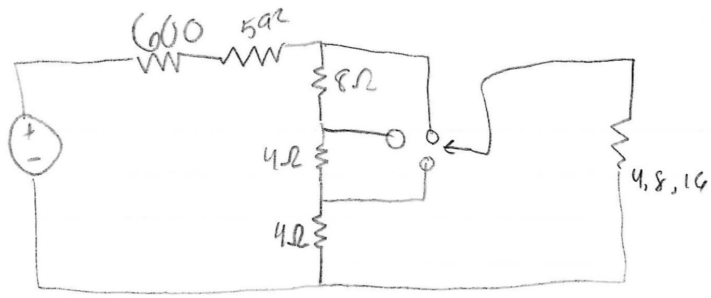
3-11



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

R_{out}

4Ω: $(4 \| 4) + 4 + 8 + 592 = 606\ \Omega$ ✓

8Ω: $(8 \| 8) + 8 + 592 = 604\ \Omega$ ✓

16Ω: $(16 \| 16) + 592 = 600\ \Omega$ ✓

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

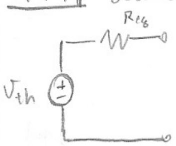
4Ω: $(600 + 592 + 8 + 4) \| 4 = 3.98\ \Omega$ ✓

8Ω: $(600 + 592 + 8) \| 8 = 7.95$ ✓

16Ω: $(600 + 592) \| 16 = 15.79$ ✓

The claim is true.

3/74 Desired:



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

$R_{eq} \leq 10\Omega$

Components:

1: $V_1 = 9V$, $R_1 = 4\Omega$ $m = 40g$

2: $V_2 = 4V$, $R_2 = .5\Omega$ $m = 15g$

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 $V_T = 36V$ by combinations of 9V and 4V batteries, verifiable by exhaustive experimentation, we conclude that the obvious two feasible designs are, so far, 4 × 9V batteries or 9 × 4V batteries

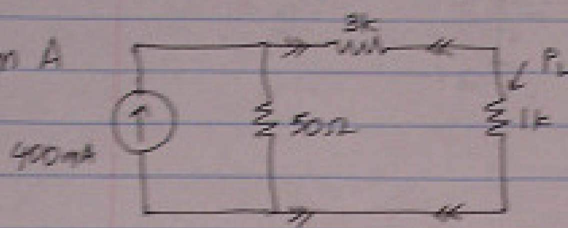
Clearly the 4 × 9V batteries has $R_{eq} = 4 \times 4 = 16\Omega > 10\Omega$, while, on the other hand, the 9 × 4V batteries have $R_{eq} = 9 \times .5 = 4.5\Omega \leq 10\Omega$. Additionally, 9 × 4V batteries have a mass of 135g, which is less than achievable by combinations of 9V. Hence, the minimum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

9 4V batteries in series //

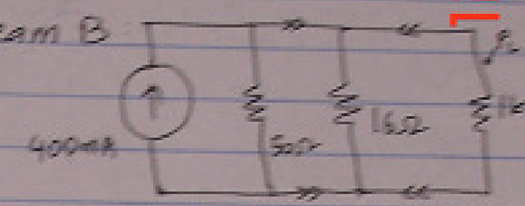
3.76) Case (i): Power delivered 25mW ± 10% (22.5 - 27.5mW)

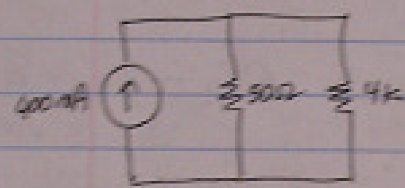
Case (ii): Power delivered 25mW ± 5% (23.75 - 26.25mW)

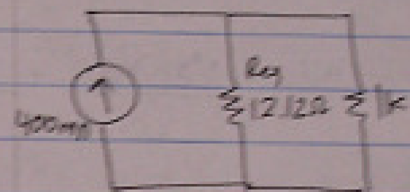
Team A



Team B







$R_{eq} = \frac{50 \times 16}{66} =$

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

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

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

$= 4.79\ mA$

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

$= 22.94\ mW$

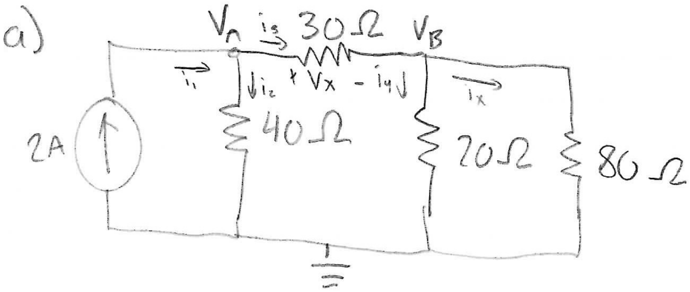
$P_{1k} = i^2R = (4.94m)^2(1k)$

$= 24.4\ mW$

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)



$$i_1 - i_2 - i_3 = 0 \qquad i_3 - i_4 - i_x = 0$$

$$2 - \frac{V_A}{40} - \frac{V_A - V_B}{30} = 0 \qquad \frac{V_A - V_B}{30} - \frac{V_B}{20} - \frac{V_B}{80} = 0$$

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

b)

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

$$\left[\begin{array}{cc|c} .0583 & -.033 & 2 \\ .033 & -.09583 & 0 \end{array}\right] \Rightarrow \left[\begin{array}{cc|c} 1 & 0 & 42.89 \\ 0 & 1 & 14.77 \end{array}\right]$$

$$\boxed{\begin{array}{l} V_A = 42.89V \\ V_B = 14.77V \end{array}}$$

Answers very sensitive to rounding, accept answers reasonably close.

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

$$i_x = \frac{V_B - 0}{80} = \frac{14.77}{80} = \boxed{.185A}$$

3/3

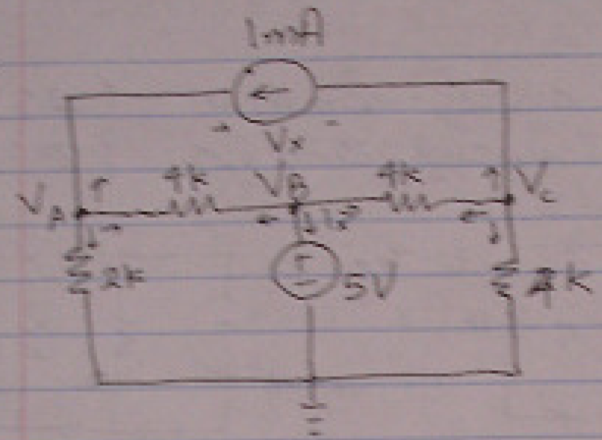
$$\begin{bmatrix} 1/4000 + 1/2000 & -1/2000 \\ -1/2000 & 1/2000 + 1/4000 + 1/2000 \end{bmatrix} \begin{bmatrix} v_A \\ v_B \end{bmatrix} = \begin{bmatrix} -20\,mA + 20\,mA \\ -20\,mA \end{bmatrix} \quad //$$

$$v_A = -14{,}545\ V$$
$$v_B = -21{,}818\ V \quad //$$

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

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

3.9)



$V_x = V_A - V_C$

$V_B = 5V$

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

$V_C = 0.5V$

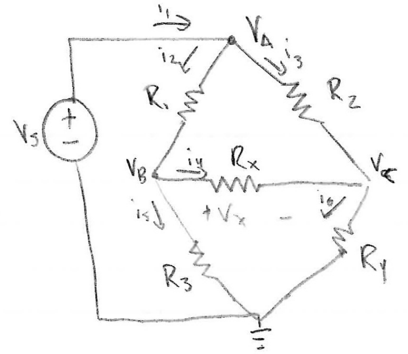
$$\begin{bmatrix} \frac{1}{4k} + \frac{1}{2k} & -\frac{1}{4k} & 0 \\ -1/4k & \frac{1}{4k} + \frac{1}{4k} & \frac{-1}{4k} \\ 0 & \frac{-1}{4k} & \frac{1}{4k} + \frac{1}{4k} \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \begin{bmatrix} 1mA \\ -i_x \\ -1mA \end{bmatrix}$$

$V_x = V_A - V_C = 3 - 0.5 = \boxed{25V = V_x}$

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

$\boxed{i_x = -1.625 mA}$

3-8



a) $V_S = V_A$

node B: $i_2 - i_4 - i_5 = 0$

$$\frac{V_S - V_B}{R_1} - \frac{V_B - V_C}{R_X} - \frac{V_B - 0}{R_3} = 0$$

$$\boxed{-\left(\frac{1}{R_1} + \frac{1}{R_X} + \frac{1}{R_3}\right)V_B + \left(\frac{1}{R_X}\right)V_C = -\left(\frac{1}{R_1}\right)V_S}$$

node C: $i_3 + i_4 - i_6 = 0$

$$\frac{V_S - V_C}{R_2} + \frac{V_B - V_C}{R_X} - \frac{V_C - 0}{R_4} = 0$$

$$\boxed{\left(\frac{1}{R_X}\right)V_B - \left(\frac{1}{R_2} + \frac{1}{R_4} + \frac{1}{R_X}\right)V_C = -\left(\frac{1}{R_2}\right)V_S}$$

b)

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

$V_B = 5V$

$V_C = 10V$ $\quad V_X = V_B - V_C = 5 - 10 = \boxed{-5V}$ (right side at higher voltage than left side)

$i_X = i_2 + i_3$

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

c) $V_X = 0 \Rightarrow V_B = V_C \Rightarrow i_4 = 0 \Rightarrow i_2 = i_5$ + $i_3 = i_6$

$i_2 = \frac{V_S - 0}{R_1 + R_3} = .012A$ $\quad \frac{V_S - V_B}{R_1} = i_2 \Rightarrow V_B = 15 - 12 = 3V = V_C$

$\frac{V_S - V_C}{R_2} = i_3 \Rightarrow i_3 = .048A$ $\quad \frac{V_C - 0}{R_4} = i_3$ $\quad \boxed{R_4 = 62.5\,\Omega}$

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:

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

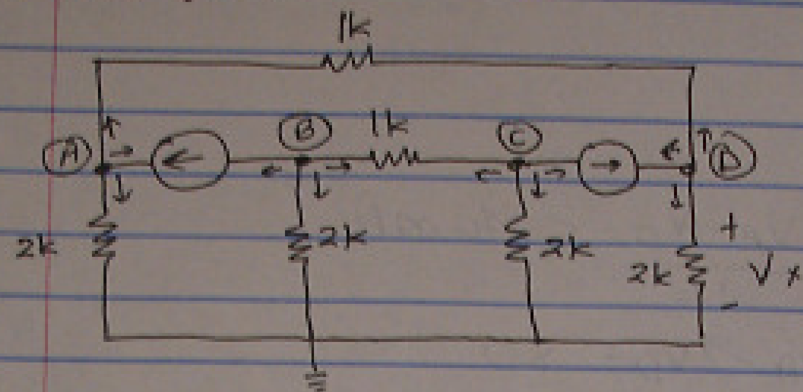
We have that $v_a = 37.5$ V. Hence,

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

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

At A. $\dfrac{V_A}{2k} + \dfrac{V_A - V_D}{1k} - 40mA = 0$ —(1)

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

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

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

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

$V_X = V_D$

from (1)

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

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

$$3V_A - 2V_D = 80$$

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

(3) in (2)

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

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

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

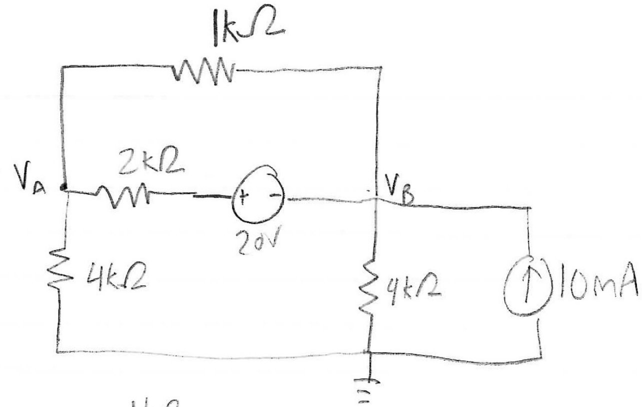
$$9V_D - 160 - 4V_D = 120$$

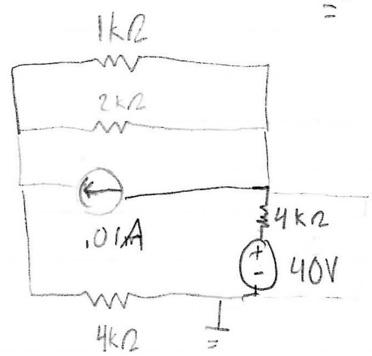
$$5V_D = 280$$

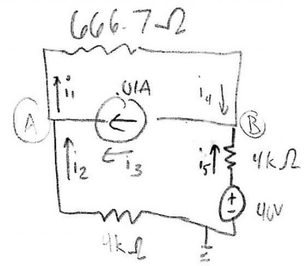
$$\boxed{V_D = 56V}$$

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

3-19







$i_2 + i_3 - i_1 = 0$

$$\frac{0-V_A}{4000} + .01 - \frac{V_A-V_B}{666.7} = 0$$

$$\left(\frac{-1}{4000} - \frac{1}{666.7}\right)V_A + \left(\frac{1}{666.7}\right)V_B = -.01$$

$i_4 - i_3 + i_5 = 0$

$$\frac{V_A-V_B}{666.7} - .01 - \frac{V_B-40}{4000} = 0$$

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

$$\boxed{\begin{array}{l} V_A = 21.54V \\ V_B = 18.46V \end{array}}$$

node voltages only required