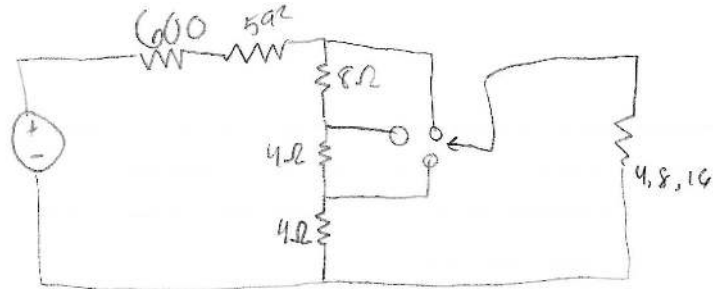


3-11



$$600 \pm 2\% = 588 - 612 \Omega$$

R_{out}

$$4 \Omega: (4 \parallel 4) + 4 + 8 + 592 = 606 \Omega \checkmark$$

$$8 \Omega: (8 \parallel 8) + 8 + 592 = 604 \Omega \checkmark$$

$$16 \Omega: (16 \parallel 16) + 592 = 600 \Omega \checkmark$$

R_{in} : V_s doesn't affect equivalent resistance so eliminate it

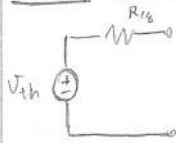
$$4 \Omega: (600 + 592 + 8 + 4) \parallel 4 = 3.98 \Omega \checkmark$$

$$8 \Omega: (600 + 592 + 8) \parallel 8 = 7.95 \Omega \checkmark$$

$$16 \Omega: (606 + 592) \parallel 16 = 15.79 \Omega \checkmark$$

The claim is true.

3/74 Desired:



$$V_{th} = 36 \text{ V}$$

$$R_0 \leq 10 \Omega$$

Components:

$$1: V_1 = 9 \text{ V}, R_1 = 4 \Omega \quad m = 40 \text{ g}$$

$$2: V_2 = 4 \text{ V}, R_2 = 5 \Omega \quad m = 15 \text{ g}$$

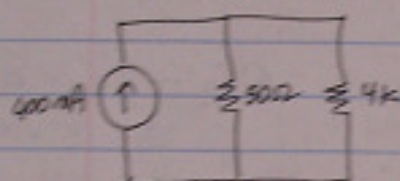
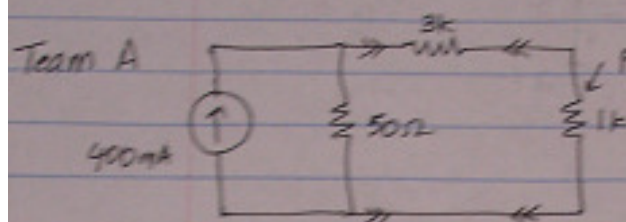
Note that the only way to achieve a voltage increase between two nodes, given the available components, is to connect a battery in between the two nodes. Inductively, we have that the desired battery is achieved by placing a number of smaller batteries in series. As it is impossible to achieve the desired $V_T = 36 \text{ V}$ by combinations of 9V and 4V batteries, verifiable by exhaustive experimentation, we conclude that the obvious two feasible designs are, so far, $4 \times 9 \text{ V}$ batteries or $9 \times 4 \text{ V}$ batteries.

Clearly the $4 \times 9 \text{ V}$ batteries has $R_{eq} = 4 \times 4 = 16 \Omega > 10 \Omega$, while, on the other hand, the $9 \times 4 \text{ V}$ batteries have $R_{eq} = 9 \times 5 = 4.5 \Omega \leq 10 \Omega$. Additionally, $9 \times 4 \text{ V}$ batteries have a mass of 135 g , which is less than achievable by combinations of 9V. Hence, the minimum mass design is

9 4V batteries in series //

9.76) Case (i): Power delivered $25\text{mW} \pm 10\%$ ($22.5 - 27.5\text{mW}$)

Case (ii): Power delivered $25\text{mW} \pm 5\%$ ($23.75 - 26.25\text{mW}$)

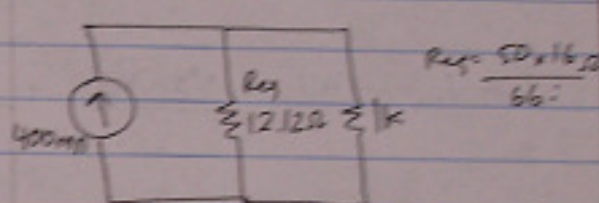
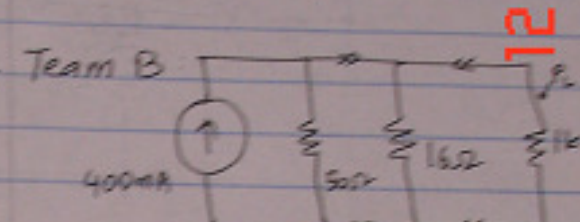


$$i_{1k} = \frac{50\Omega (400\text{mA})}{4.05k}$$

$$= \frac{20}{4.05k} = 4.94\text{mA}$$

$$P_{1k} = i^2 R = (4.94\text{mA})^2 (1k)$$

$$= 24.4\text{mW}$$



$$i_{1k} = \frac{12.12 (400\text{mA})}{1012.12}$$

$$= 4.79\text{mA}$$

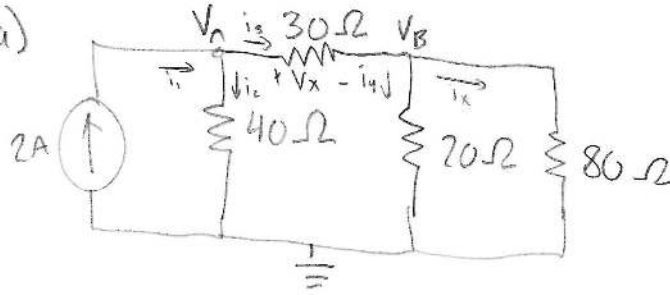
$$P_{1k} = (4.79\text{mA})^2 (1k)$$

$$= 22.94\text{mW}$$

Case (i): For case (i), since team B uses less power and still remains under the given constraint, it is preferred.

Case (ii): Only team A remains within the constraint for case (ii), and hence team A is chosen.

3.1 a)



$$i_1 - i_2 - i_3 = 0$$

$$i_3 - i_4 - i_x = 0$$

$$2 - \frac{V_A}{40} - \frac{V_A - V_B}{30} = 0$$

$$\frac{V_A - V_B}{30} - \frac{V_B}{20} - \frac{V_B}{80} = 0$$

$$\boxed{V_A \left(\frac{1}{40} + \frac{1}{30} \right) - V_B \left(\frac{1}{30} \right) = 2} \quad \boxed{\frac{V_A}{30} - \left(\frac{1}{50} + \frac{1}{20} + \frac{1}{80} \right) V_B = 0}$$

b)

$$\begin{bmatrix} \left(\frac{1}{40} + \frac{1}{30} \right) & -\frac{1}{30} \\ \frac{1}{30} & -\left(\frac{1}{50} + \frac{1}{20} + \frac{1}{80} \right) \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0.0583 & -0.033 & | & 2 \\ 0.033 & -0.09583 & | & 0 \end{bmatrix} \Rightarrow \begin{bmatrix} 1 & 0 & | & 42.89 \\ 0 & 1 & | & 14.77 \end{bmatrix}$$

$$\boxed{V_A = 42.89V}$$

$$\boxed{V_B = 14.77V}$$

c)

$$V_x = V_A - V_B = \boxed{28.12V}$$

$$i_x = \frac{V_B - 0}{80} = \frac{14.77}{80} = \boxed{0.185A}$$

Answers very sensitive to rounding, accept answers reasonably close.

3/3

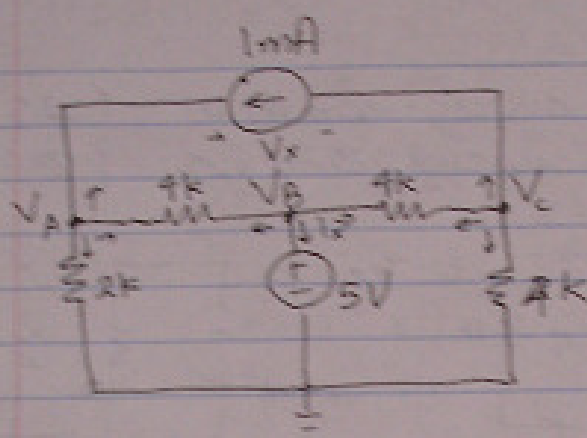
$$\begin{bmatrix} \frac{1}{4000} + \frac{1}{2000} & -\frac{1}{2000} \\ -\frac{1}{2000} & \frac{1}{2000} + \frac{1}{4000} + \frac{1}{2000} \end{bmatrix} \begin{bmatrix} v_A \\ v_B \end{bmatrix} = \begin{bmatrix} -20 \text{ mA} + 20 \text{ mA} \\ -20 \text{ mA} \end{bmatrix} //$$

$$\begin{aligned} v_A &= -14,545 \text{ V} \\ v_B &= -21,818 \text{ V} \end{aligned} //$$

$$v_x = \frac{v_B}{2} = -10,909 \text{ V} //$$

$$i_x = \frac{v_A - v_B}{2000} = 3,6364 \text{ mA} //$$

3.4)



$$V_x = V_A - V_C$$

$$V_B = 5V$$

At V_A : $-1mA + \frac{V_A - V_B}{4k} + \frac{V_A}{2k} = 0 \Rightarrow 6V_A - 2V_B = 8$

$$V_A = (8 + 10)/6$$

$$V_A = 3V$$

At V_B : $\frac{V_B - V_A}{4k} + \frac{V_B - V_C}{4k} + i_x = 0$

At V_C : $1mA + \frac{V_C - V_B}{4k} + \frac{V_C}{4k} = 0 \Rightarrow 2V_C - V_B = -4$

$$V_C = 0.5V$$

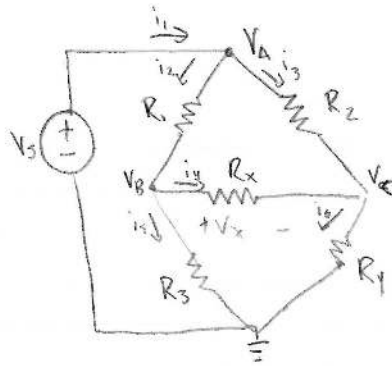
$$\begin{bmatrix} \frac{1}{2k} + \frac{1}{4k} & -\frac{1}{4k} & 0 \\ -\frac{1}{4k} & \frac{1}{4k} + \frac{1}{4k} & -\frac{1}{4k} \\ 0 & -\frac{1}{4k} & \frac{1}{4k} + \frac{1}{4k} \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \begin{bmatrix} 1mA \\ -i_x \\ -1mA \end{bmatrix}$$

$$V_x = V_A - V_C = 3 - 0.5 = \boxed{2.5V = V_x}$$

$$i_x = \frac{V_A - V_B}{4k} + \frac{V_C - V_B}{4k} = \frac{-2}{4k} + \frac{-4.5}{4k} = \frac{-6.5}{4k}$$

$$i_x = \boxed{-1.625mA}$$

3-8



a) $V_s = V_A$

node B: $i_2 - i_4 - i_5 = 0$
 $\frac{V_s - V_B}{R_1} - \frac{V_B - V_C}{R_x} - \frac{V_B - 0}{R_3} = 0$

$$\left[-\left(\frac{1}{R_1} + \frac{1}{R_x} + \frac{1}{R_3}\right) V_B + \left(\frac{1}{R_x}\right) V_C = -\left(\frac{1}{R_1}\right) V_s \right]$$

node C: $i_5 + i_4 - i_6 = 0$
 $\frac{V_s - V_C}{R_2} + \frac{V_B - V_C}{R_x} - \frac{V_C - 0}{R_4} = 0$

$$\left[\left(\frac{1}{R_x}\right) V_B - \left(\frac{1}{R_2} + \frac{1}{R_4} + \frac{1}{R_x}\right) V_C = -\left(\frac{1}{R_2}\right) V_s \right]$$

b) $\begin{bmatrix} .002 & -.007 \\ -.007 & .002 \end{bmatrix} \begin{bmatrix} V_B \\ V_C \end{bmatrix} = \begin{bmatrix} -.06 \\ -.015 \end{bmatrix}$

$V_B = 5V$

$V_C = 10V$

$V_x = V_B - V_C = 5 - 10 = -5V$ (right side at higher voltage than left side)

$i_x = i_2 + i_3$

$i_x = \frac{V_s - V_B}{R_1} + \frac{V_s - V_C}{R_2} = \frac{15 - 5}{1000} + \frac{15 - 10}{250} = .03A$

c) $V_x = 0 \Rightarrow V_B = V_C \Rightarrow i_4 = 0 \Rightarrow i_2 = i_1 + i_3 = i_6$
 $i_2 = \frac{V_s - 0}{R_1 + R_3} = .012A$
 $\frac{V_s - V_B}{R_1} = i_2 \Rightarrow V_B = 15 - 12 = 3V = V_C$
 $\frac{V_s - V_C}{R_2} = i_3 \Rightarrow i_3 = .048A$
 $\frac{V_C - 0}{R_4} = i_3 \Rightarrow R_4 = 62.5\Omega$

3.12

The top, middle node is node A. The voltage at node A is denoted v_A . The KCL equation at node A is as follows:

$$\left(\frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4 + R_5} \right) v_A = i_s + \frac{v_s}{R_1 + R_2}.$$

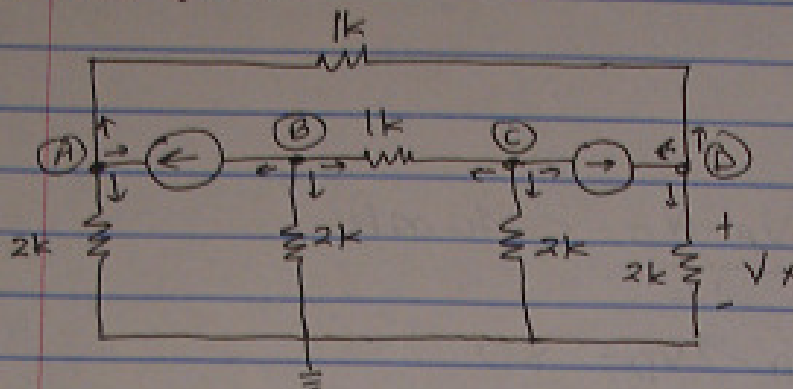
We have that $v_a = 37.5$ V. Hence,

$$i_x = \frac{v_A - v_s}{R_1 + R_2} = 25 \text{ mA, and}$$
$$v_x = \frac{v_A R_4}{R_3 + R_4 + R_5} = 18.75 \text{ V.}$$

The power dissipated, which equals the power generated is

$$P = i_s v_A = 3.75 \text{ W.}$$

3.14 Solve for V_x



KCL

$$\text{At A: } \frac{V_A}{2k} + \frac{V_A - V_D}{1k} - 40\text{mA} = 0 \quad \text{---(1)}$$

$$\text{At B: } \frac{V_B}{2k} + \frac{V_B - V_C}{1k} + 40\text{mA} = 0$$

$$\text{At C: } \frac{V_C - V_B}{1k} + \frac{V_C}{2k} + 20\text{mA} = 0$$

$$\text{At D: } \frac{V_D}{2k} + \frac{V_D - V_A}{1k} - 20\text{mA} = 0 \quad \text{---(2)}$$

$$\begin{bmatrix} \frac{1}{2k} + \frac{1}{1k} & 0 & 0 & -\frac{1}{1k} \\ 0 & \frac{1}{2k} + \frac{1}{1k} & -\frac{1}{1k} & 0 \\ 0 & -\frac{1}{1k} & \frac{1}{1k} + \frac{1}{2k} & 0 \\ -\frac{1}{1k} & 0 & 0 & \frac{1}{2k} + \frac{1}{1k} \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \\ V_D \end{bmatrix} = \begin{bmatrix} 40\text{mA} \\ -40\text{mA} \\ -20\text{mA} \\ 20\text{mA} \end{bmatrix}$$

$$V_x = V_D$$

from (1)

$$\frac{V_A}{2k} + \frac{V_A - V_D}{1k} = 40 \text{ mA}$$

$$V_A + 2V_A - 2V_D = 80$$

$$3V_A - 2V_D = 80$$

$$V_A = \frac{80 + 2V_D}{3} \quad \text{---(3)}$$

(3) in (2)

$$\frac{V_D}{2k} + \frac{V_D - V_A}{1k} = 20 \text{ m}$$

$$V_D + 2V_D - 2V_A = 40$$

$$3V_D - 2\left(\frac{80 + 2V_D}{3}\right) = 40$$

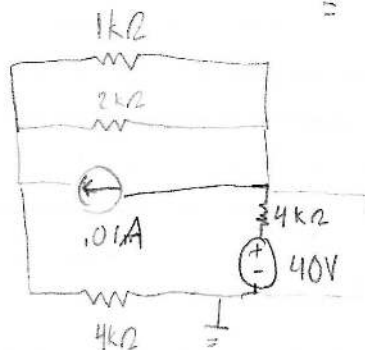
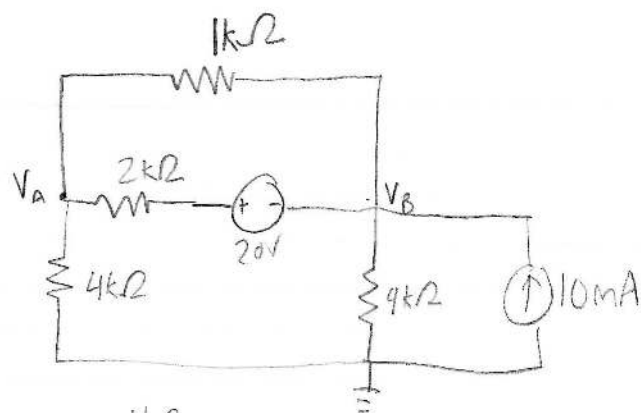
$$9V_D - 160 - 4V_D = 120$$

$$5V_D = 280$$

$$\boxed{V_D = 56V}$$

$$\Rightarrow \boxed{V_x = 56V}$$

3-19

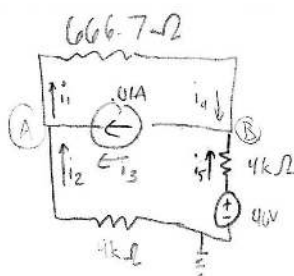


$$i_2 + i_3 - i_1 = 0$$

$$\frac{0 - V_A}{4000} + 0.01 - \frac{V_A - V_B}{666.7} = 0$$

$$\left(-\frac{1}{4000} - \frac{1}{666.7}\right)V_A + \left(\frac{1}{666.7}\right)V_B = -0.01$$

$$\begin{aligned} V_A &= 21.54V \\ V_B &= 18.46V \end{aligned}$$



$$i_4 - i_5 + i_3 = 0$$

$$\frac{V_A - V_B}{666.7} - 0.01 - \frac{V_B - 40}{4000} = 0$$

$$\left(\frac{1}{666.7}\right)V_A - \left(\frac{1}{666.7} + \frac{1}{4000}\right)V_B = 0$$

node voltages only required