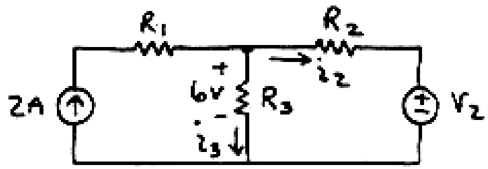
Chapter 3 – Resistive Circuits

Exercises

Ex 3.3-1



$$i_3 = \frac{6V}{R_3} = \frac{6V}{2\Omega} = 3A$$

from KCL at top node

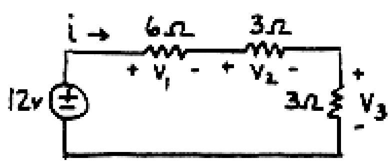
$i_2 = 2 - i_3 = 2 - 3 = -1A$

KVL around 2nd loop : $-6 + R_2 i_2 + v_2 = 0 \quad \Rightarrow \underline{v_2 = 6-(1)(-1) = 7V}$

Ex 3.3-2 $$-18 + 0 - 12 - v_a = 0 \quad \Rightarrow \quad v_a = -30 \text{ V}$$

Ex 3.3-3 $$-v_a - 10 + 4v_a - 8 = 0 \quad \Rightarrow \quad v_a = \frac{18}{3} = 6 \text{ V}$$

Ex 3.4-1



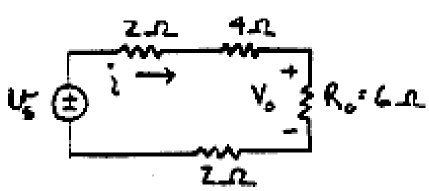
from voltage divider

$$v_3 = 12\left(\frac{3}{3+9}\right) = \underline{3V} \ \therefore \ i = \frac{v_3}{3} = \underline{1A}$$

$$\left.\begin{aligned} \text{now} \quad P_{6\Omega} &= i^2(6) = (1)^2(6) = 6W \\ P_{3\Omega_1} &= i^2(3) = (1)^2(3) = 3W \\ P_{3\Omega_2} &= i^2(3) = (1)^2(3) = 3W \end{aligned}\right\} P_{6\Omega} + P_{3\Omega_1} + P_{3\Omega_2} = 12W \text{ absorbed}$$

$$P_{source} = vi = (12V)(1A) = 12W \text{ supplied}$$

Ex 3.4-2



if $P_0 = 6W$ and $R_0 = 6\Omega \Rightarrow i^2 = \frac{P_0}{R_0} = \frac{6}{6} = 1$ or $i = 1A$

$\therefore \ v_0 = iR_0 = (1)(6) = \underline{6V}$

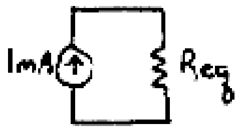
from KVL: $-v_s + i(2+4+6+2) = 0 \Rightarrow \underline{v_s = 14i = 14V}$

Ex 3.4-3 from voltage divider $\Rightarrow v_m = \frac{25}{25+75} 8 = 2 \quad V$

Ex 3.4-4 from voltage divider $\Rightarrow v_m = \frac{25}{25+75}(-8) = -2 \quad V$

Ex. 3.5-1

Equiv. Ckt.



$$\frac{1}{\text{Reg}} = \frac{1}{1}+\frac{1}{1}+\frac{1}{1}+\frac{1}{1}$$

$$\text{Reg} = \underline{1/4\ \text{k}\Omega}$$

i in each R= $\frac{1}{4}$(1mA) = $\underline{\frac{1}{4}\text{mA}}$

Ex 3.5-2 from current divider $\Rightarrow i_m = \frac{10}{10+40}(-5) = -2 \quad \text{A}$

Ex 3.6-1

$$R_p = \frac{(4)(2)}{4+2} = \frac{8}{6} = \underline{\frac{4}{3}\Omega}$$

$$\therefore V = R_p\ (3\text{A}) = \frac{4}{3}(3) = \underline{4\text{V}}$$

Problems

Section 3-3 Kirchoff's Laws

P3.3-1

KVL : $v_1 + 2 - 3 - 6 - 8 + 4 = 0$ (outside loop)

$\underline{v_1 = +11 \text{ V}}$

KVL : $v_2 + 2 - 3 - 6 = 0$ (right mesh)

$\underline{v_2 = 7 \text{ V}}$

KVL : $3 + 2 - i_3 = 0$ (top node)

$\underline{i_3 = 5 \text{ A}}$

P3.3-2

KVL : $-v_1 + 2 + 4 + 5 = 0$ (outside loop)

$\underline{v_1 = 11 \text{ V}}$

KCL : $-1 + 3 + i_4 = 0$ (top,left node)

$\underline{i_4 = -2\text{A}}$

KCL : $1 + i_3 - 3 = 0$ (bottom, left node)

$\underline{i_3 = 2 \text{ A}}$

KCL : $-i_4 + 2 + i_2 = 0$ (top,right node)

$-(-2) + 2 + i_2 = 0 \quad \Rightarrow \quad \underline{i_2 = -4\text{A}}$

P3.3-3

KVL : $-12 - R_2(3) + v = 0$ (outside loop)

$$v = 12 + 3R_2 \quad \text{or} \quad R_2 = \frac{v-12}{3}$$

KCL $i + \frac{12}{R_1} - 3 = 0$ (top node)

$$i = 3 - \frac{12}{R_1} \quad \text{or} \quad R_1 = \frac{12}{3-i}$$

(a)

$$v = 12 + 3(3) = \underline{21\ \text{V}}$$

$$i = 3 - \frac{12}{6} = \underline{1\ \text{A}}$$

(b)

$$R_2 = \frac{2-12}{3} = \underline{-\frac{10}{3}\Omega}\ ; \quad R_1 = \frac{12}{3-1.5} = \underline{8\Omega}$$

(c) $24 = -12\ i$, because 12 and i adhere to the passive convention.

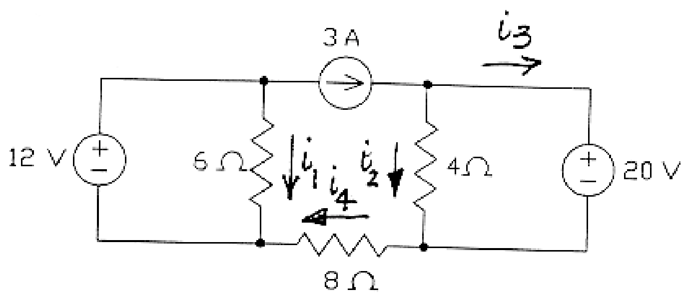
$$\therefore \underline{i = -2\text{A}} \quad \text{and} \quad R_1 = \frac{12}{3+2} = \underline{2.4\Omega}$$

$9 = 3v$, because 3 and v do not adhere to the passive convention

$$\therefore \underline{v = 3} \quad \text{and} \quad R_2 = \frac{3-12}{3} = \underline{-3\Omega}$$

The situations described in (b) and (c) cannot occur if R_1 and R_2 are required to be nonnegative.

P3.3-4



$$i_1 = \frac{12}{6} = 2\text{A}$$

$$i_2 = \frac{20}{4} = 5\text{A}$$

$$i_3 = 3 - i_2 = -2\text{A}$$

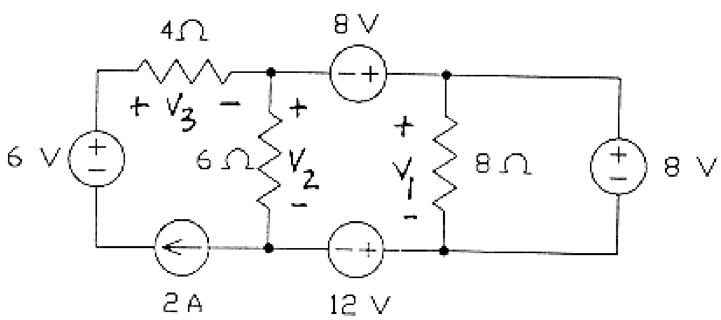
$$i_4 = i_2 + i_3 = 3\text{A}$$

Power absorbed by the 4Ω resistor = $4 \cdot i_2^2$ = $\underline{100\ \text{W}}$

Power absorbed by the 6Ω resistor = $6 \cdot i_1^2$ = $\underline{24\ \text{W}}$

Power absorbed by the 8Ω resistor = $8 \cdot i_4^2$ = $\underline{72\ \text{W}}$

P3.3-5



$$v_1 = 8\text{V}$$

$$v_2 = -8+8+12 = 12\ \text{V}$$

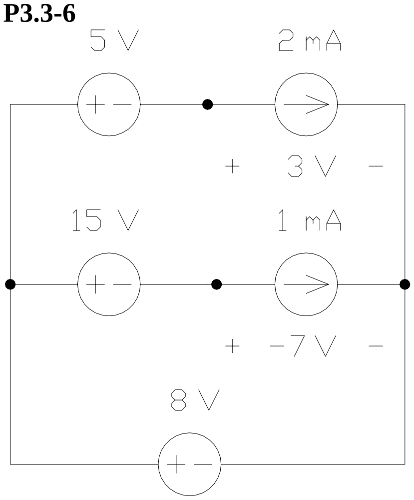
$$v_3 = 2 \cdot 4 = 8\text{V}$$

$$4\Omega : P = \frac{v_3^2}{4} = \underline{16\ \text{W}}$$

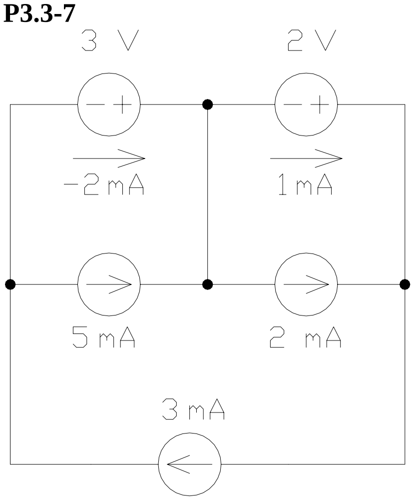
$$6\Omega : P = \frac{v_2^2}{6} = \underline{24\ \text{W}}$$

$$8\Omega : P = \frac{v_1^2}{8} = \underline{8\ \text{W}}$$

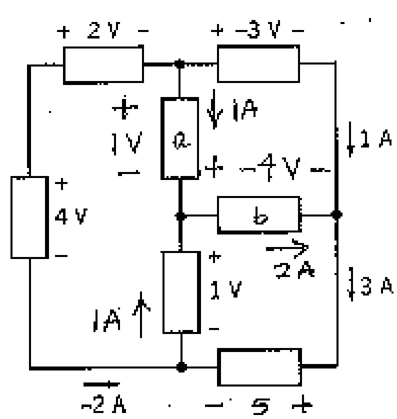
P3.3-6



P3.3-7

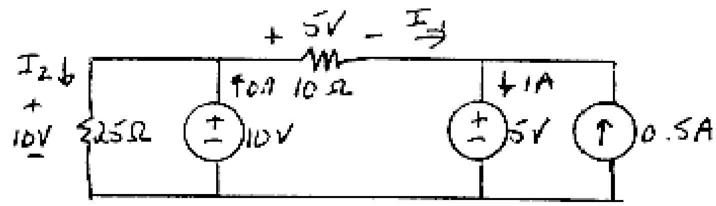


P3.3-8



P_a = (1V) (1A) = <u>+1 Wabsorbed</u>
P_b = (–4V) (2A) = <u>–8 Wabsorbed</u>
= <u>–8 Wabsorbed</u>

P3.3-9



$$I_1 = \frac{5V}{10\Omega} = 0.5\text{ A}$$

$$I_2 = \frac{10V}{25\Omega} = 0.4\text{ A}$$

$$P_{10V} = (-10)\,(0.9) = -9W_{absorbed} = \underline{9W_{delivered}}$$

$$P_{5V} = (5)\,(1) = \underline{5W_{absorbed}}$$

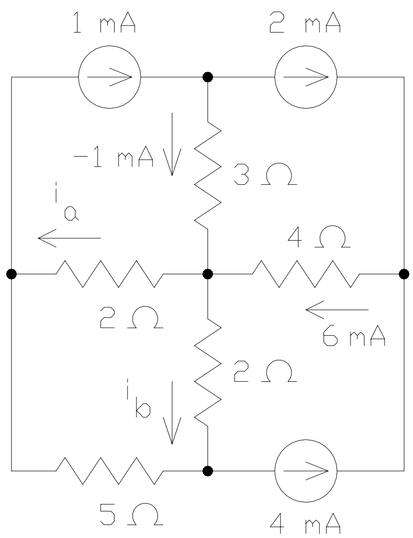
$$P_{0.5A} = (-5)\,(0.5) = -2.5W_{absorbed} = \underline{2.5W_{delivered}}$$

$$P_{10\Omega} = (5)\,(0.5) = \underline{2.5W_{absorbed}}$$

$$P_{25\Omega} = (10)\,(0.4) = \underline{4W_{absorbed}}$$

$$\Sigma\, P_{absorbed} = \underline{0W} \qquad \text{energy balance}$$

P3.3-10



$$i_a + i_b = 6 - 1 = 5\text{ mA} = 0.005\text{ A}$$

$$-2\,i_a + 2i_b - 5\left(i_a - 0.001\right) = 0$$

Solving yields:

$$i_a = 0.00167 = 1.67\text{ mA}$$

$$i_b = 0.005 - i_a = 0.00333 = 3.33\text{ mA}$$

Section 3-4 A Single-Loop Circuit – The Voltage Divider

P3.4-1

$$V_1 = \frac{6}{6+3+5+4}\;12 = \frac{6}{18}\;12 = \underline{4\text{ V}}$$

$$V_2 = \frac{3}{18}\;12 = \underline{2V}\;;\; V_3 = \frac{5}{18}\;12 = \underline{\frac{10}{3}\text{ V}}$$

$$V_4 = \frac{4}{18}12 = \underline{\frac{8}{3}\text{ V}}$$

P3.4-2

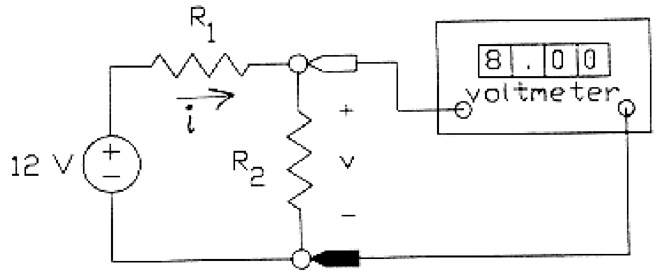
(a) $R = 6 + 3 + 2 + 4 = \underline{15\Omega}$

(b) $i = \frac{28}{R} = \frac{28}{15} = \underline{1.867\text{ A}}$

(c) $P = 28 \cdot i$ (28 and i do not adhere to the passive convention.)

$= 28(1.867) = \underline{52.27\text{ W}}$

P3.4-3



$iR_2 = v = 8\text{ V}$

$12 = iR_1 + v = iR_1 + 8$

$\Rightarrow 4 = iR_1$

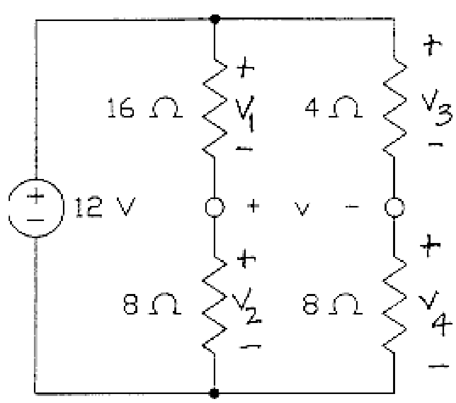
(a) $i = \dfrac{8}{R_2} = \dfrac{8}{100}$; $R_1 = \dfrac{4}{i} = \dfrac{4 \cdot 100}{8} = \underline{50\Omega}$

(b) $i = \dfrac{4}{R_1} = \dfrac{4}{100}$; $R_2 = \dfrac{8}{i} = \dfrac{8 \cdot 100}{4} = \underline{200\Omega}$

(c) $1.2 = 12\, i \Rightarrow i = 0.1\text{ A}$; $R_1 = \dfrac{4}{i} = \underline{40\Omega}$

$R_2 = \dfrac{8}{i} = \underline{80\Omega}$

P3.4-4



Voltage division

$v_1 = \dfrac{16}{16+8} 12 = 8\text{ V}$

$v_3 = \dfrac{4}{4+8} 12 = 4\text{ V}$

KVL: $v_3 - v - v_1 = 0$

$\underline{v = -4\text{ V}}$

P3.4-5

using voltage divider: $v_0 = \left(\dfrac{100}{100+2R}\right) v_s$

$\left.\begin{array}{l} \text{with } v_s = 20\text{ V and } v_0 = 9\text{ V, } R = 61\Omega \\ \text{with } v_s = 28\text{ V and } v_0 = 13\text{ V, } R = 58\Omega \end{array}\right\} \underline{R = 60\Omega}$

Section 3-5 Parallel Resistors and Current Division

P3.5-1

$$i_1 = \frac{\frac{1}{6}}{\frac{1}{6}+\frac{1}{3}+\frac{1}{2}+\frac{1}{1}}\ 4 = \frac{1}{1+2+3+6}\ 4 = \underline{\frac{1}{3}\text{ A}}$$

$$i_2=\frac{\frac{1}{3}}{\frac{1}{6}+\frac{1}{3}+\frac{1}{2}+\frac{1}{1}}\ 4=\underline{\frac{2}{3}\text{ A}};\quad i_3=\frac{\frac{1}{2}}{\frac{1}{6}+\frac{1}{3}+\frac{1}{2}+\frac{1}{1}}\ 4=\underline{1\text{ A}}$$

$$i_4 = \frac{1}{\frac{1}{6}+\frac{1}{3}+\frac{1}{2}+1}\ 4 = \underline{2\text{ A}}$$

P3.5-2

(a) $\frac{1}{R} = \frac{1}{6}+\frac{1}{12}+\frac{1}{4} = \frac{1}{2} \Rightarrow \underline{R = 2}$

(b) $v = 6\cdot 2 = \underline{12\text{ V}}$

(c) $P = 6\cdot 12 = \underline{72\text{ W}}$

P3.5-3

$$i = \frac{8}{R_1} \text{ or } R_1 = \frac{8}{i}$$

$$8 = R_2(2-i) \Rightarrow i = 2-\frac{8}{R_2} \text{ or } R_2 = \frac{8}{2-i}$$

(a) $i = 2-\frac{8}{12} = \underline{\frac{4}{3}\text{ A}}\ ;\ R_1 = \frac{8}{4/3} = \underline{6\Omega}$

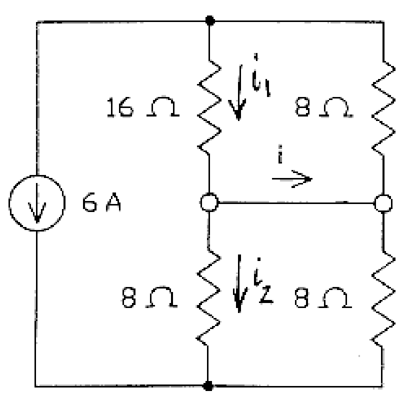
(b) $i = \frac{8}{12} = \underline{\frac{2}{3}\text{ A}}\ ;\ R_2 = \frac{8}{2-\frac{2}{3}} = \underline{6\Omega}$

(c) $R_1=R_2$ will cause $i=\frac{1}{2}2 = 1$ A. The current in both R_1 and R_2 will be 1 A.

$2\cdot\frac{R_1 R_2}{R_1+R_2} = 8$; when $R_1=R_2$ $\quad 2\cdot\frac{1}{2}R_1 = 8 \Rightarrow R_1 = 8$

$\therefore \underline{R_1 = R_2 = 8\Omega}$

P3.5-4



Current division:

$$i_1=\frac{8}{16+8}(-6)=-2\text{ A}$$

$$i_2=\frac{8}{8+8}(-6)=-3\text{ A}$$

$$i = i_1 - i_2 = \underline{+1\text{ A}}$$

P3.5-5 current division: $i_2 = \left(\dfrac{R_1}{R_1 + R_2}\right) i_s$ and Ohm's Law: $v_o = i_2 \, R_2$ yields

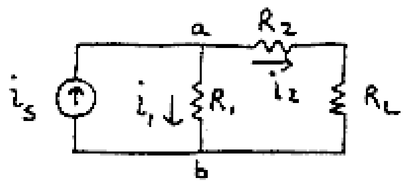
$$i_s = \left(\frac{v_o}{R_2}\right)\left(\frac{R_1+R_2}{R_1}\right)$$

plugging in $R_1 = 4\Omega$, $v_o = 9$ V gives $i_s = 3.15$ A

and $R_1 = 6\Omega$, $v_o = 13$ V gives $i_s = 3.47$ A

So any $\underline{3.15 \text{ A} \le i_s \le 3.47 \text{ A}}$ keeps $9 \text{ V} \le \mathbf{v}_o < 13$ V.

P3.5-6



$$\text{now } i_2 = \frac{v_{ab}}{R_2 + R_L} = \frac{40}{10+30} = 1 \text{ A}$$

$$\text{from KCL : } i_1 = i_s - i_2 = 2 - 1 = 1 \text{ A}$$

$$\therefore \; R_1 = \frac{V_{ab}}{i_1} = \frac{40 \text{ V}}{1 \text{ A}} = \underline{40\Omega}$$

<u>Section 3-7</u> Circuit Analysis

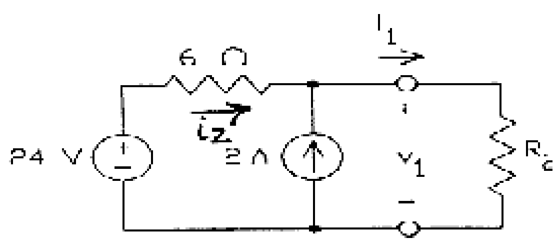
P3.7-1

(a) $$R = 16 + \frac{48 \cdot 24}{48+24} = \underline{32 \ \Omega}$$

(b) $$v = \frac{\dfrac{32 \cdot 32}{32+32}}{8 + \dfrac{32 \cdot 32}{32+32}} 24 = \underline{16 \text{ V}} \; ; \; i = \frac{16}{32} = \underline{\frac{1}{2} \text{ A}}$$

(c) $$i_2 = \frac{48}{48+24} \cdot \frac{1}{2} = \underline{\frac{1}{3} \text{ A}}$$

P3.7-2



(a) $$R_1 = 4 + \frac{3 \cdot 6}{3+6} = \underline{6\Omega}$$

(b) $$\frac{1}{R_p} = \frac{1}{12} + \frac{1}{6} + \frac{1}{6} \Rightarrow R_p = 2.4\Omega$$

$$R_2 = 8 + R_p = \underline{10.4\Omega}$$

(c) $$i_2 + 2 = i_1$$

$$-24 + 6 i_2 + R_2 i_1 = 0$$

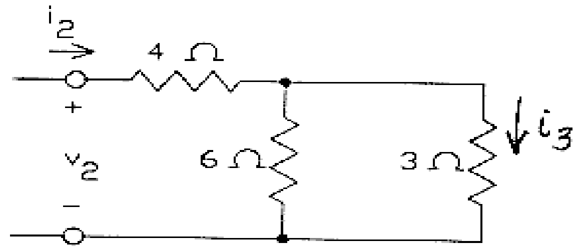
$$-24 + 6(i_1 - 2) + 10.4 i_1 = 0$$

$$i_1 = \frac{36}{16.4} = \underline{2.2 \text{ A}} \quad v_1 = i_1 \, R_2 = 2.2(10.4) = \underline{22.88 \text{ V}}$$

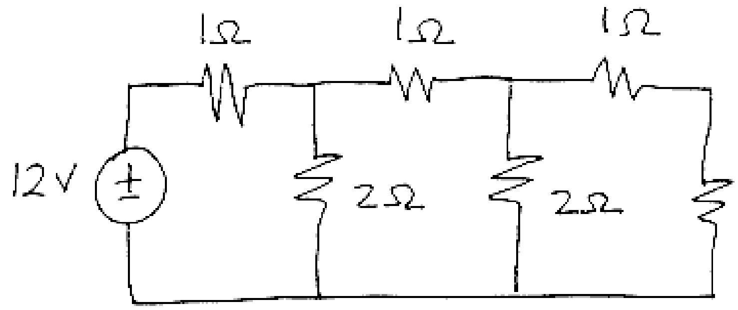
(d) $i_2 = \dfrac{\frac{1}{6}}{\frac{1}{6}+\frac{1}{6}+\frac{1}{12}}\ 2.2 = \underline{0.878\text{ A}},\ v_2 = (0.878)\ (6)\ = \underline{5.3\text{ V}}$

(e) $i_3 = \dfrac{6}{3+6}\, i_2 = 0.585\text{ A}$

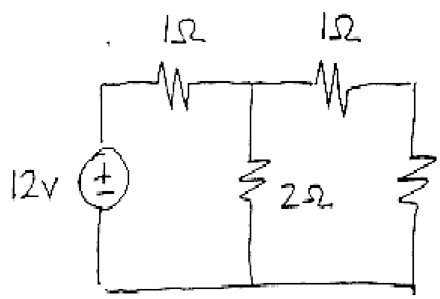
$P = 3i_3^2 = \underline{1.03\text{ W}}$



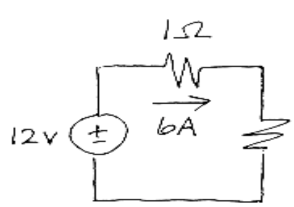
P3.7-3



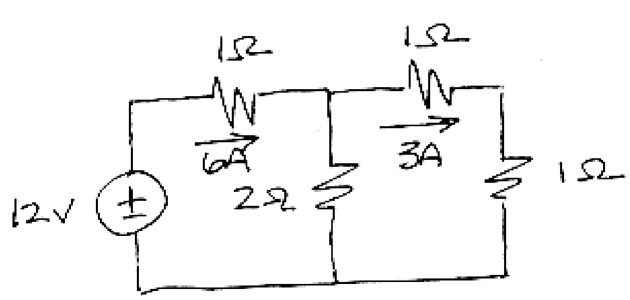
$\dfrac{2(1+1)}{2+(1+1)} = 1\Omega$

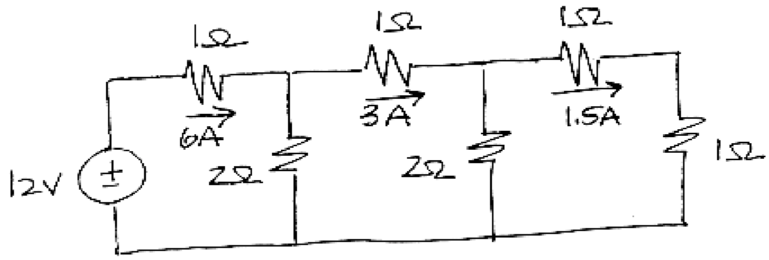


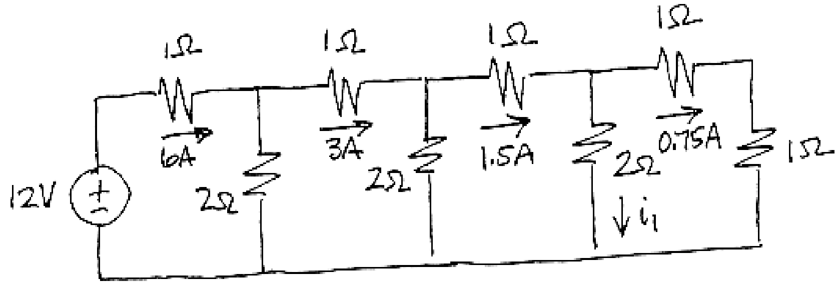
$\dfrac{2(1+1)}{2+(1+1)} = 1\Omega$



$\dfrac{2(1+1)}{2+(1+1)} = 1\Omega$





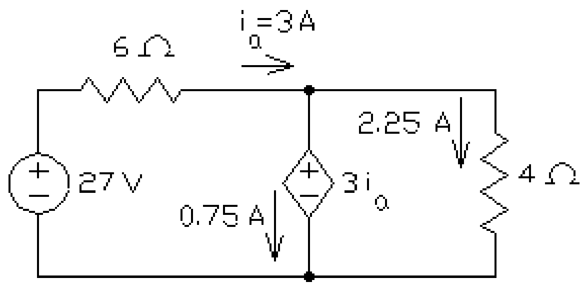


$i_1 = \frac{1}{2}(1.5) = \underline{\frac{3}{4}\text{A}}$

P 3.7-4

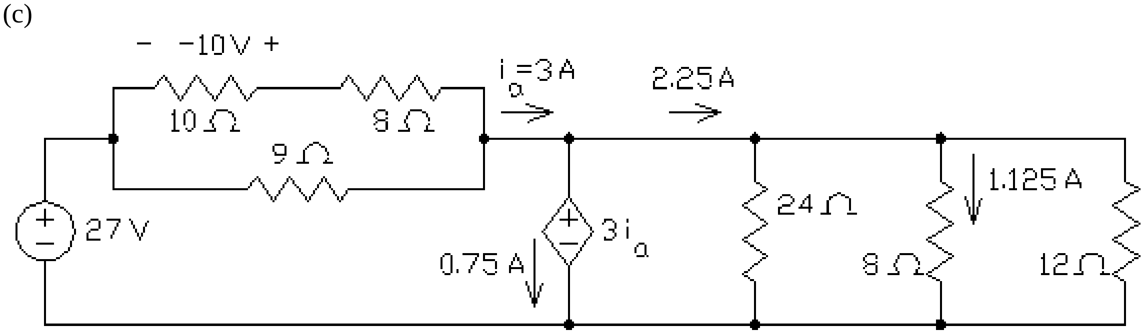
(a) $\frac{1}{R_2} = \frac{1}{24} + \frac{1}{12} + \frac{1}{8} \quad \Rightarrow \quad R_2 = 4\,\Omega$ and $R_1 = \frac{(10+8)\cdot 9}{(10+8)+9} = 6\,\Omega$

(b)



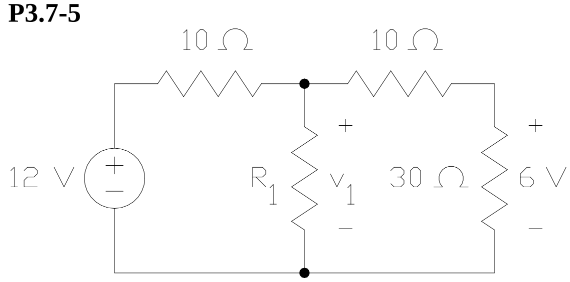
First, apply KVL to the left mesh to get $-27 + 6i_a + 3i_a = 0 \quad \Rightarrow \quad i_a = 3\text{ A}$. Next, apply KVL to the left mesh to get $4i_b - 3i_a = 0 \quad \Rightarrow \quad i_b = 2.25\text{ A}$.

(c)

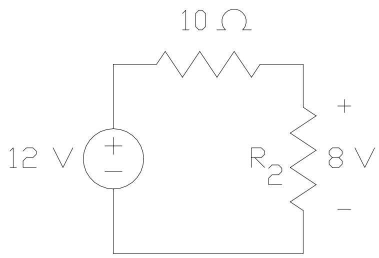


$$i_2 = \frac{\frac{1}{8}}{\frac{1}{24} + \frac{1}{8} + \frac{1}{12}} 2.25 = 1.125\text{ A} \quad \text{and} \quad v_1 = -(10)\left[\frac{9}{(10+8)+9} 3\right] = -10\text{ V}$$

P3.7-5



$$\frac{30}{10+30} v_1 = 6 \quad \Rightarrow \quad v_1 = 8 \text{ V}$$



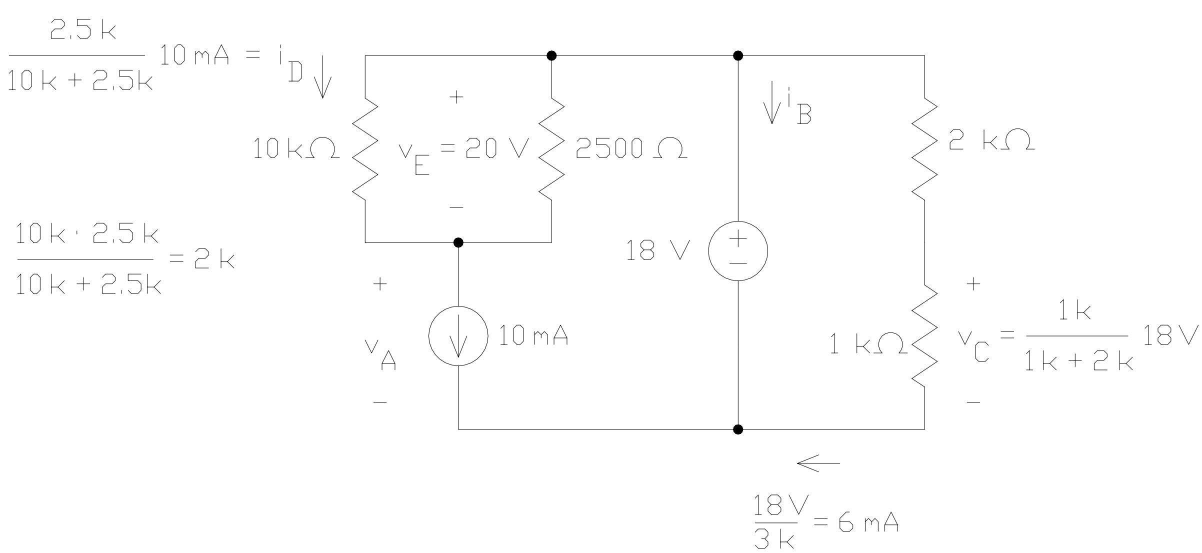
$$\frac{R_2}{R_2+10} 12 = 8 \quad \Rightarrow \quad R_2 = 20\,\Omega$$

$$20 = \frac{R_1(10+30)}{R_1+(10+30)} \quad \Rightarrow \quad R_1 = 40\,\Omega$$

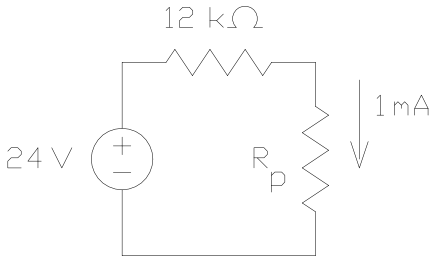
Alternate values that can be used to change the numbers in this problem:

meter reading, V	Right-most resistor, Ω	R_1, Ω
6	30	40
4	30	10
4	20	15
4.8	20	30

P3.7-6



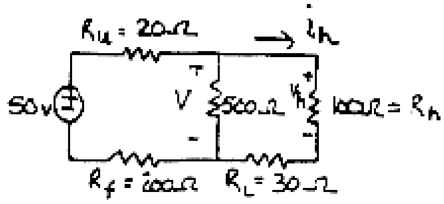
P 3.7-7

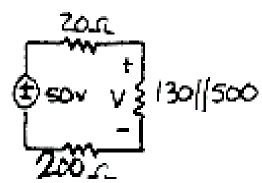


$$1\times10^{-3} = \frac{24}{12\times10^{3}+R_p} \quad \Rightarrow R_p = 12\times10^{3} = 12\ \text{k}\Omega$$

$$12\times10^{3} = R_p = \frac{\left(21\times10^{3}\right)R}{\left(21\times10^{3}\right)+R} \quad \Rightarrow \quad R = 28\ \text{k}\Omega$$

P3.7-





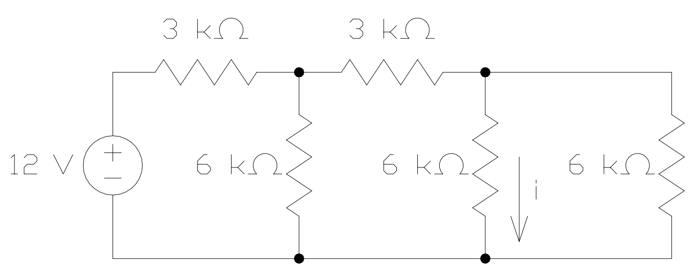
(Note: $R_h = 100\Omega$)

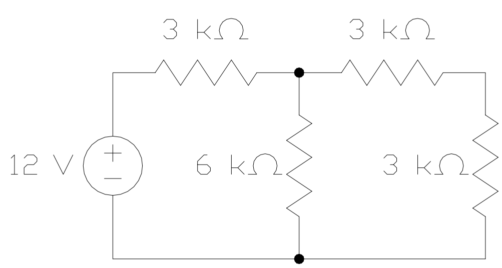
Voltage divider $\Rightarrow$ $v = 50\left(\frac{130\|500}{130\|500+200+20}\right) = 15.963\ \text{V}$

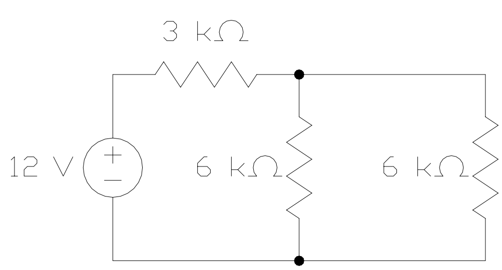
$$\therefore v_h = v\left(\frac{100}{100+30}\right) = (15.963)\left(\frac{10}{13}\right) = \underline{12.279\ \text{V}}$$

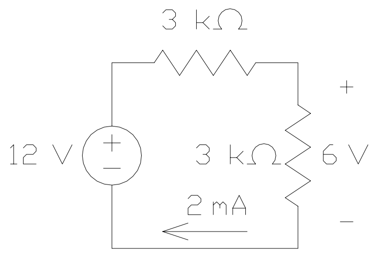
$$\therefore\ i_h = \frac{v_h}{100} = \underline{.12279\ \text{A}}$$

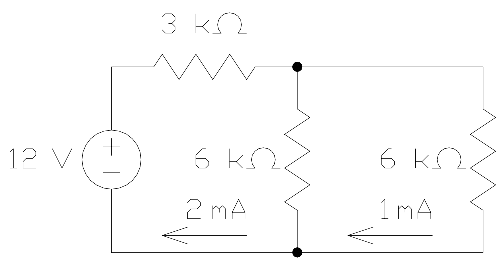
P 3.7-9

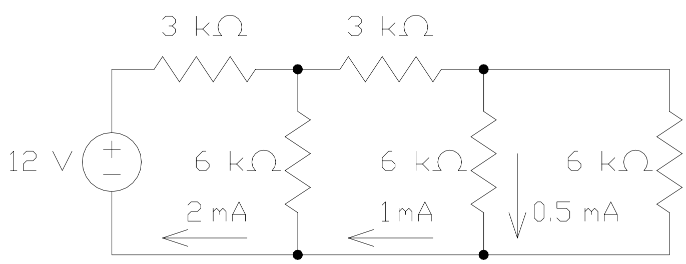






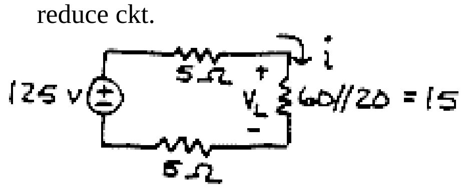






P3.7-10

reduce ckt.



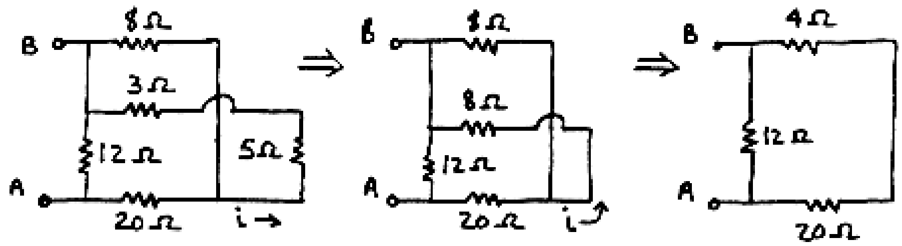
$$i = \frac{125\text{V}}{25\Omega} = 5\text{ A}$$

$$\therefore\ v_L = 15i = 15(5) = 75\text{ V}$$

$$\therefore\ P_L = \frac{{v_L}^2}{R_L} = \frac{(75)^2}{20} = \underline{281.25\text{ W}}$$

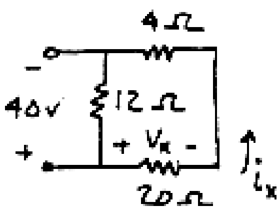
P 3.7-11

a)



$$Req = 24 \| 12 = \frac{(24)(12)}{24 + 12} = \underline{8\Omega}$$

b)



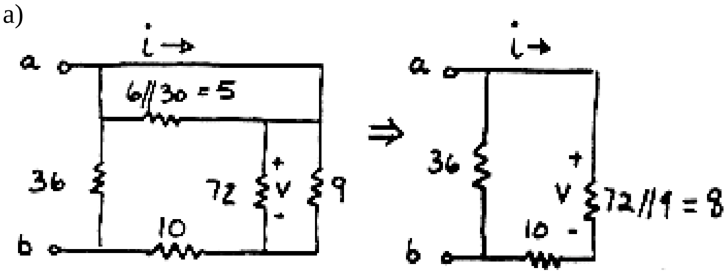
from voltage divider

$$v_x = 40\left(\frac{20}{20+4}\right) = 100/3\,\text{V} \qquad \therefore i_x = \frac{100/3}{20} = \frac{5}{3}\text{A}$$

from current divider $i = i_x\left(\frac{8}{8+8}\right) = \underline{5/6 \text{ A}}$

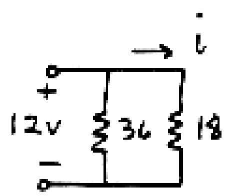
P3.7-12

a)



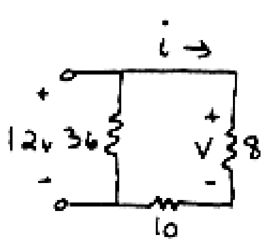
$$Req = 36 \| 18 = \frac{(36)(18)}{36 + 18} = \underline{12\ \Omega}$$

b)



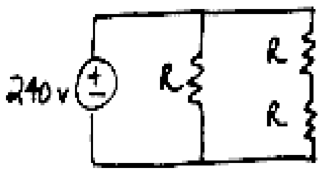
$i = 12/18 = \underline{2/3 \text{ A}}$

c)



$v = i(8) = \left(2/3\right)(8) = \underline{16/3 \text{ V}}$

P3.7-13

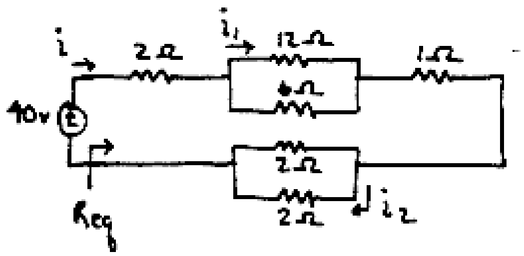


$$R_{eq} = \frac{2R(R)}{2R+R} = \frac{2}{3}R$$

$$P_{\substack{\text{deliv.}\\ \text{to ckt}}} = \frac{v^2}{R_{eq}} = \frac{240}{\frac{2}{3}R} = 1920 \text{ W}$$

Thus $\underline{R = 45\Omega}$

P3.7-14



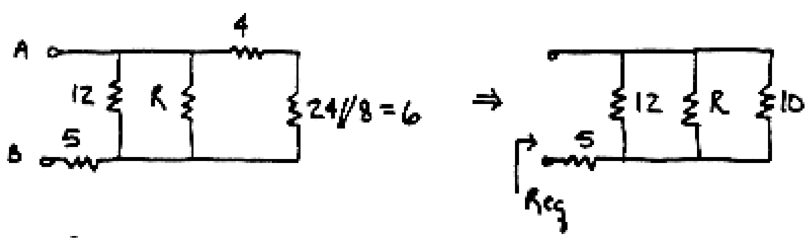
$$R_{eq} = 2+1+\left(6\|12\right)+\left(2\|2\right)$$
$$= 3+4+1 = \underline{8\ \Omega}$$

$$\therefore i = \frac{40}{Req} = \frac{40}{8} = \underline{5\ A}$$

from current divider $i_1 = i\left(\frac{6}{6+12}\right) = (5)\left(\frac{1}{3}\right) = \underline{\frac{5}{3}\ A}$

$$i_2 = i\left(\frac{2}{2+2}\right) = (5)\left(\frac{1}{2}\right) = \underline{\frac{5}{2}\ A}$$

P3.7-15

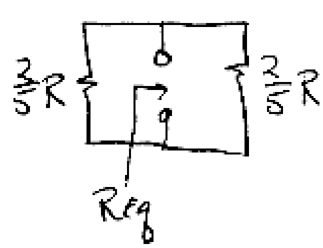


$$Req = 5+\frac{1}{\frac{1}{12}+\frac{1}{R}+\frac{1}{10}} = 9;$$ solving for R yields $\underline{R = 15\Omega}$

P3.7-16

R in parallel with $R = \frac{R}{2}$, R series with $R = 2R$

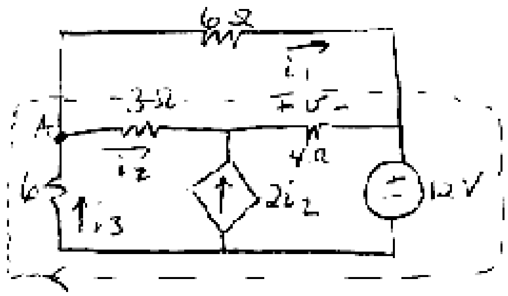
$$\frac{R}{2}\| 2R = \frac{\left(\frac{R}{2}\right)(2R)}{\frac{R}{2}+2R} = \frac{2}{5}R$$ ← same for both sides



$$Req = \frac{\left(\frac{2}{5}R\right)\left(\frac{2}{5}R\right)}{\frac{2}{5}R+\frac{2}{5}R} = \frac{R}{5}$$ but $Req = 20\Omega$, $\therefore$ $\underline{R=100\Omega}$

Verification Problems

VP 3-1



KCL @ A: $i_3 = i_1 + i_2$

$-1.167 = -0.833 + (-0.333)$

$-1.167 = -1.166$ OK

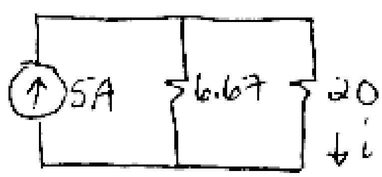
KVL around dotted loop

$6i_3 + 3i_2 + v + 12 = 0$

yields $\underline{v = -4.0\text{ V}}$ $\underline{\text{not}}$ $v = -2.0$ V

VP 3-2

reduce circuit $5 + 5 = 10$ in parallel with 20Ω gives 6.67Ω



by current division;

$$i = \left(\frac{6.67}{20 + 6.67}\right) 5 = \underline{1.25\text{ A}}$$

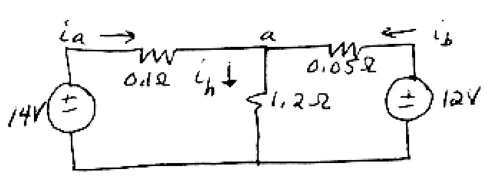
∴ Reported value was correct.

VP 3-3

$$v_0 = \left(\frac{320}{320+650+230}\right)(24) = \underline{6.4\text{ V}}$$

∴ Reported value was incorrect.

VP 3-4



KVL left loop: $-14 + 0.1i_a + 1.2i_h = 0$

KVL right loop: $-12 + 0.05i_b + 1.2i_h = 0$

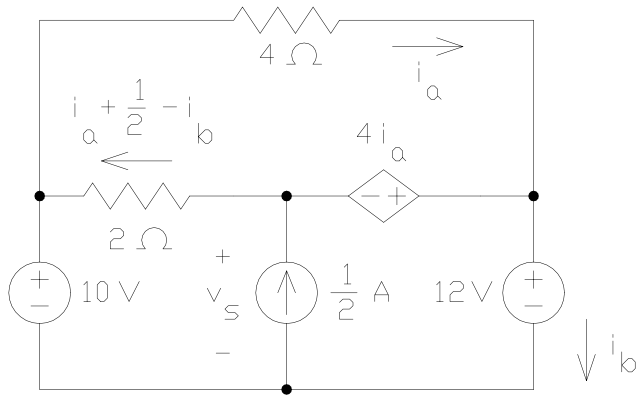
KCL @ a: $i_a + i_b = i_h$ ← This alone shows the reported results were incorrect.

Solving the three above equations yields:

$\underline{i_a = 16.8\text{ A}}$ $\underline{i_h = 10.3\text{ A}}$ ∴ Reported values were incorrect.

$\underline{i_b = -6.49\text{ A}}$

VP3-5



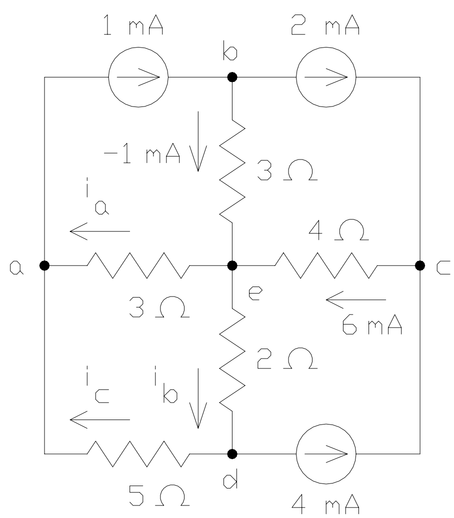
Top mesh: $0 = 4\,i_a + 4\,i_a + 2\left(i_a + \frac{1}{2} - i_b\right) = 10\,(-0.5) + 1 - 2\,(-2)$

Lower left mesh: $v_s = 10 + 2\,(i_a + 0.5 - i_b) = 10 + 2(2) = 14$ V

Lower right mesh: $v_s + 4\,i_a = 12 \quad \Rightarrow \quad v_s = 12 - 4\,(-0.5) = 14$ V

The KVL equations are satisfied so the analysis is correct.

VP 3-6 Apply KCL at nodes b and c to get:



KCL equations:

Node e: $-1 + 6 = 0.5 + 4.5$

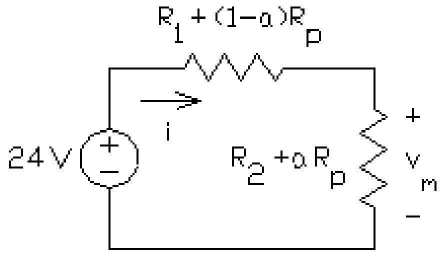
Node a: $0.5 + i_c = -1 \quad \Rightarrow \quad i_c = -1.5$ mA

Node d: $i_c + 4 = 4.5 \quad \Rightarrow \quad i_c = 0.5$ mA

That's a contradiction. The given values of i_a and i_b are not correct.

Design Problems

DP 3-1



Using voltage division:

$$v_m = \frac{R_2 + aR_p}{R_1 + (1-a)R_p + R_2 + aR_p} 24 = \frac{R_2 + aR_p}{R_1 + R_2 + R_p} 24$$

v_m = 8 V when a = 0 $\Rightarrow$

$$\frac{R_2}{R_1 + R_2 + R_p} = \frac{1}{3}$$

v_m = 12 V when a = 1 $\Rightarrow$

$$\frac{R_2 + R_p}{R_1 + R_2 + R_p} = \frac{1}{2}$$

The specification on the power of the voltage source indicates

$$\frac{24^2}{R_1 + R_2 + R_p} \le \frac{1}{2} \quad \Rightarrow \quad R_1 + R_2 + R_p \ge 1152\ \Omega$$

Try R_p = 2000 Ω. Substituting into the equations obtained above using voltage division gives $3R_2 = R_1 + R_2 = 2000$ and $2(R_2 + 2000) = R_1 + R_2 + 2000$. Solving these equations gives $R_1 = 6000\ \Omega$ and $R_2 = 2000\ \Omega$.

With these resistance values, the voltage source supplies 48 mW while R_1, R_2 and R_p dissipate 12 mW, 4 mW and 8 mW respectively. Therefore the design is complete.

DP 3-2

Try $R_2 = \infty$. That is, R_2 is an open circuit. From KVL, 8 V will appear across R1. Using voltage division, $\frac{200}{R_1+200}12 = 4 \quad \Rightarrow \quad R_1 = 400\ \Omega$. The power required to be dissipated by R_1 is $\frac{8^2}{400} = 0.16\text{ W} < \frac{1}{8}\text{ W}$. To reduce the voltage across any one resistor, let's implement R1 as the series combination of two 200 Ω resistors. The power required to be dissipated by each of these resistors is $\frac{4^2}{200} = 0.08\text{ W} < \frac{1}{8}\text{ W}$.

Now let's check the voltage:

$$11.88\frac{190}{190+420} < v_0 < 12.12\frac{210}{210+380}$$

$$3.700 < v_0 < 4.314$$

$$4-7.5\% < v_0 < 4+7.85\%$$

Hence, $v_o = 4\text{ V} \pm 8\%$ and the design is complete.

DP 3-3

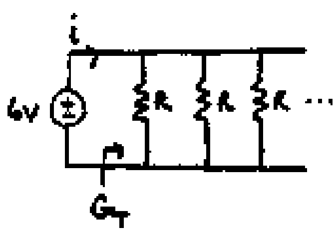
$$v_{ab} \cong 200\text{mV}$$

$$v = \frac{10}{10+R}\ 120V_{ab} = \frac{10}{10+R}(120)(.2)$$

$$\text{let } v = 16 = \frac{240}{10+R} \Rightarrow \underline{R = 5\Omega}$$

$$\therefore\ P = \frac{16^2}{10} = \underline{25.6\text{W}}$$

DP 3-4



$$i = G_T v = \frac{N}{R}v$$

$$\text{where } G_T = \sum_{n=1}^{N}\frac{1}{R_n} = N\left(\frac{1}{R}\right)$$

$$\therefore\ N = \frac{iR}{v} = \frac{(9)(12)}{6} = \underline{18\text{ bulbs}}$$