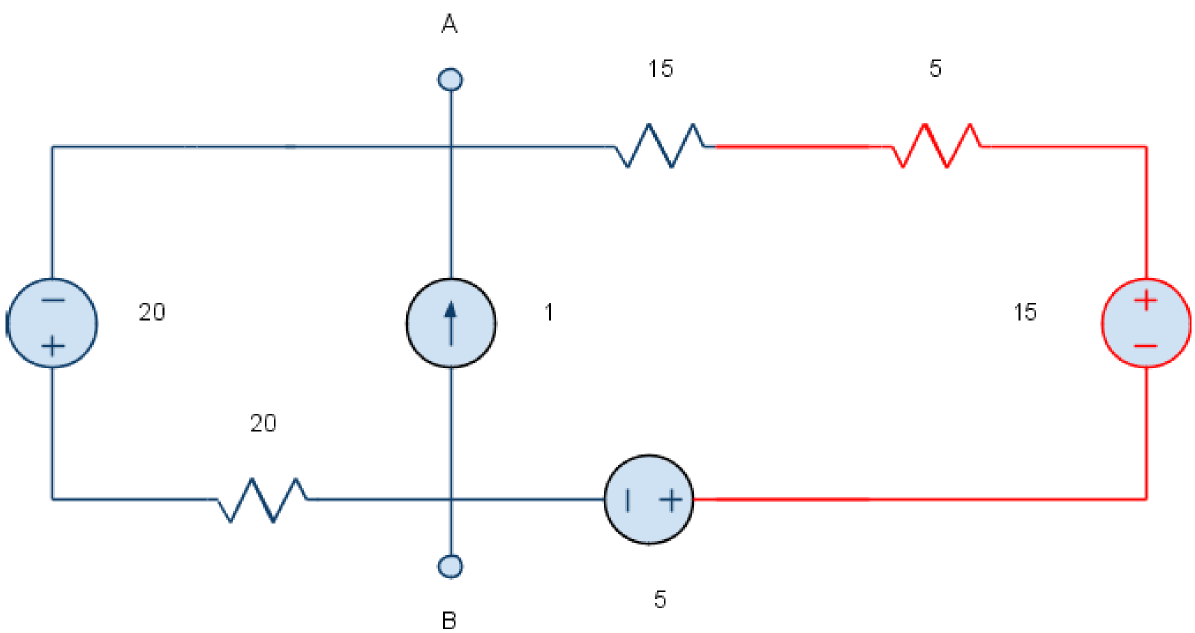
i_x is same current through 8kΩ resistor

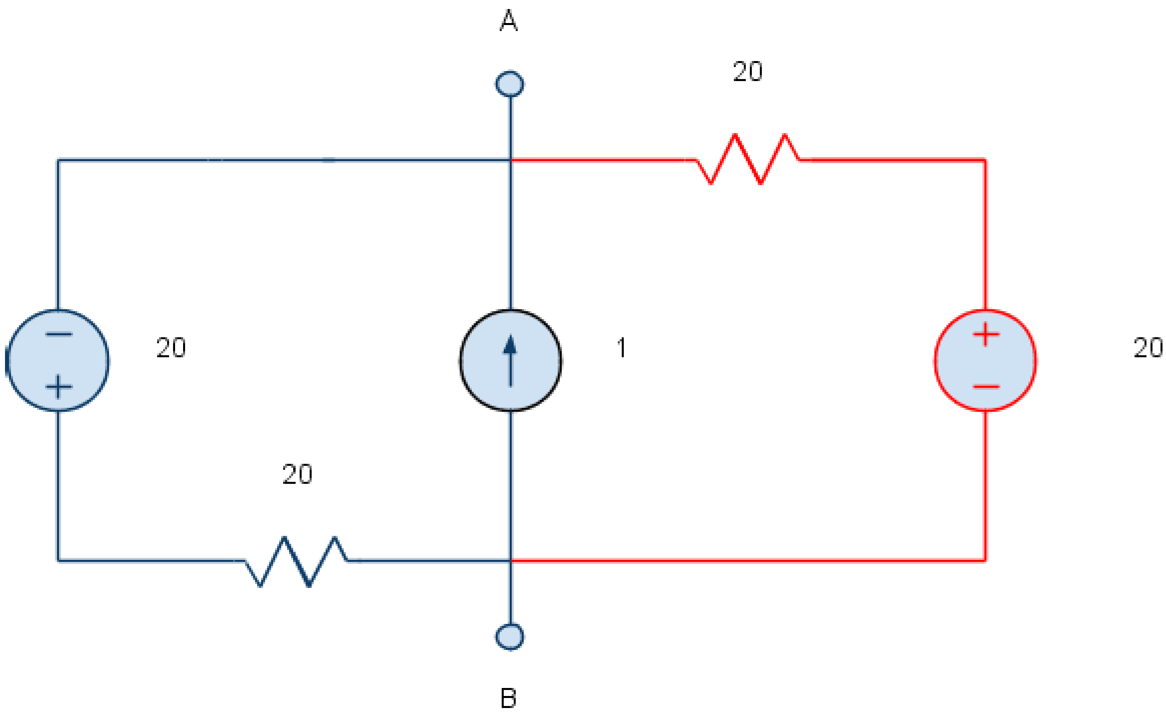
$$\frac{V_C - V_B}{8k\Omega} = i_x = \frac{-25 - 25}{8k\Omega} = -6.25mA = i_x$$

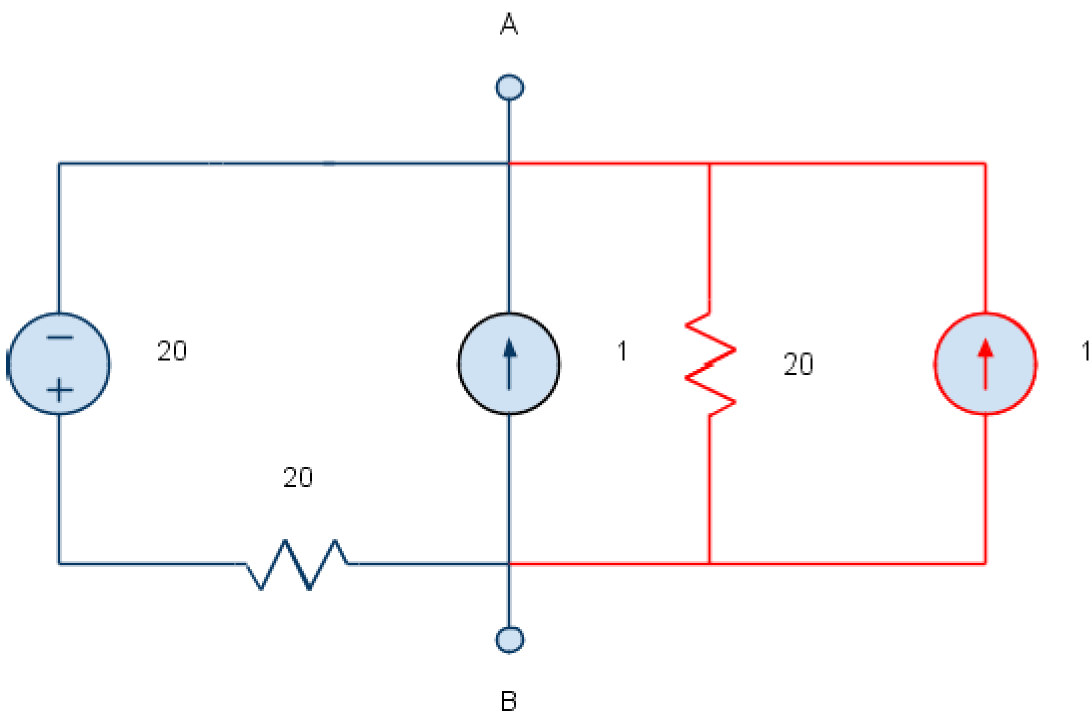
3.46

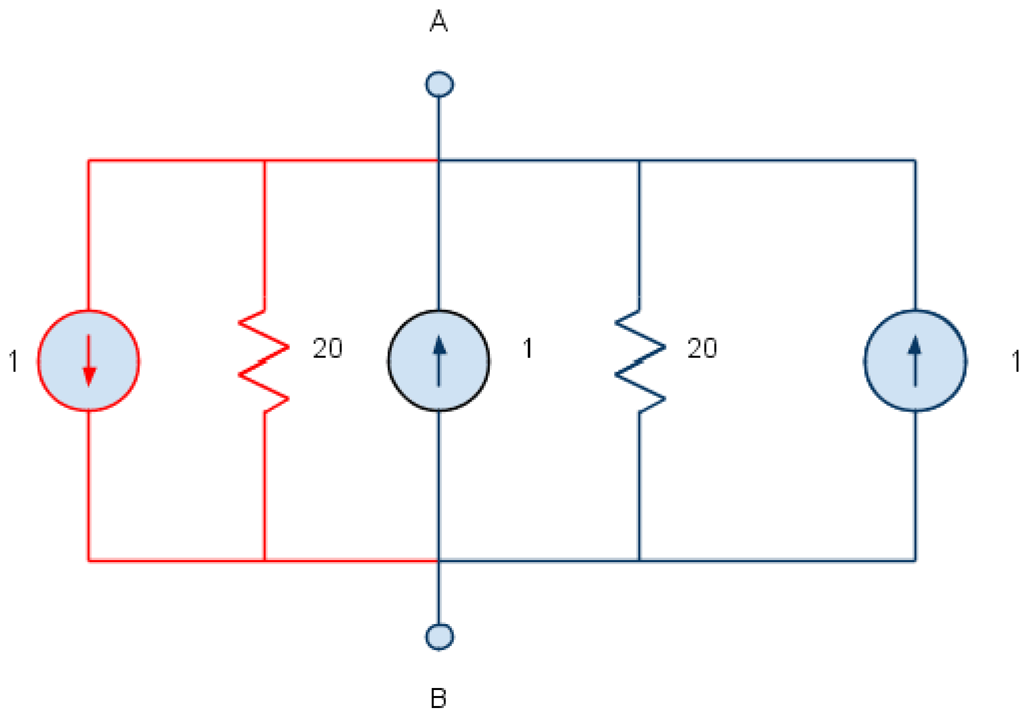

A
5
15
20
1
5
3
15
B
5

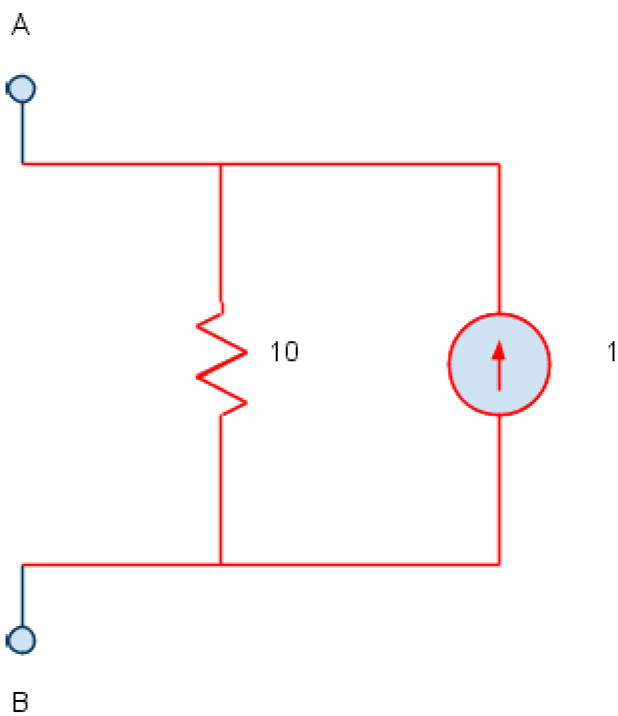

A
5
15
20
1
5
3
15
B
5


A
15
5
20
1
15
20
B
5


A
20
20
1
20
20
B

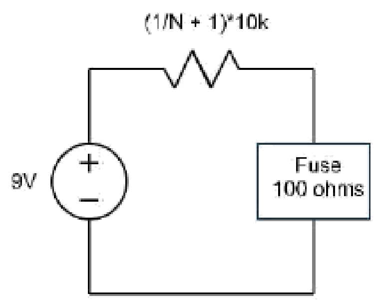

A
20
1
20
1
20
B


A
1
20
1
20
1
B


A
10
1
B

3.47

This problem is made significantly easier by applying source transformations. Consider the two output nodes as the nodes which connect the fuse. Transforming the circuit, we have,

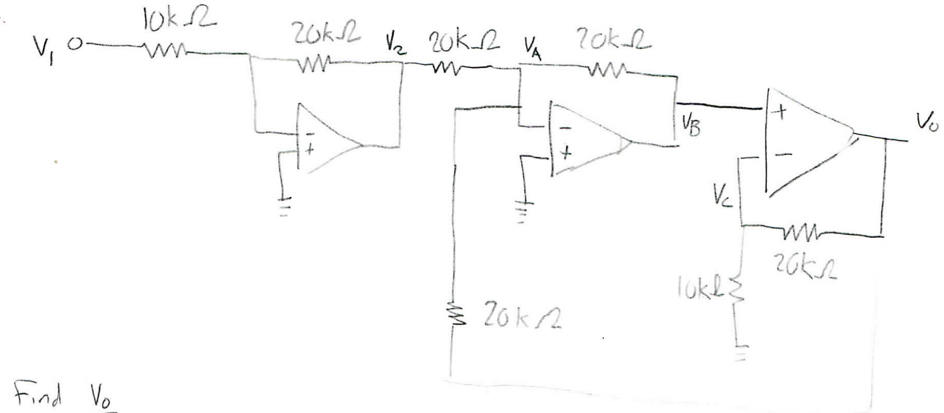


From this new circuit, the current through the fuse is

$$i = \frac{9 \text{ V}}{10\left(\frac{1}{N}+1\right)\ \text{k}\Omega + 100\ \text{k}\Omega} \leq .75 \text{ mA}.$$

After some calculations, we have that $N \leq 5.3$ in order to satisfy the current constraint across the fuse. Thus, the maximum number of loads is $N = 5$.

4-40



Find $\frac{V_o}{V_1}$

First op-amp is an inverter, so $V_2 = \frac{-20k}{10k} \cdot V_1 = -2V_1$

$V_2 = -2V_1$ (1)

$V_A = 0$, at node A: $\frac{V_2 - 0}{20k} + \frac{V_o - 0}{20k} + \frac{V_B - 0}{20k} = 0 \Rightarrow V_2 + V_o + V_B = 0$ (2)

$V_B = V_C$ at node C: $\frac{0 - V_C}{10k} + \frac{V_o - V_C}{20k} = 0 \Rightarrow -2V_C + V_o - V_C = 0$

$V_o = 3V_C$

$V_o = 3V_B$ (3)

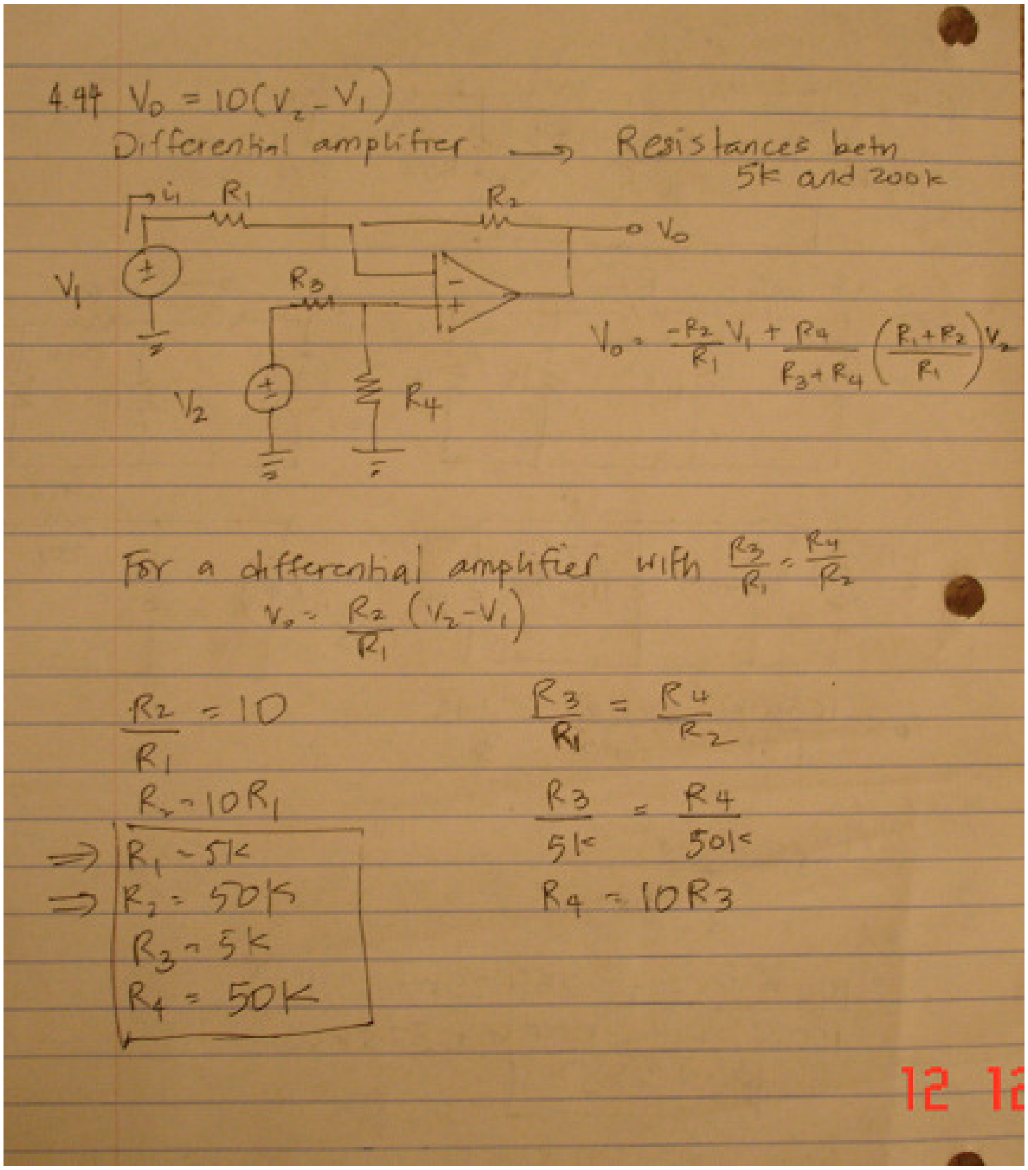
combining eqns (1) & (3) into (2)

$V_2 + V_o + V_B = 0$ (2)

$-2V_1 + V_o + \frac{V_o}{3} = 0$

$\frac{4V_o}{3} = 2V_1$

$$\boxed{\frac{V_o}{V_1} = \frac{3}{2}}$$



4.44 $V_o = 10(V_2 - V_1)$

Differential amplifier → Resistances betn 5k and 200k

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

For a differential amplifier with $\frac{R_3}{R_1} = \frac{R_4}{R_2}$

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

$\frac{R_2}{R_1} = 10$

$R_2 = 10R_1$

⇒ $R_1 = 5k$

⇒ $R_2 = 50k$

$R_3 = 5k$

$R_4 = 50k$

$\frac{R_3}{R_1} = \frac{R_4}{R_2}$

$\frac{R_3}{5k} = \frac{R_4}{50k}$

$R_4 = 10R_3$

4.57

The transducer is described by $v_{TR} = (.05P - .75)$ mV and it has an internal resistance of $R_{TR} = 300\Omega$. The desired output characteristic, on the other hand, is for a pressure of $P = 20$ mm Hg to produce $v_O = 1$ V and for a pressure of $P = 200$ mm Hg to produce $v_O = 10$ V. Hence, the desired v_{TR} to v_O equation is

$$\frac{v_O - 10}{v_i - 9.25 \text{ mA}} = \frac{9}{9 \text{ mA}},$$
$$\Rightarrow v_O = .75 + 10^3 v_i.$$

One possible realization of this circuit is as follows. Note that the designed circuit is possible because there is no uncertainty in the transducer resistance. This may be seen as a practical flaw in the proposed solution.

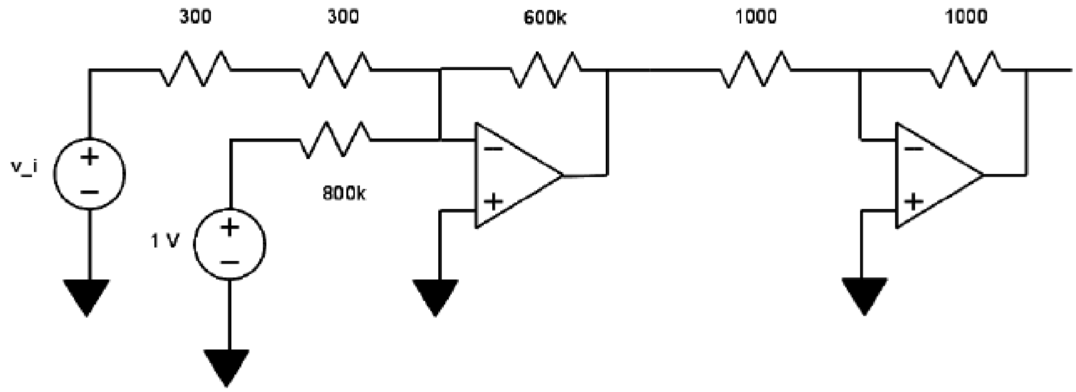


Figure 1: Resistances are in Ω or kΩ with obvious notation.

Keep in mind that there are many possible designs, some of which may not even using the same sequence of Op-Amp blocks.