Resistive Circuits

(Chapter 3)

Textbook:

Electric Circuits

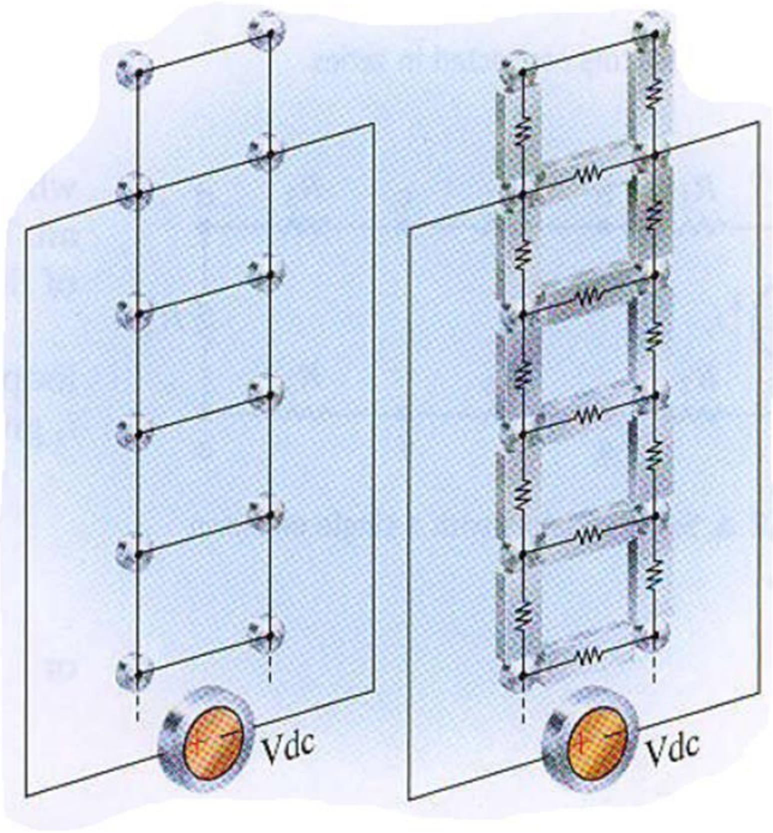
James W. Nilsson & Susan A. Riedel

9th Edition.

Link to download materials: **Blackboard**

Practical Perspective A Rear Window Defroster

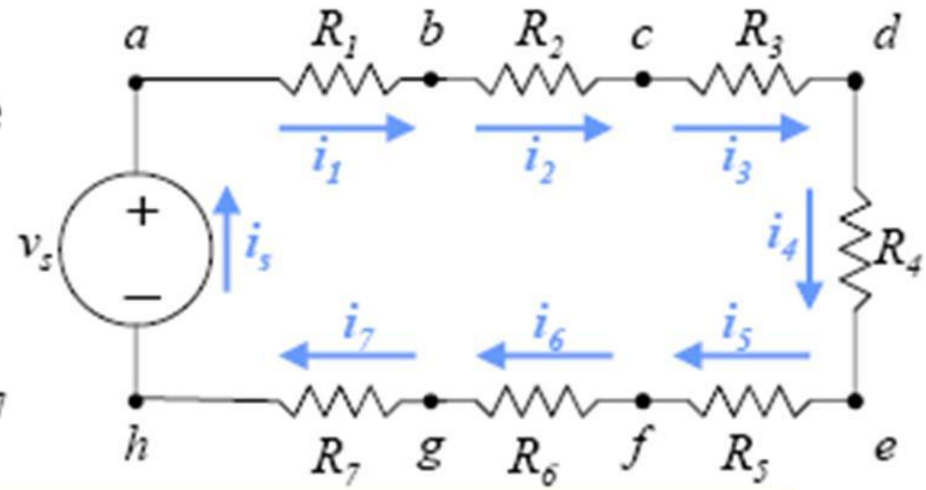
The rear window defroster grid on an automobile is an example of a resistive circuit that performs a useful function.



How does this grid work to defrost the rear window?
How are the properties of the grid determined?

Resistors in series

- Just two elements connected at a single node are said to be in series.
- Applying KCL at all nodes.



$$i_s = i_1 = i_2 = i_3 = i_4 = i_5 = i_6 = i_7$$

Series-connected circuit elements carry the same current

- Applying KVL

$$-v_s + i_s R_1 + i_s R_2 + i_s R_3 + i_s R_4 + i_s R_5 + i_s R_6 + i_s R_7 = 0$$

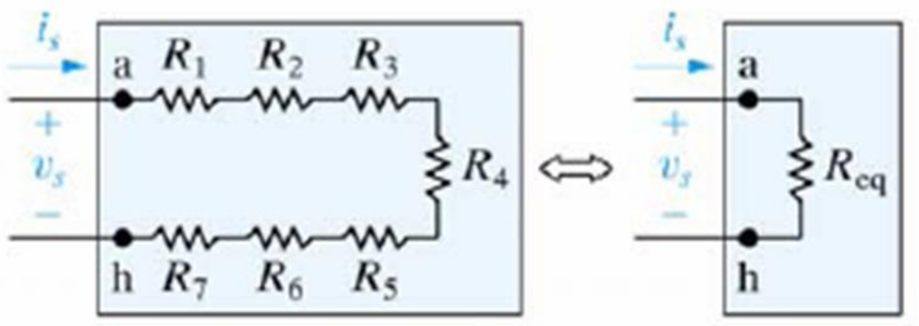
or $$v_s = i_s \underbrace{\left(R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7\right)}_{R_{eq}}$$

$$R_{eq} = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7 \longrightarrow \boxed{v_s = i_s R_{eq}}$$

Resistors in series (cont.)

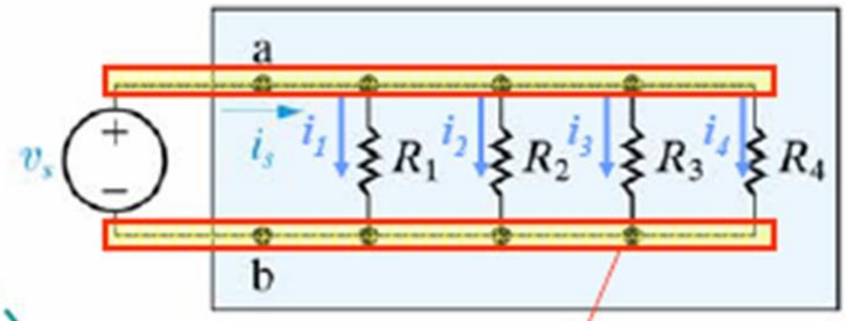
- In general, if k resistors are connected in series, the equivalent single resistor has a resistance equal to the sum of the k resistances, or

$$\boxed{R_{eq} = \sum_{i=1}^{k} R_i = R_1 + R_2 + \ldots + R_k}$$



Resistors in parallel

- When two elements connect at a single <u>node</u> <u>pair</u>, they are said to be connected in parallel.
- Parallel-connected circuit elements have the same voltage across their terminals.



- Applying KCL

$$i_s = i_1 + i_2 + i_3 + i_4$$

- From Ohm's law

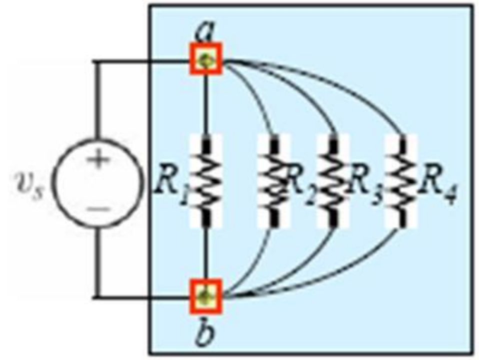
$$i_1 R_1 = i_2 R_2 = i_3 R_3 = i_4 R_4 = v_s$$

- Therefore

$$i_1 = \frac{v_s}{R_1},\ i_2 = \frac{v_s}{R_2},\ i_3 = \frac{v_s}{R_3}\ \&\ i_4 = \frac{v_s}{R_4}$$

$$i_s = \frac{v_s}{R_1} + \frac{v_s}{R_2} + \frac{v_s}{R_3} + \frac{v_s}{R_4}$$

Same node "No elements connected between nodes"



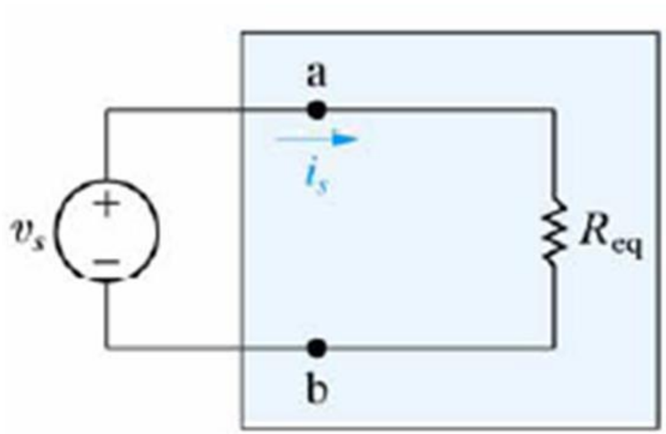
Resistors in parallel (cont.)

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

$$\frac{i_s}{v_s} = \frac{1}{R_{eq}} = \left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)$$

$$\frac{1}{R_{eq}} = \sum_{i=1}^{k}\frac{1}{R_i} = \left(\frac{1}{R_1}+\frac{1}{R_2}+\ldots+\frac{1}{R_k}\right)$$

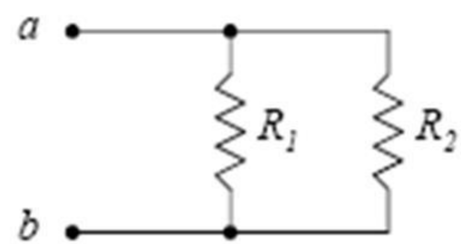
$$G_{eq} = \sum_{i=1}^{k} G_i = \left(G_1+G_2+\ldots+G_k\right)$$



- Special Case (two resistors in parallel)

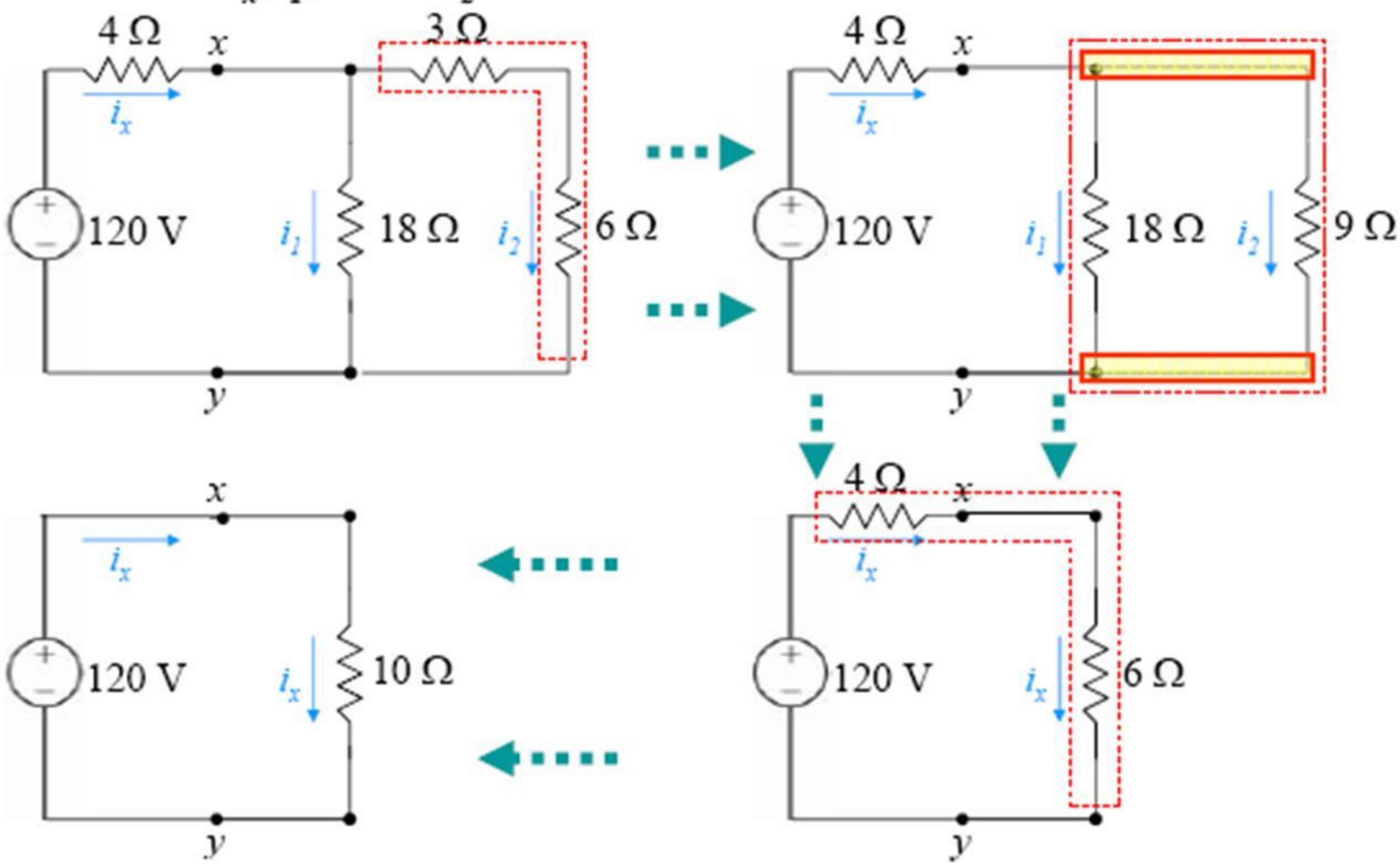
$$\frac{1}{R_{eq}} = \frac{1}{R_1}+\frac{1}{R_2} = \frac{R_1+R_2}{R_1R_2}$$

$$R_{eq} = \frac{R_1R_2}{R_1+R_2}$$

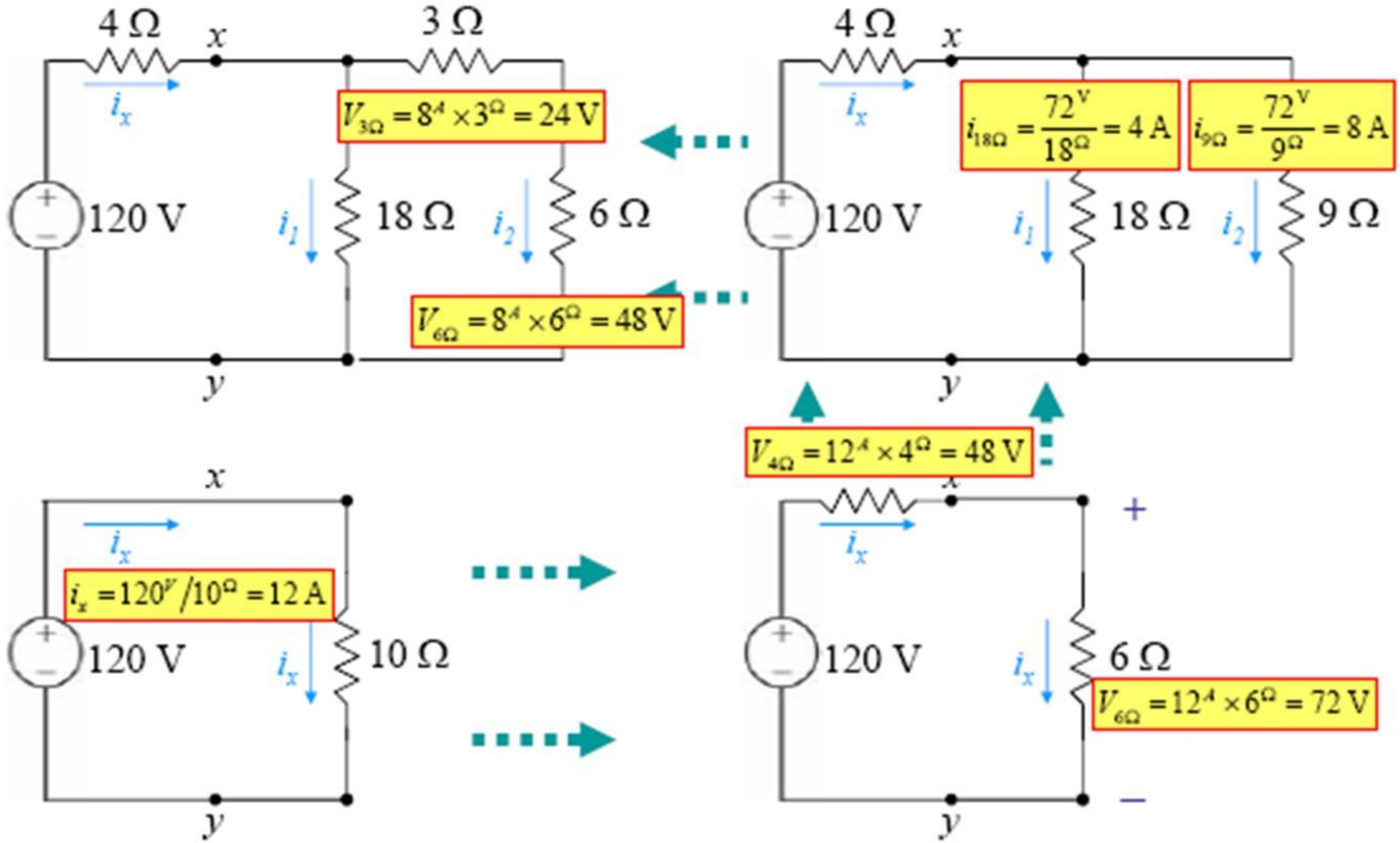


Example 3.1

- Find i_x, i_1, and i_2?



Example (Cont.)



Assessing Objective 1

- Find (a) v, (b) power delivered to the circuit by the current source, and (c) the power dissipated in the 10 Ω resistor.

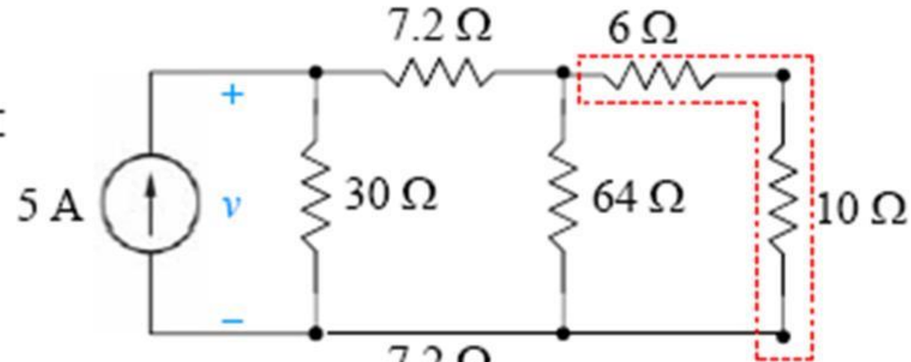
Ans.:

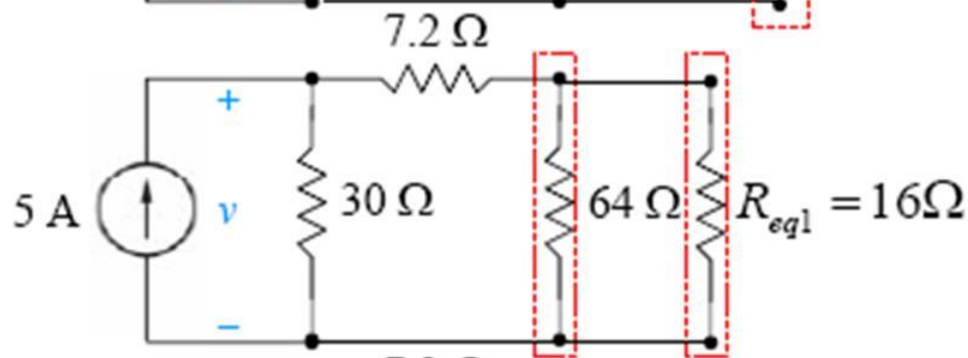
- The 6 Ω is in series with the 10 Ω,

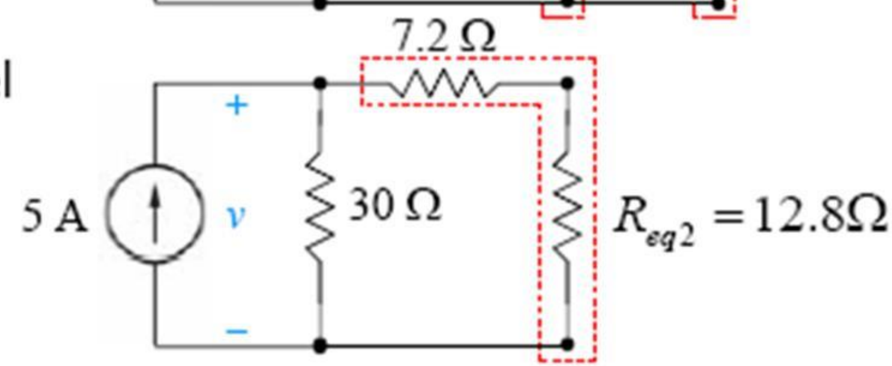
$$R_{eq1} = 6 + 10 = 16\,\Omega$$

- The 16 Ω is in parallel with the 64 Ω,

$$R_{eq2} = \frac{16 \times 64}{16 + 64} = 12.8\,\Omega$$







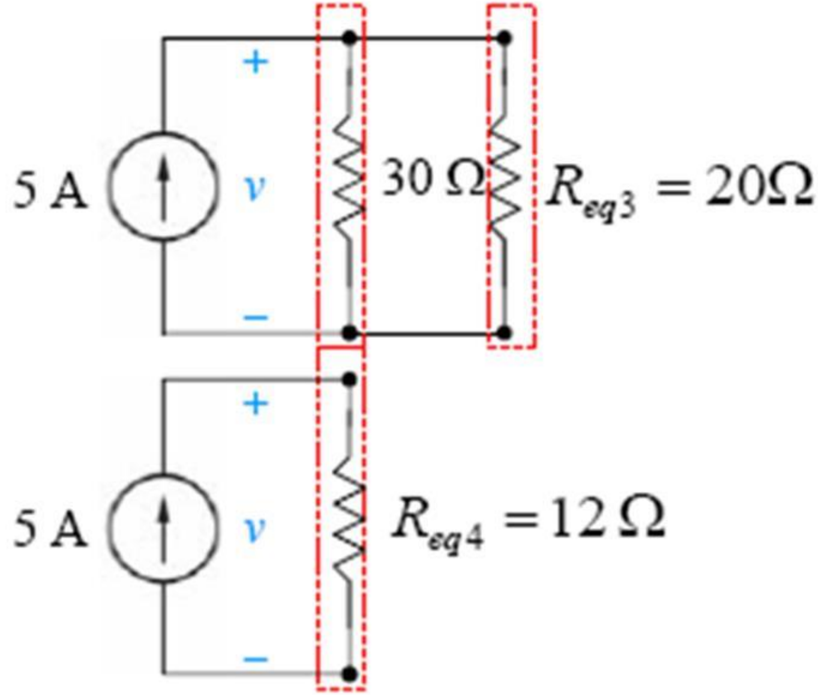
Example (cont.)

- The 12.8 Ω is in series with the 7.2 Ω,

$$R_{eq3} = 7.2 + 12.8 = 20\,\Omega$$

- The 30 Ω is in parallel with the 20 Ω,

$$R_{eq4} = \frac{30 \times 20}{30 + 20} = 12\,\Omega$$

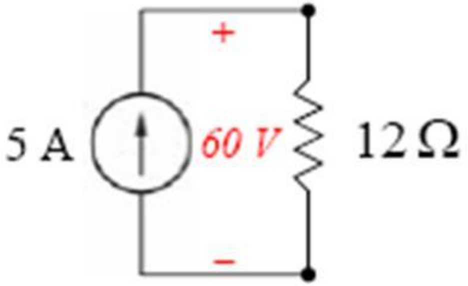


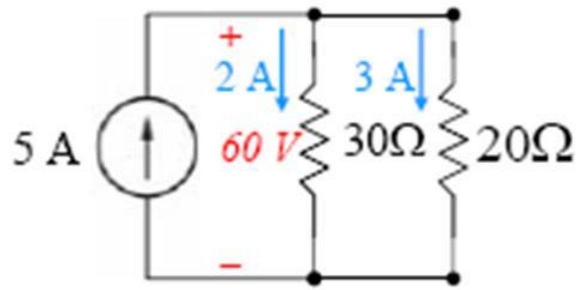
- Now applying Ohm's Law $v = iR_{eq4} = 5^{A}12^{\Omega} = 60\text{ V}$

- Power delivered by the current source

$$p = iv = 5^{A}60^{V} = 300\text{ W}$$

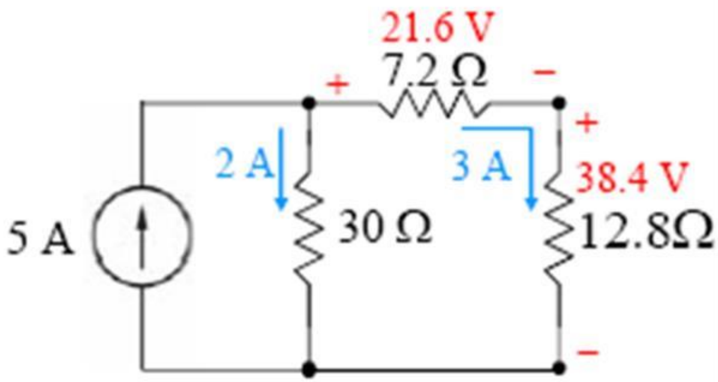
Example (cont.)





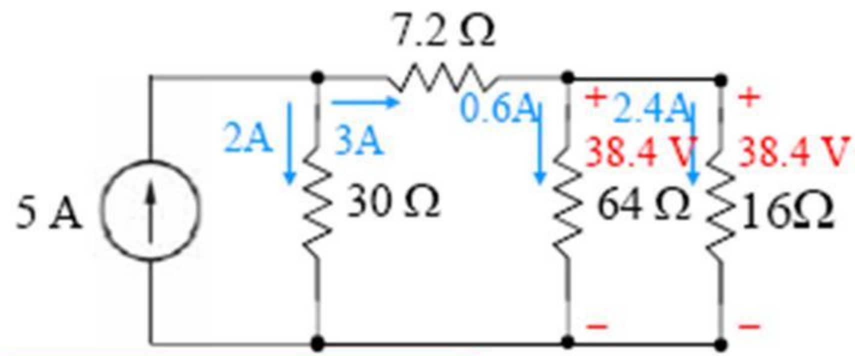
$$i_{30\Omega} = \frac{60^{V}}{30^{\Omega}} = 2\text{ A}$$

$$i_{20\Omega} = \frac{60^{V}}{20^{\Omega}} = 3\text{ A}$$



$$v_{7.2\Omega} = 3^{A} \times 7.2^{\Omega} = 21.6\text{ V}$$

$$v_{12.8\Omega} = 3^{A} \times 12.8^{\Omega} = 38.4\text{ V}$$



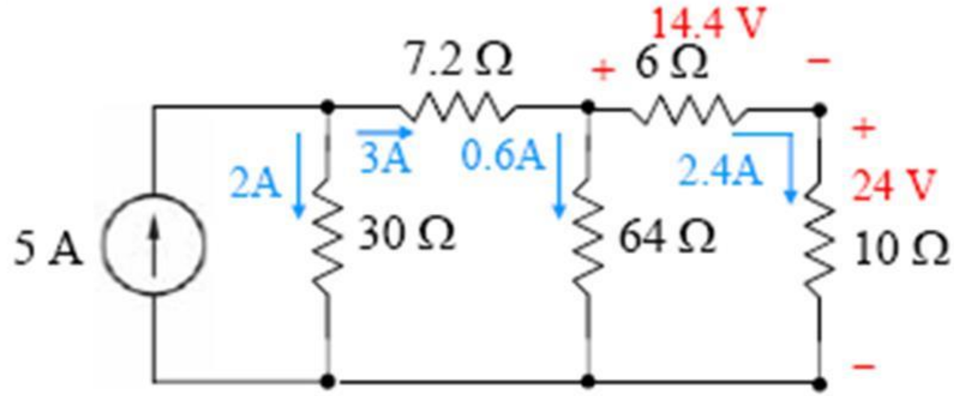
$$i_{64\Omega} = \frac{38.4^{V}}{64^{\Omega}} = 0.6\text{ A}$$

$$i_{16\Omega} = \frac{38.4^{V}}{16^{\Omega}} = 2.4\text{ A}$$

Example (cont.)

$$\boxed{v_{6\Omega} = 2.4^{A} \times 6^{\Omega} = 14.4\ \text{V}}$$

$$\boxed{v_{10\Omega} = 2.4^{A} \times 10^{\Omega} = 24\ \text{V}}$$

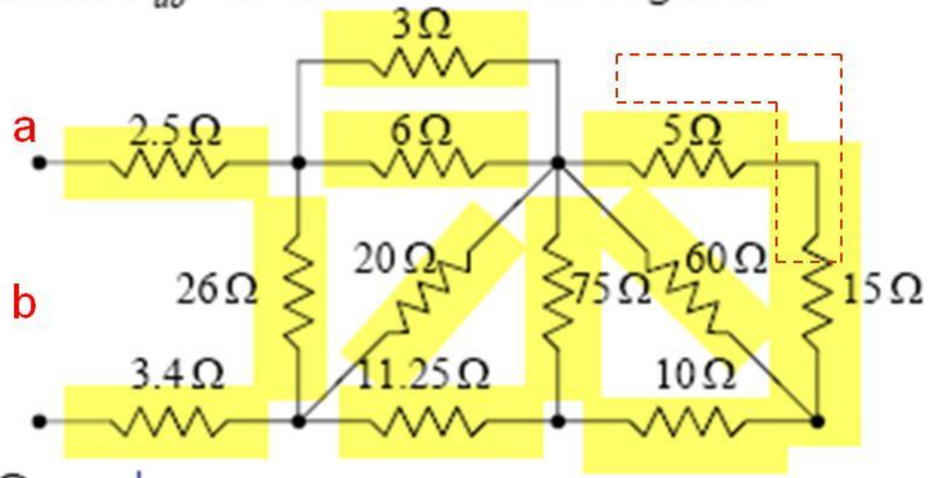


- The power dissipated in the 10 Ω resistor

$$\boxed{p_{10\Omega} = 2.4^{A} \times 24^{V} = 57.6\ \text{W}}$$

Problems

- Find the equivalent resistance R_{ab} for the circuit in Figure.



$R_{5\Omega}$ & $R_{15\Omega}$ are in series

$$R_{eq1} = R_{5\Omega} + R_{15\Omega} = 20\Omega$$

$$R_{eq2} = R_{eq1} \,//\, R_{60\Omega} = \frac{20 \times 60}{20 + 60} = 15\Omega$$

$$R_{eq3} = R_{eq2} + R_{10\Omega} = 15 + 10 = 25\Omega$$

$$R_{eq4} = R_{eq3} \,//\, R_{75\Omega} = \frac{25 \times 75}{25 + 75} = 18.75\Omega$$

$$R_{eq5} = R_{eq4} + R_{11.25\Omega} = 18.75 + 11.25 = 30\Omega$$

$$R_{eq6} = R_{eq5} \,//\, R_{20\Omega} = \frac{30 \times 20}{30 + 20} = 12\Omega$$

$$R_{eq7} = R_{3\Omega} \,//\, R_{6\Omega} = \frac{3 \times 6}{3 + 6} = 2\Omega$$

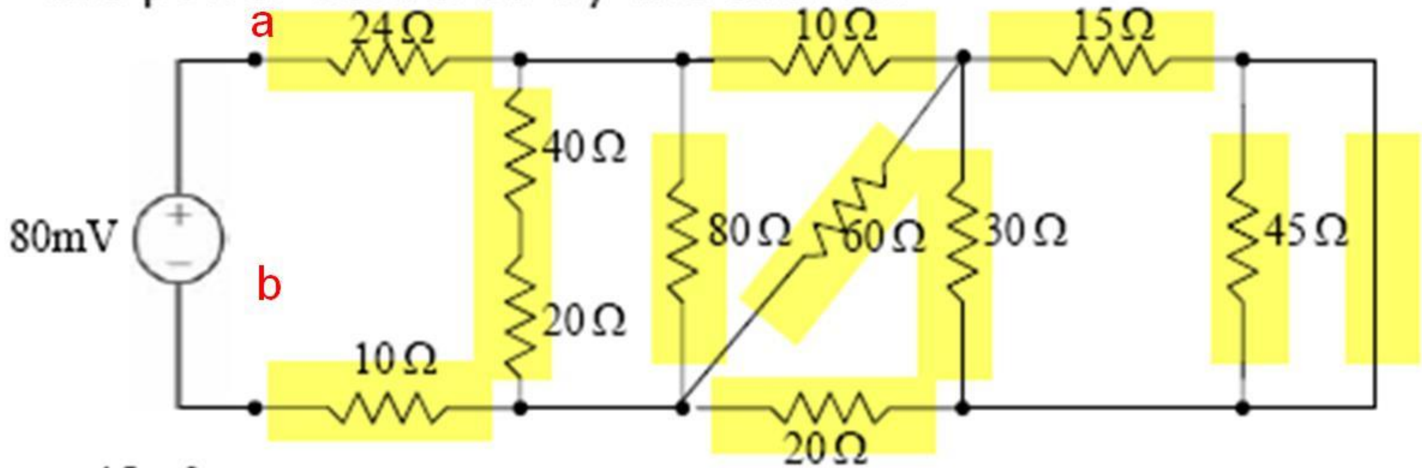
$$R_{eq8} = R_{eq6} + R_{eq7} = 2 + 12 = 14\Omega$$

$$R_{eq9} = R_{eq8} \,//\, R_{26\Omega} = \frac{14 \times 26}{14 + 26} = 9.1\Omega$$

$$R_{eq10} = R_{2.5\Omega} + R_{eq9} + R_{3.4\Omega} = \underline{15\Omega}$$

Problems

- In the circuit shown, find the equivalent resistance R_{ab}, and the power delivered by the source.



$$R_{eq1} = \frac{45 \times 0}{45 + 0} = 0\Omega \text{ (Short Circuit)}$$

$$R_{eq2} = \frac{15 \times 30}{15 + 30} = 10\Omega$$

$$R_{eq3} = 30 + 20 = 50\Omega$$

$$R_{eq4} = \frac{30 \times 60}{30 + 60} = 20\Omega$$

$$R_{eq5} = 10 + 20 = 30\Omega$$

$$R_{eq6} = \frac{1}{\frac{1}{60} + \frac{1}{80} + \frac{1}{30}} = 16\Omega$$

$$R_{eq7} = 24 + 16 + 10 = 50\Omega$$

$$P_{80mV} = \frac{\left(80 \times 10^{-3}\right)^2}{50} = 128\mu W$$

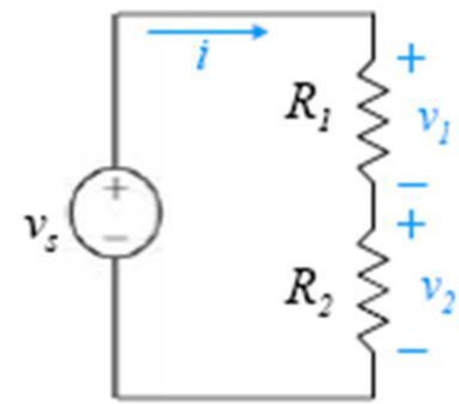
The voltage-divider circuit

Apply KVL

$$v_s = iR_1 + iR_2$$

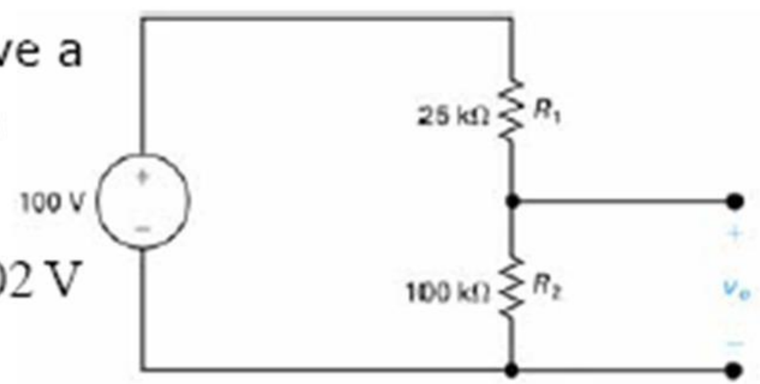
$$i = \frac{v_s}{R_1 + R_2}$$

$$v_1 = iR_1 = v_s \frac{R_1}{R_1 + R_2} \quad \& \quad v_2 = iR_2 = v_s \frac{R_2}{R_1 + R_2}$$



Example:

If the resistors used in the circuit have a tolerance of ±10%. Find v_{omax} and v_{omin}



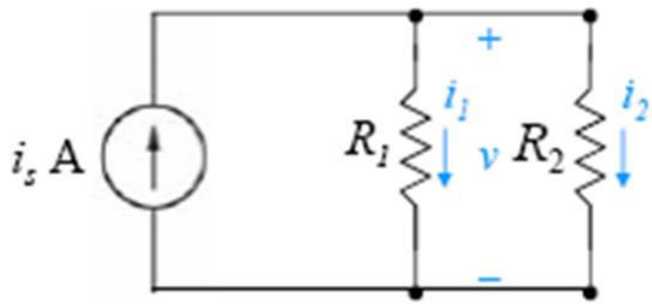
Ans.:-

$$v_o(\mathrm{max}) = 100\frac{100\times1.1}{100\times1.1+25\times0.9} = 83.02\ \mathrm{V}$$

$$v_o(\mathrm{min}) = 100\frac{100\times0.9}{100\times0.9+25\times1.1} = 76.60\ \mathrm{V}$$

The current-divider circuit

$R_1 // R_2 \Longrightarrow R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$



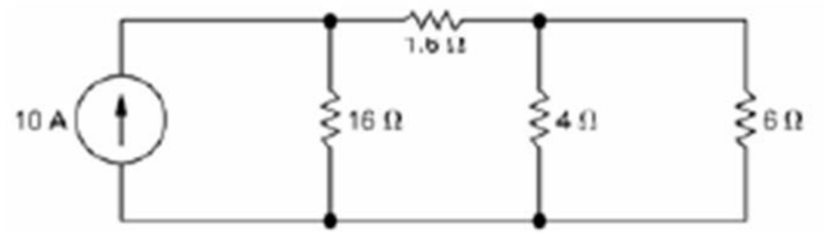
Ohm's Law

$$v = i_1 R_1 = i_2 R_2 = i_s R_{eq} = i_s \frac{R_1 R_2}{R_1 + R_2}$$

$$i_1 = \frac{R_2}{R_1 + R_2} i_s \quad \& \quad i_2 = \frac{R_1}{R_1 + R_2} i_s$$

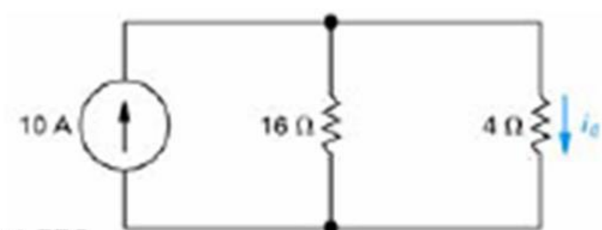
Example:

Find the power dissipated in the 6 Ω resistor



Ans.:- $6\,\Omega // 4\,\Omega + 1.6\,\Omega$

$$R_{eq} = \frac{4 \times 6}{4 + 6} + 1.6 = 4\,\Omega$$



Using Current Divider

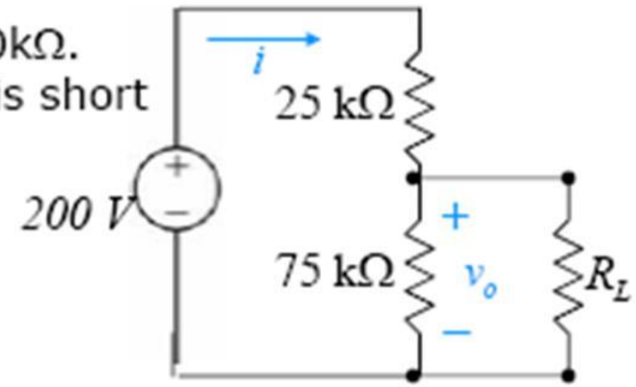
$$i_o = \frac{16}{16 + 4} 10 = 8\text{ A}$$

Using Current Divider

$$i_6 = \frac{4}{4 + 6} 8 = 3.2\text{ A} \qquad P_6 = i_{6\Omega}^2 R_{6\Omega} = 61.44\text{ W}$$

Assessing Objective 2

Find (a) v_o at no load, (b) v_o when R_L=150kΩ. (c) Power dissipated in 25 kΩ if the load is short circuited. (d) max. power in 75 kΩ.



Ans.:-

(a) $v_o = 200\dfrac{75k}{75k+25k} = 150\ \text{V}$

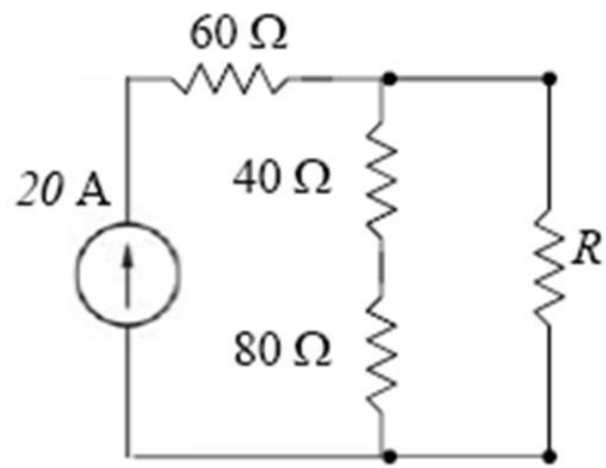
(b) $R_{eq} = \dfrac{75k \times 150k}{75k+150k} = 50k\Omega \Rightarrow v_o = 200\dfrac{50k}{50k+25k} = 133.33\ \text{V}$

(c) $P_{25k\Omega} = \dfrac{V^2}{R_{25k\Omega}} = \dfrac{200^2}{25k} = 1.6\ \text{W}$

(d) $P_{75k\Omega}^{\max} = \dfrac{V^2}{R_{75k\Omega}} = \dfrac{150^2}{75k} = 0.3\ \text{W}$

Assessing Objective

Find (a) R so $i_{80\Omega}$=4A, (b) $P_{R\Omega}$, (c) P_{20A}



Ans.:-

(a) $i_{80\Omega} = 4 = \dfrac{R}{R+80+40}20 \Rightarrow R = 30\Omega$

(b) $P_{R\Omega} = i_{R\Omega}^2 R = 7680\ \Omega$

(c) $V_{20A} = 20^A \times 60^\Omega + 4^A \times 120^\Omega = 1680\ \mathrm{V}$

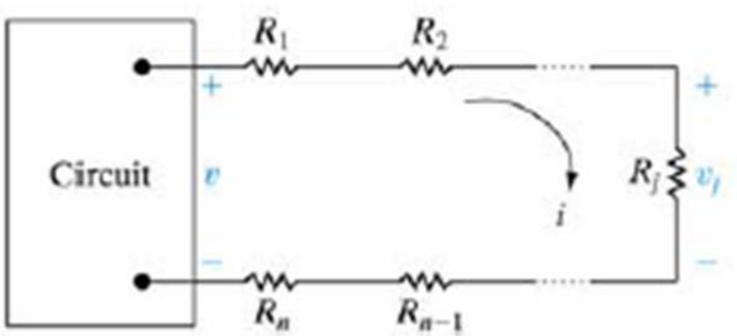
$P_{20A} = 20^A \times 1680^V = 33600\ \mathrm{W}$

Voltage Division and Current Division

$$i = \frac{v}{R_1 + R_2 + \ldots + R_n} = \frac{v}{R_{eq}}$$

$$v_j = iR_j$$

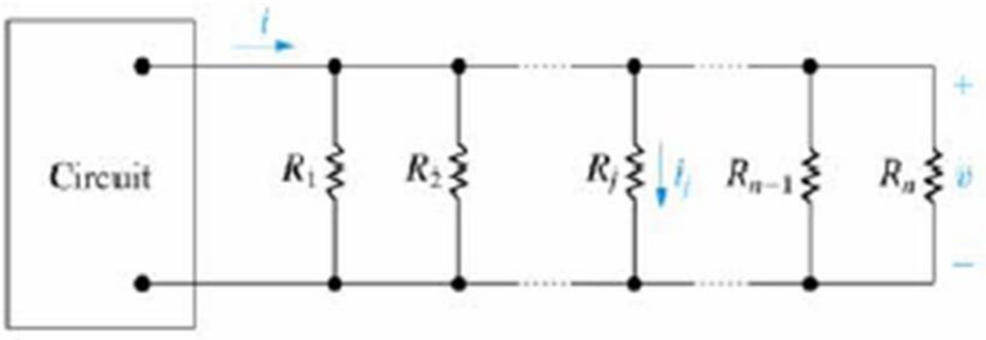
$$\boxed{v_j = \frac{R_j}{R_{eq}} v}$$



$$v = i(R_1 \| R_2 \| \ldots \| R_n) = iR_{eq}$$

$$v = i_j R_j$$

$$\boxed{i_j = \frac{R_{eq}}{R_j} i}$$

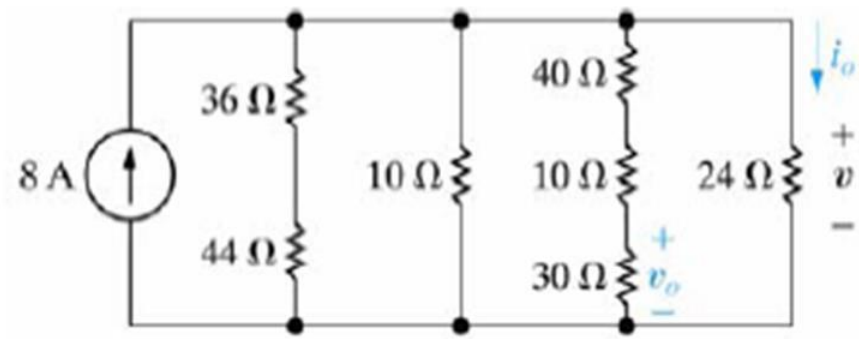


Example 3.4

Use current division to find i_o and voltage division to find v_o

Ans.:-

$$R_{eq} = \frac{1}{\frac{1}{80}+\frac{1}{10}+\frac{1}{80}+\frac{1}{24}} = 6\,\Omega$$



Current Division

$$i_o = \frac{6}{24} 8^{A} = 2\text{ A}$$

Ohm's Law

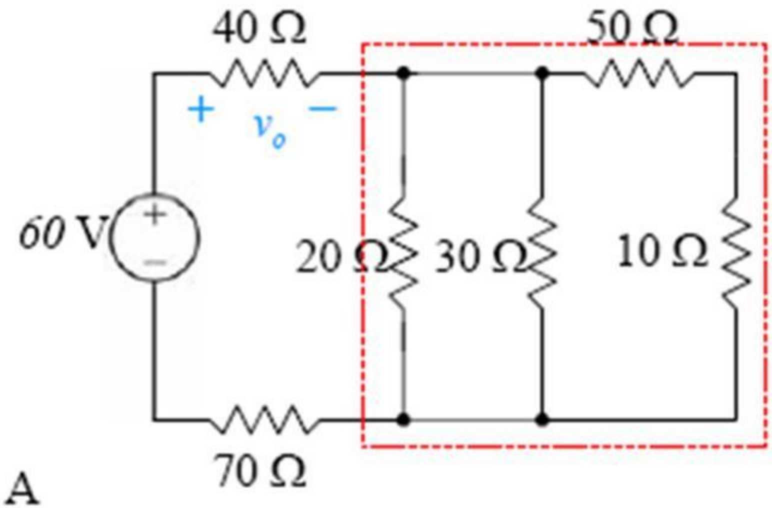
$$v_{24} = 2^{\text{A}} 24^{\Omega} = 48\text{ V}$$

Voltage Division

$$v_o = 48^{\text{V}} \frac{30^{\Omega}}{80^{\Omega}} = 18\text{ V}$$

Assessing Objective 3

Use voltage division & current division to find (a) v_o, (b) $i_{40\Omega}$ & $i_{30\Omega}$, (c) $P_{50\Omega}$.



Ans.:-

(a) $$R_{eq1} = \frac{1}{\frac{1}{20}+\frac{1}{30}+\frac{1}{60}} = 10\,\Omega$$

$$v_o = 60^V \frac{40}{40+10+70} = 20\text{ V}$$

(b) $$i_{40\Omega} = \frac{60^V}{120^\Omega} = 0.5\text{ A}$$

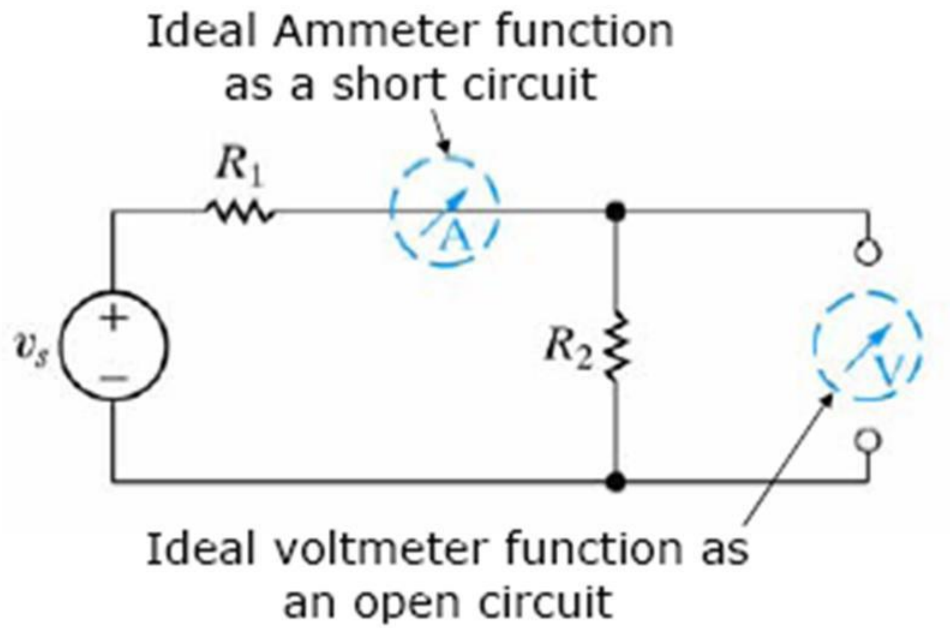
$$i_{30\Omega} = i_{40\Omega}\frac{R_{eq1}}{R_{30\Omega}} = 0.5^A \frac{10}{30} = 0.1667\text{ A}$$

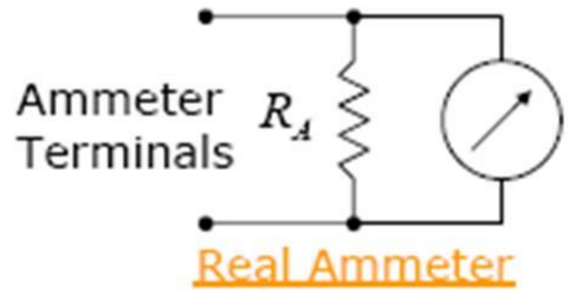
(c) $$v_{R_{eq1}} = 60^V \frac{10}{40+10+70} = 5\text{ V} \Rightarrow v_{50\Omega} = 5^V \frac{50}{50+10} = 4.1667\text{ V}$$

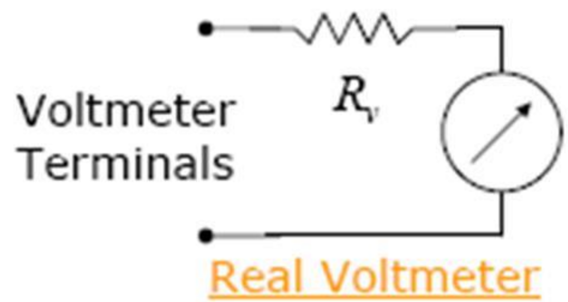
$$P_{50\Omega} = \frac{V_{50\Omega}^2}{R_{50\Omega}} = 0.3472\text{ W}$$

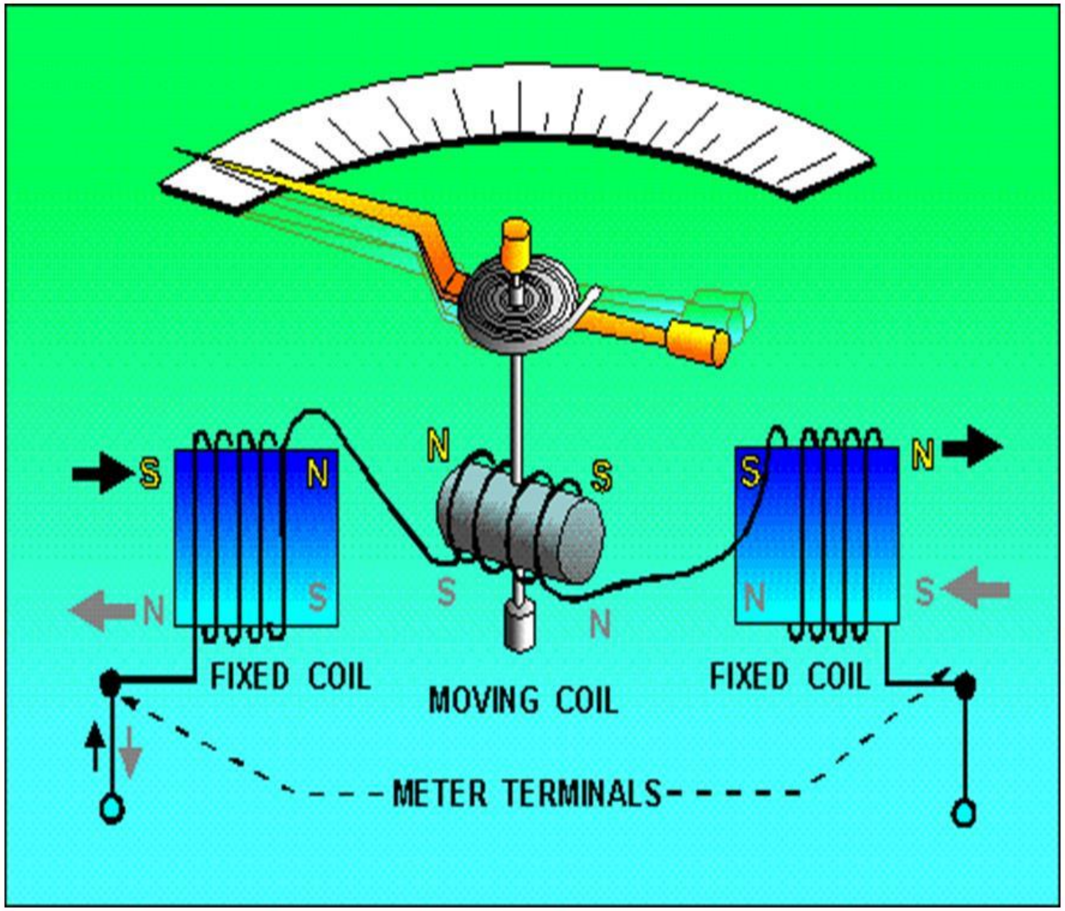
Measuring Voltage and Current

- An ammeter is an instrument designed to measure current; it is placed in series with the circuit element whose current is being measured.
- A voltmeter is an instrument designed to measure voltage; it is placed in parallel with the element whose voltage is being measured.








S
N
N
S
S
N
N
S
N
S
S
N
FIXED COIL
MOVING COIL
FIXED COIL
METER TERMINALS

Example 3.5 & 3.6

(a) A 50 mV, 1 mA ammeter with a full scale of 10 mA. Determine R_A.

(b) How much resistance is added to the circuit when the 10 mA meter is inserted to measure current?

ans.:

(a) Meaning: When 10 mA is to be measured 1 mA will be moving in the coil; accordingly 9 mA will be moving in the R_A.

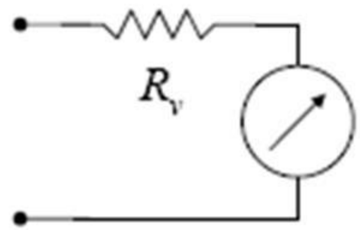
$$9\times10^{-3} R_A = 50\times10^{-3} \dashrightarrow R_A = 50/9 = 5.555\,\Omega$$

(b) $R_m = \dfrac{50\,mV}{10\,mA} = 5\,\Omega$

(a) A 50 mV, 1 mA ammeter with a full scale of 150 V. Determine R_v.

(b) How much resistance is added to the circuit when the 150 V meter is inserted to measure current?

ans.:



(a) $R_{movement} = \dfrac{50\,mV}{1\,mA} = 50\,\Omega,\ 50\times10^{-3} = \dfrac{50}{R_v + 50}$ 150

$R_v = 149{,}950\,\Omega$

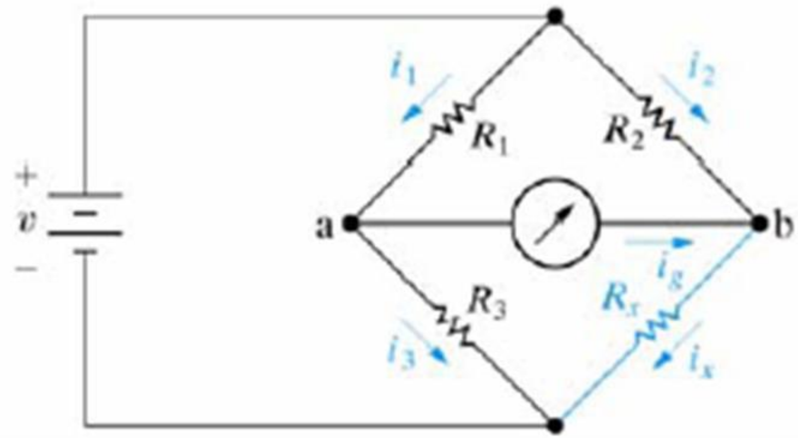
(b) $R_m = \dfrac{150^V}{10^{-3}} = 150{,}000\,\Omega$

Measuring Resistance-The Wheatstone Bridge

- To find R_x, the value of R_3 is adjusted until there is no current in the meter.

$i_g = 0$ Means balanced bridge.

& V_{ab}=0 "same potential at a as b"



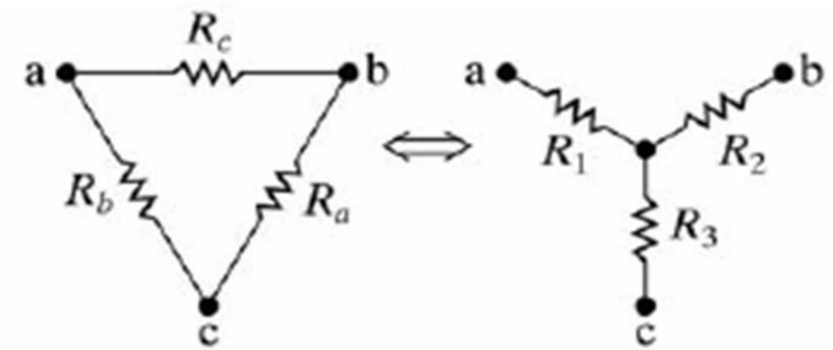
KCL $\quad i_1 = i_3 \quad \& \quad i_2 = i_x$

KVL $\quad i_3 R_3 = i_x R_x \;\; \& \;\; i_1 R_1 = i_2 R_2$

$$i_1 R_3 = i_2 R_x$$

$$\frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{R_x}{R_3} \Rightarrow \boxed{R_x = \frac{R_2}{R_1} R_3}$$

The Δ-to-Y transformation **(Delta-to-Wye/Pi-to-Tee)**



- The resistance between terminals a and b must be the same whether we use Δ-connected set or the Y-connected circuit.

$$R_{ab} = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c} = R_1 + R_2$$

$$R_{bc} = \frac{R_a(R_b + R_c)}{R_a + R_b + R_c} = R_2 + R_3$$

$$R_{ca} = \frac{R_b(R_c + R_a)}{R_a + R_b + R_c} = R_1 + R_3$$

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c}$$

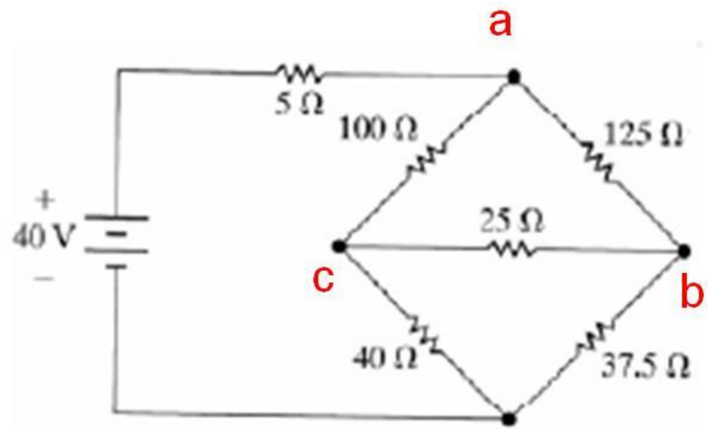
$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

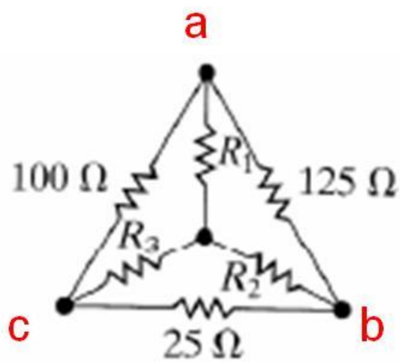
Example 3.7



Find the current and power supplied by the 40 V source.

Ans.:

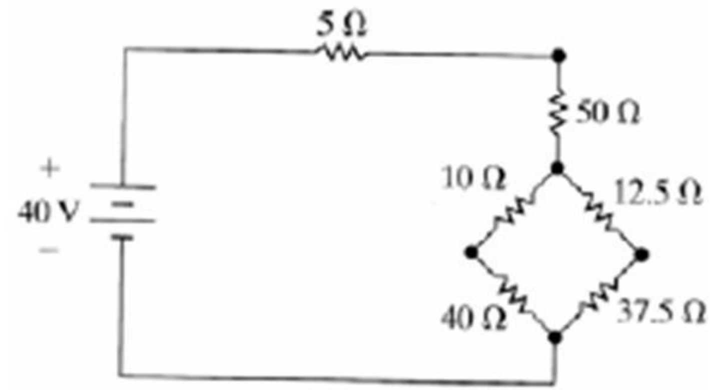
We can convert Δ(100, 125, 25 Ω) or Δ(25,40,37.5 Ω)



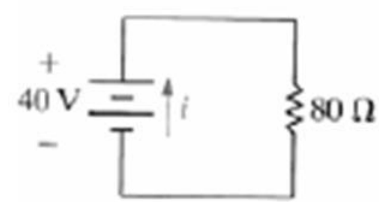
$$R_1 = \frac{100 \times 125}{100+125+25} = 50\,\Omega$$

$$R_2 = \frac{125 \times 25}{100+125+25} = 12.5\,\Omega$$

$$R_2 = \frac{100 \times 25}{100+125+25} = 10\,\Omega$$



$$R_{eq} = 5 + 50 + \frac{(10+40)\times(12.5+37.5)}{(10+40)+(12.5+37.5)} = 80\,\Omega$$

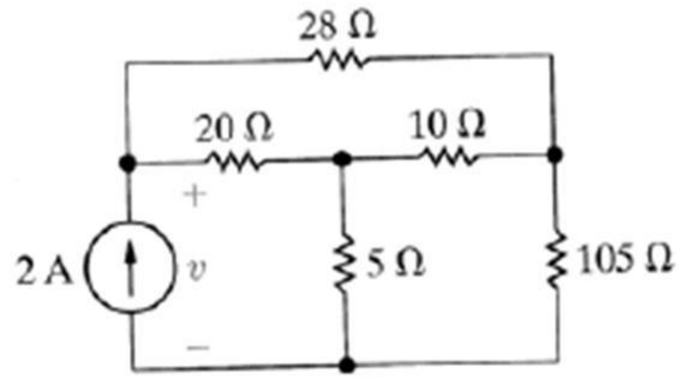


$$i = \frac{40^{V}}{80^{\Omega}} = \underline{0.5\text{ A}}$$

$P = 0.5^{A}$ x 40v = 20W

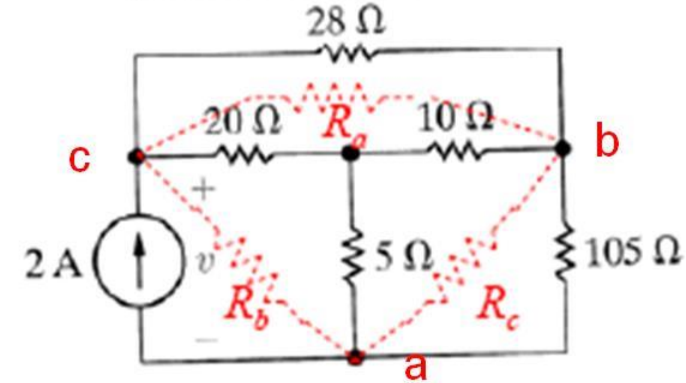
Assessing Objective 6

Use Y-to-Δ transformation to find v.



Ans.:

$$R_a = \frac{20\times10+10\times5+5\times20}{5} = 70\,\Omega$$



$$R_b = \frac{20\times10+10\times5+5\times20}{10} = 35\,\Omega$$

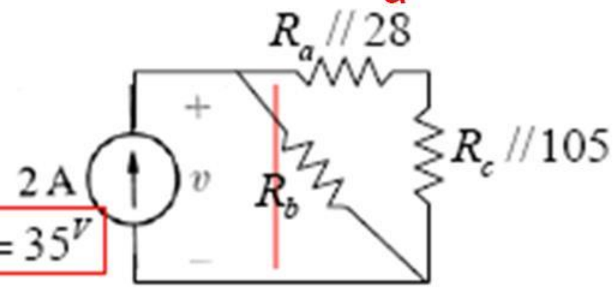
$$R_c = \frac{20\times10+10\times5+5\times20}{20} = 17.5\,\Omega$$

$$R_{eq1} = \frac{28\times70}{28+70} = 20\,\Omega$$

$$R_{eq2} = \frac{17.5\times105}{17.5+105} = 15\,\Omega$$

$$R_{eq3} = \frac{35\times(20+15)}{35+(20+15)} = 17.5\,\Omega$$

$$\boxed{v = 2^A \times 17.5^\Omega = 35^V}$$

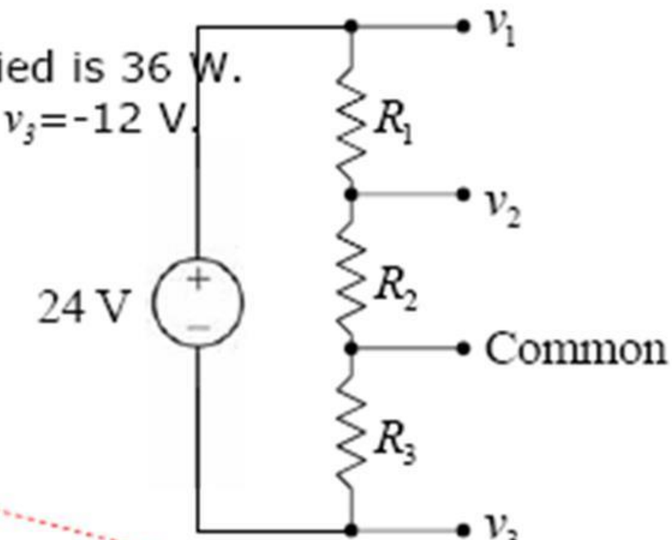


Problem

Select R_1, R_2 & R_3 in the circuit to meet the following design requirements:

a) The total power supplied is 36 W.

b) v_1=12 V, v_2=6 V, and v_3=-12 V.



Ans.:-

(a) $$P_{24^V} = \frac{V^2}{R_{eq}} = \frac{(24)^2}{R_1 + R_2 + R_3} = 36$$

$$R_1 + R_2 + R_3 = 16\,\Omega$$

(b) Using Voltage dividers

$$v_1 = 24^V \frac{R_1 + R_2}{R_1 + R_2 + R_3} = 12^V, R_1 + R_2 = \frac{12}{24} \times \boxed{(R_1 + R_2 + R_3)} = 8\,\Omega, \quad R_1 + R_2 = 8\,\Omega$$

$$v_2 = 24^V \frac{R_2}{R_1 + R_2 + R_3} = 6^V, \quad R_2 = \frac{6}{24} \times (R_1 + R_2 + R_3) = 4\,\Omega \Rightarrow \boxed{R_2 = 4\,\Omega}$$

$$\boxed{R_1 = 4\,\Omega}$$

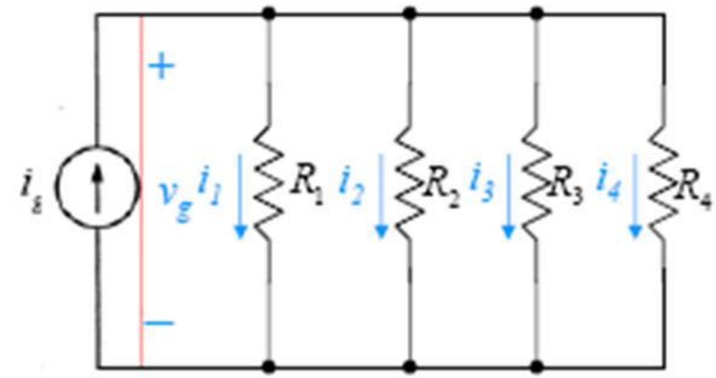
$$v_3 = -24^V \frac{R_3}{R_1 + R_2 + R_3} = -12^V \Rightarrow \boxed{R_3 = 8\,\Omega}$$

Problem

Specify the value of the resistors in the circuit to meet the following design criteria: i_g=8 mA; v_g=4 V, $i_1=2i_2$; $i_2=10i_3$; and $i_3=i_4$.

Ans.:-

$$v_g = i_g R_{eq}, \quad \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$



$$4^V = 8\times10^{-3}\left(\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}}\right)$$

$$\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4} = 2\times10^{-3},$$

$$\boxed{i_j = \frac{v}{R_j} = \frac{R_{eq}}{R_j} i}$$

$$i_1 = 2i_2 = \frac{R_{eq}}{R_1} i_g = 2\frac{R_{eq}}{R_2} i_g, \quad R_2 = 2R_1$$

$$i_2 = 10 i_3 \longrightarrow R_3 = 10 R_2$$

$$i_3 = i_4 \longrightarrow R_3 = R_4$$

$$\frac{1}{R_1}+\frac{1}{2R_1}+\frac{1}{20R_1}+\frac{1}{20R_1} = \frac{32}{20R_1} = 2\times10^{-3}$$

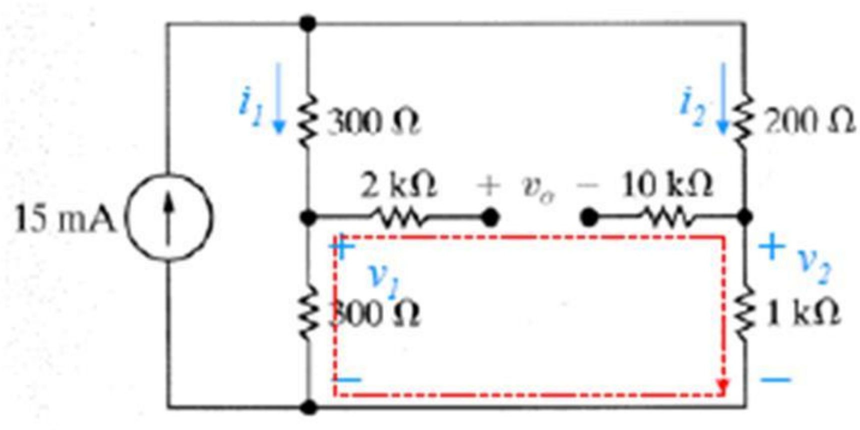
$$\boxed{R_1 = 800\,\Omega} \qquad \boxed{R_2 = 1.6\,\text{k}\Omega} \qquad \boxed{R_3 = R_4 = 1.6\,\text{k}\Omega}$$

Problem

Find v_o?

Ans.:-

Using current dividers



$$i_1 = \frac{200+1000}{300+300+200+1000} 15\text{mA}$$

$$\boxed{i_1 = 10\text{mA}}$$

$$i_2 = \frac{300+300}{300+300+200+1000} 15\text{mA}$$

$$\boxed{i_2 = 5\text{mA}}$$

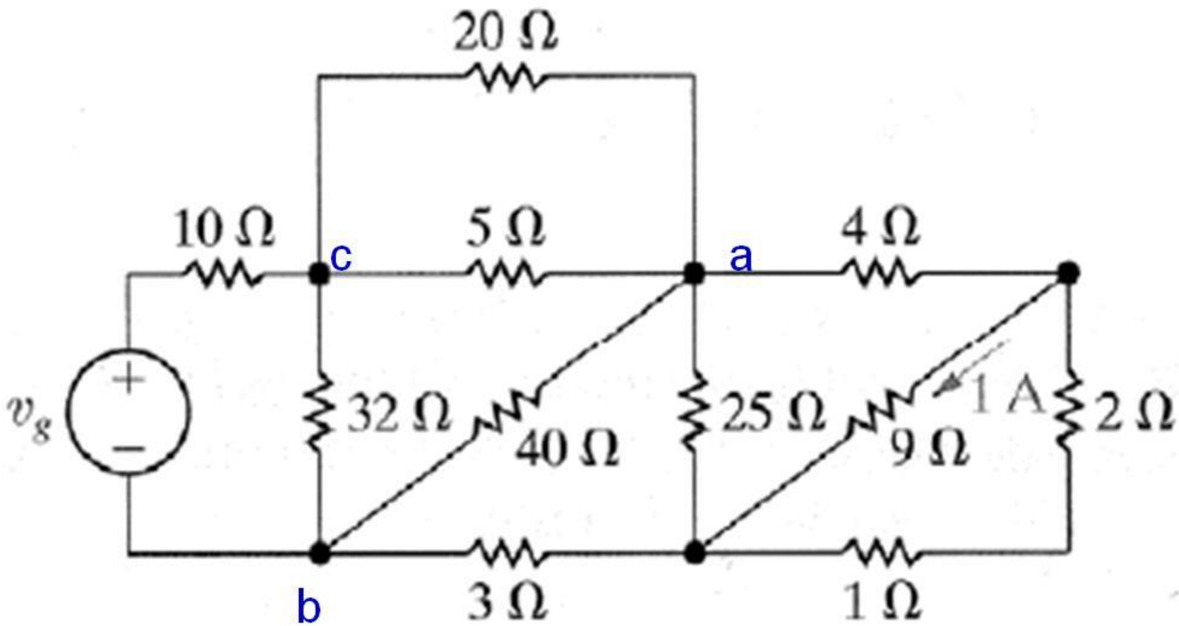
$v_1 = 10\times10^{-3}\times300 = 3\text{ V}$, $\quad v_2 = 5\times10^{-3}\times1000 = 5\text{ V}$

Applying KVL $v_o + v_2 - v_1 = 0 \Rightarrow v_o = v_1 - v_2 = 3 - 5$

$$v_o = -2\text{ V}$$

Problem

Find (a) v_g, (b) power dissipated in 20 Ω.

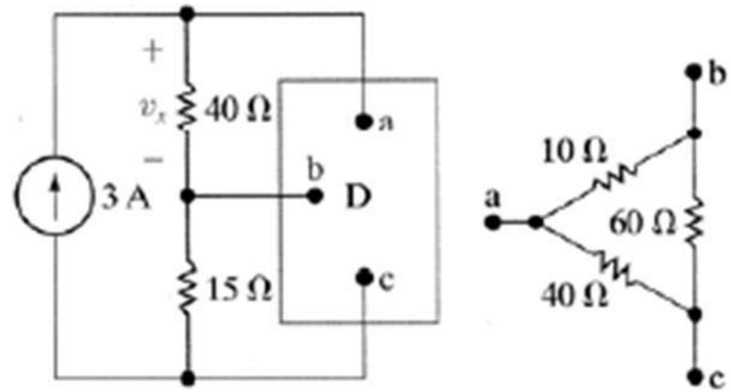


$V_{9\Omega} = 9V \rightarrow I_{2,1\Omega} \rightarrow$
$I_{4\Omega} \rightarrow V_{25\Omega} \rightarrow I_{25\Omega} \rightarrow$
$I_{3\Omega} \rightarrow V_{40\Omega} \rightarrow I_{40\Omega}$

$Z_{ab} = [(\{[(2+1)//9]+4\}//25)+3]//40$
$V_{ab} = V_{40\Omega} = V_{32\Omega}\ Z_{ab}/(Z_{ab} + 20//5) \rightarrow V_{32\Omega} \rightarrow I_{32\Omega} \rightarrow I_g = I_{40\Omega} + I_{3\Omega} + I_{32\,\Omega}$
$Z_{cb} = (Z_{ab} + (20//5))//32 \rightarrow V_g = I_g(10+Z_{cb}) \rightarrow P_{20\Omega}$

Problem

- Find v_x when the device in (b) is connected to the circuit.



(a) (b)

Ans.:

$$R_{eq_1} = \frac{40\times 10}{40+10} = 8\,\Omega$$

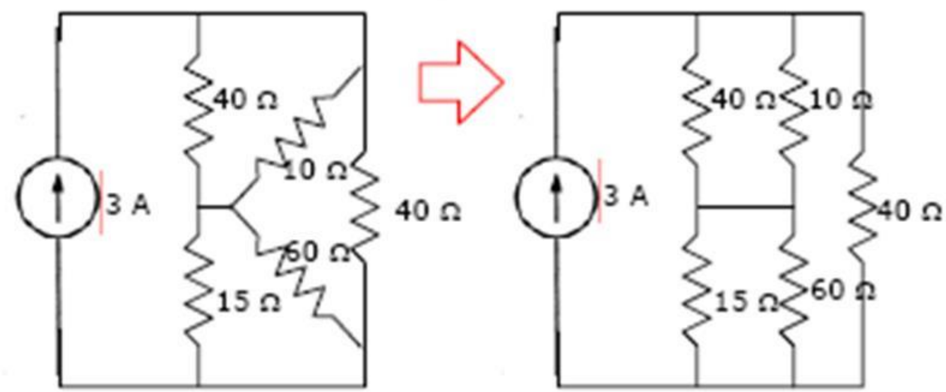
$$R_{eq2} = \frac{60\times 15}{60+15} = 12\,\Omega$$

$$R_{eq3} = 8+12 = 20\,\Omega$$

$$i_{\mathrm{Req3}} = 3\frac{40}{20+40} = 2\ \mathrm{A}$$

$$i_{40\Omega} = 2\frac{10}{10+40} = 0.4\ \mathrm{A}$$

$$v_x = 0.4^{4}40^{\Omega} = 16\ \mathrm{V}$$

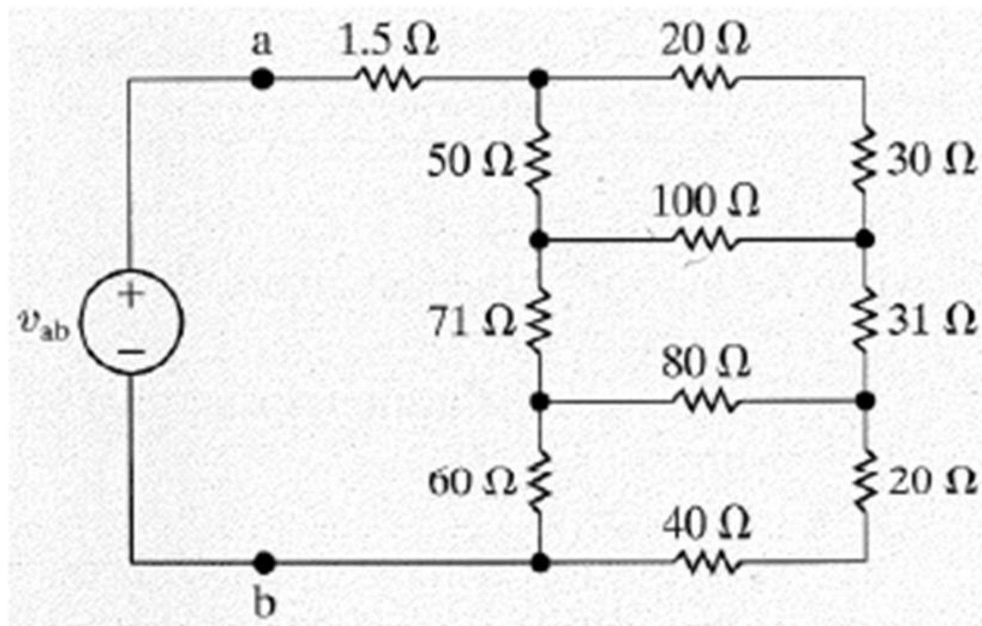


Problem

(a) Find the resistance seen by the ideal voltage source in the circuit.

(b) If v_{ab} equals 400 V, how much power is dissipated in the 31 Ω resistor.

Ans.:



$$R_{eq_{ab}} = 80\,\Omega$$

$$P_{31\Omega} = 279\ \mathrm{W}$$

Convert upper and lower delta circuits to Y cicuits, we have a simpler circuit