ESc201: Introduction to Electronics

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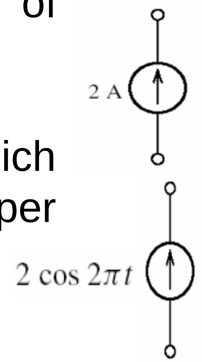
Recap

Current: The time rate of flow of electrical charge $i(t) = \dfrac{dq(t)}{dt}$

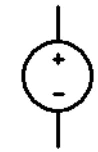
– The units are amperes (A), which are equivalent to coulombs per second (*C/s*)



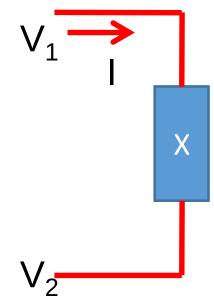
Direction of current flow is opposite to direction of electron flow

Voltage difference is the Source of current flow

Units of Voltage: Volts (V)



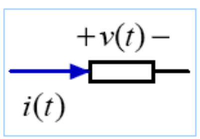
Power



$$P=(V_1-V_2)\times I$$

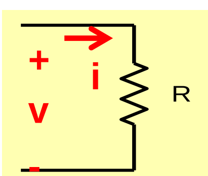
$$P(t)=\frac{dw}{dt} \Rightarrow \quad w=\int_{t1}^{t2} p(t)dt$$

Ohm's law



$$v(t)=R\times i(t)$$

$$i(t)=\frac{v(t)}{R}=G\times v(t)$$



$$P=i^2\times R$$

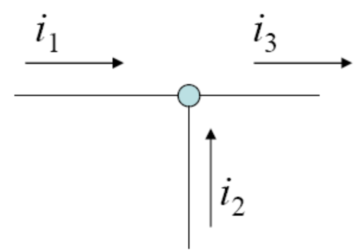
$$P=\frac{v^2}{R}$$

Two elements are connected in series if there is no other element connected to the node joining them. Same current flows

Two elements are connected in parallel if both ends of one element are connected directly to corresponding ends of the other. **Same voltage**

Kirchhoff's Current Law (KCL)

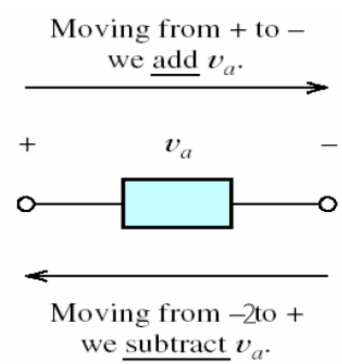
Sum of currents entering a node is equal to sum of currents leaving a node



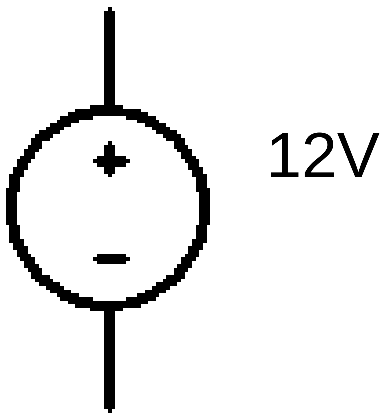
$$i_1+i_2=i_3$$

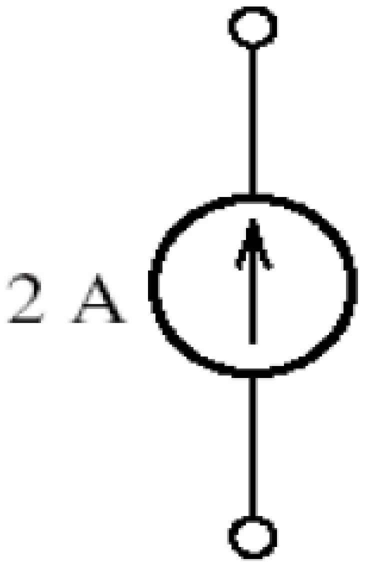
Kirchhoff's Voltage Law (KVL)

The algebraic sum of the voltages equals zero for any closed path (loop) in an electrical circuit

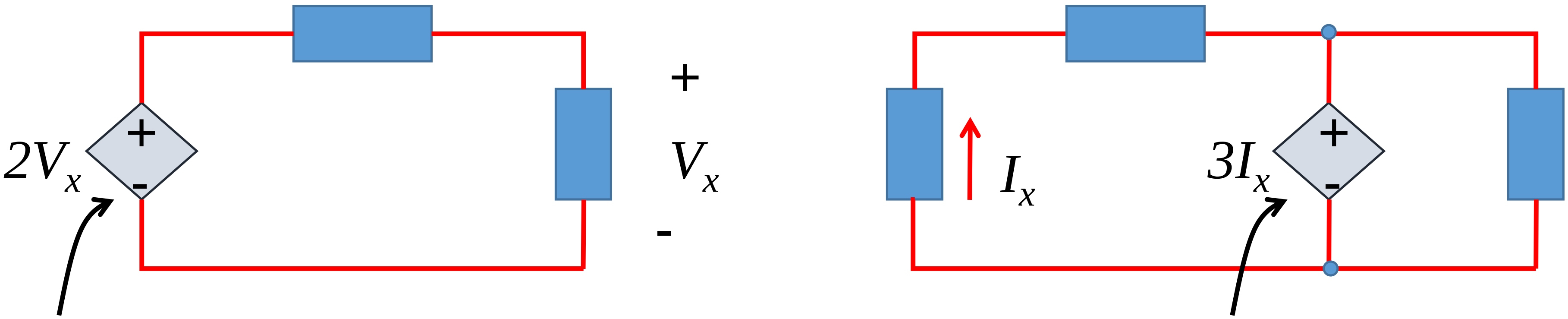


Independent Sources





Dependent (Controlled) Voltage Sources



Voltage-controlled
Voltage source

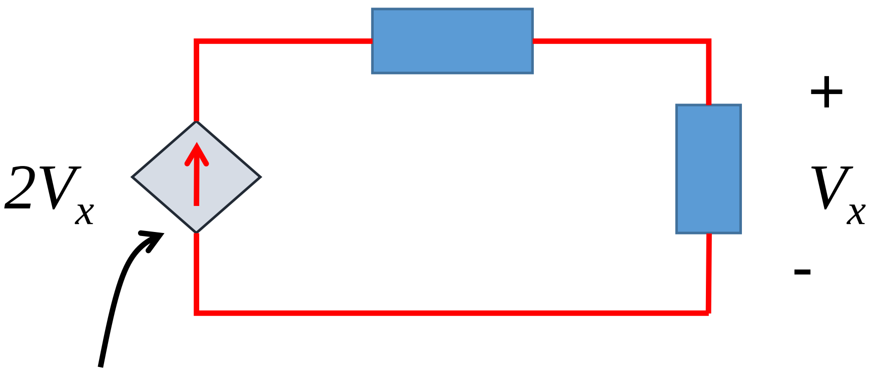
Current-controlled
Voltage source

- Very useful in constructing circuit models for real-world devices such as transistors and amplifiers (we'll see examples in the course)

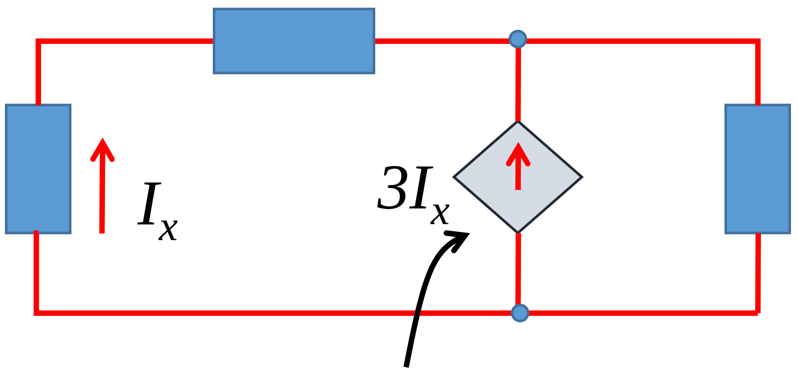
- For a voltage controlled source: $V = K_1 V_x$,
  K_1 is a gain parameter with no units

- For a current controlled source: $V = K_2 I_x$,
  K_2 is a gain parameter with units [V/A]

Dependent (Controlled) Current Sources



Voltage-controlled
current source



Current-controlled
current source

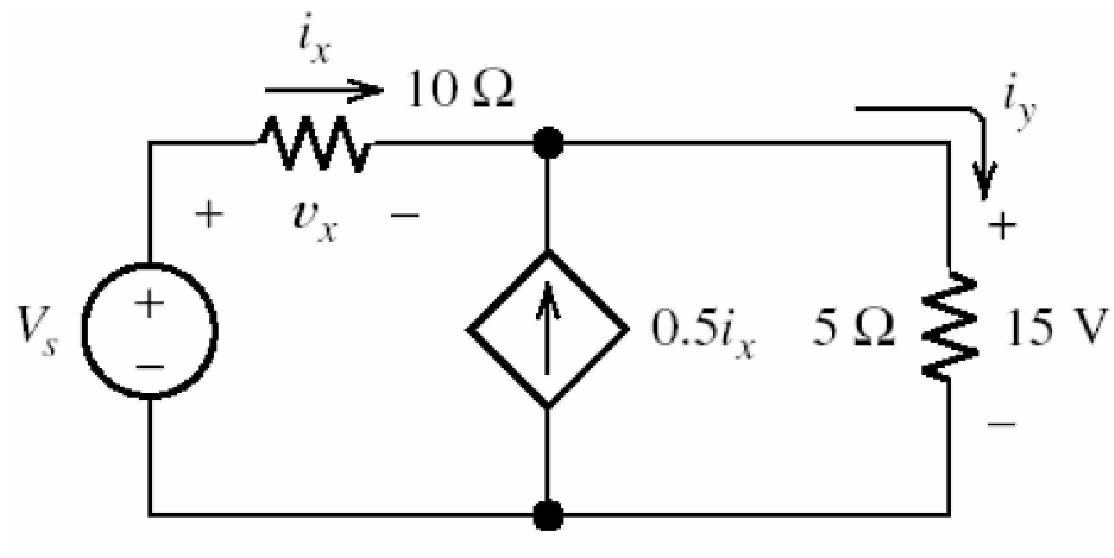
- Very useful in constructing circuit models for real-world devices such as transistors and amplifiers amplifiers (we'll see examples in the course)

- For a voltage controlled source: $I = K_3 V_x$,
  K_3 *is a gain parameter with units* [A/V]

- For a current controlled source: $I = K_4 I_x$,
  K_4 *is a gain parameter with no units*

Example:

Find the source voltage in the following circuit



$$i_y = \frac{15\ \text{V}}{5\ \Omega} = 3\ \text{A}$$

$$i_x + 0.5 i_x = i_y$$

$$i_x = 2\ \text{A}$$

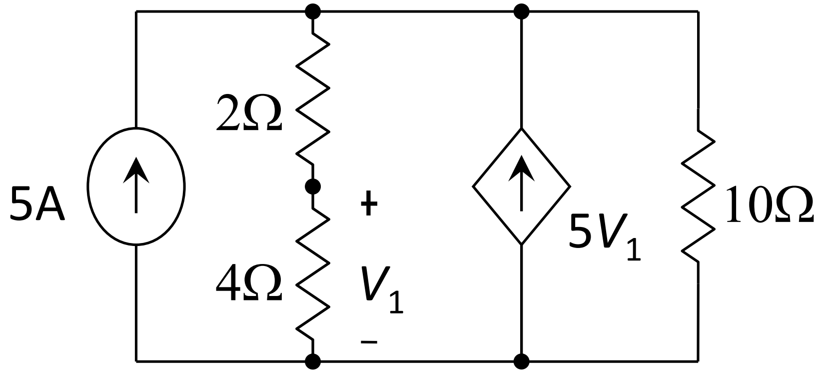
$$v_x = 10 i_x = 20\ \text{V}$$

$$V_s = v_x + 15$$

$$V_s = 35\ \text{V}$$

Determine the power dissipated in the 10Ω resistor.

Assignment 1
Problem 4



Basic Circuit Analysis

Objectives

1. Solve circuits (i.e., find currents and voltages of interest) by combining resistances in series and parallel

2. Apply the voltage-division and current-division principles

3. Solve circuits by the node-voltage technique

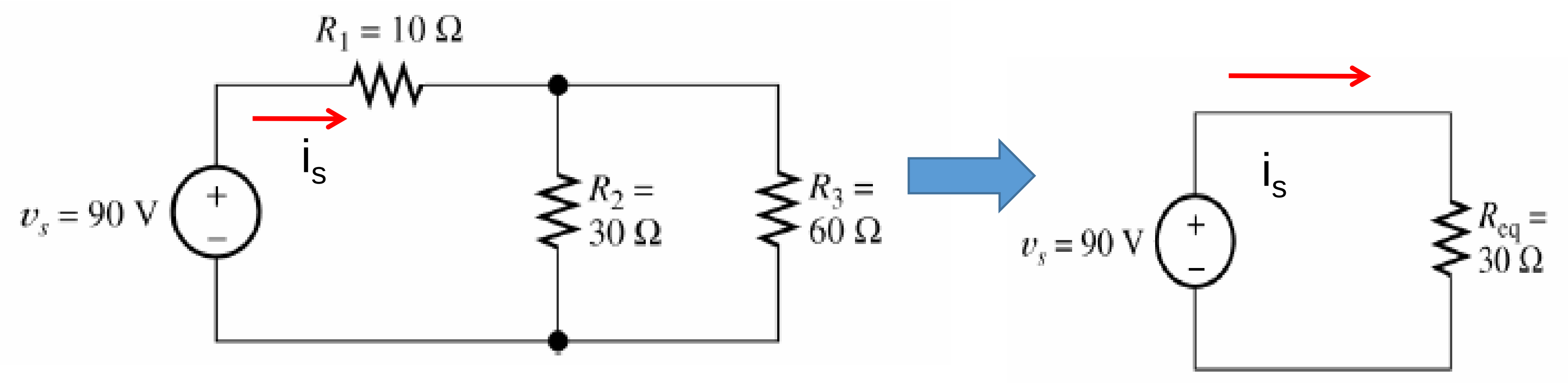
4. Solve circuits by the mesh-current technique

5. Find Thévenin and Norton equivalents and apply source transformations

6. Apply the superposition principle

Simplification Techniques

As engineers we like to be **efficient** : achieve the objective with minimum effort.

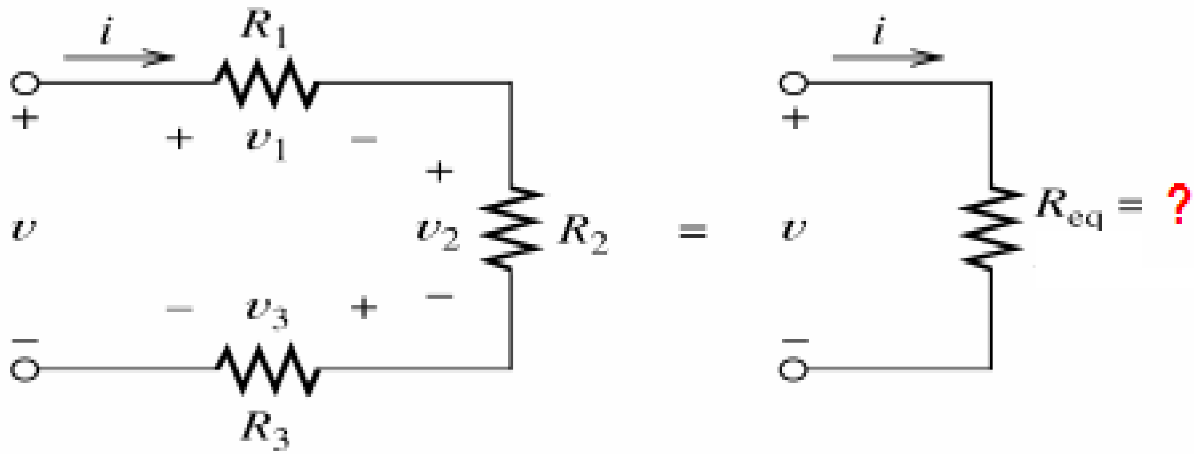


Concept of equivalent circuits

Two circuits are equivalent if they have the same current-voltage behavior

Develop equivalent circuits by combining several resistors into a single equivalent resistor

Series Resistances



(a) Three resistances in series

(b) Equivalent resistance

From (a)

$$v_1 = R_1 i$$

$$v_2 = R_2 i$$

$$v_3 = R_3 i$$

Using KVL :

$$v = v_1 + v_2 + v_3$$

$$= (R_1 + R_2 + R_3)i$$

From (b)

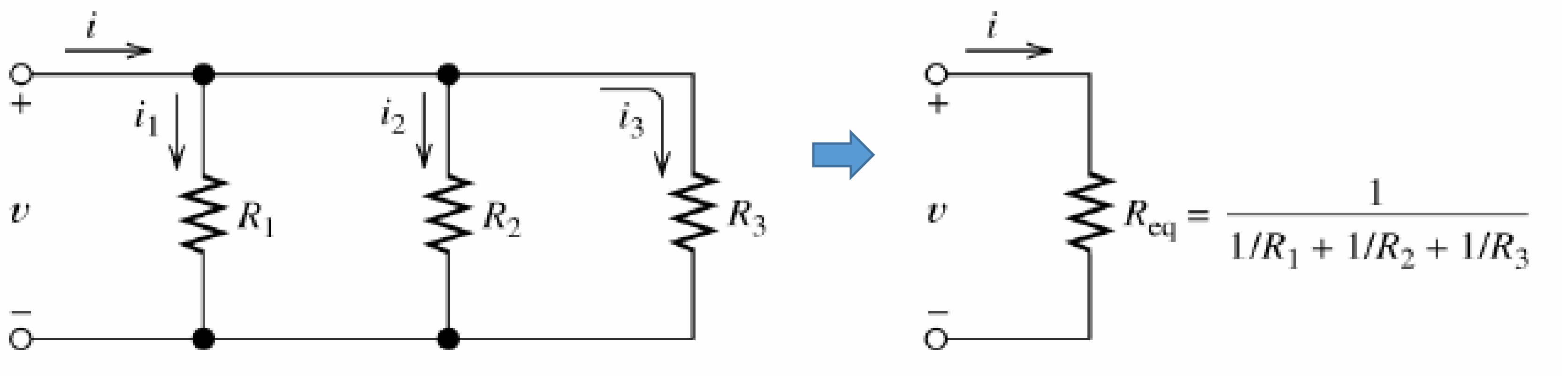
$$v = R_{eq} i$$

Thus,

$$R_{eq} = R_1 + R_2 + R_3$$

Both circuits are equivalent as far as ***v* vs. *i*** relation is concerned.

Parallel Resistances



(a) Three resistances in parallel

(b) Equivalent resistance

From (a):

$i_1 = v / R_1$

$i_2 = v / R_2$

$i_3 = v / R_3$

By KCL

$i = i_1 + i_2 + i_3$

$= (\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3})v$

From (b)

$$i = (\frac{1}{R_{eq}})v$$

Thus,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Special Case

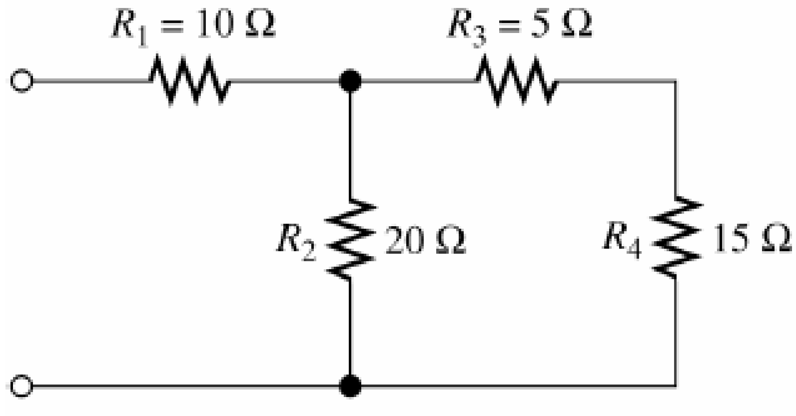
- Two Resistors in Parallel R_1 and R_2

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

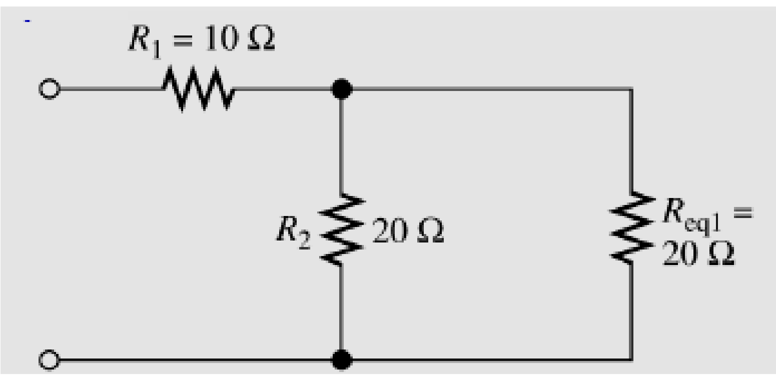
- Always R_{eq} is less than the smallest resistor

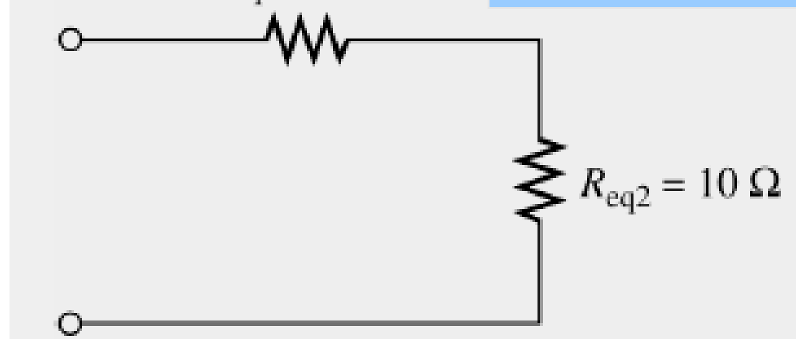
- If R_1 or R_2 is zero (short circuit), then $R_{eq} = 0$

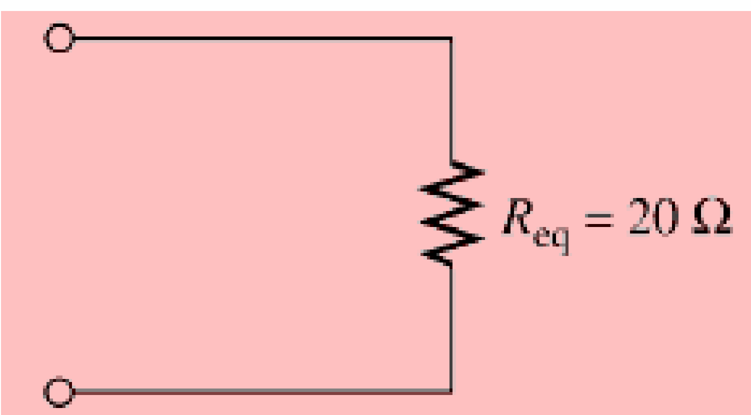
Example Use concept of series and parallel resistances to simplify



$$R_{eq2} = \frac{R_2 R_{eq1}}{R_2 + R_{eq1}}$$



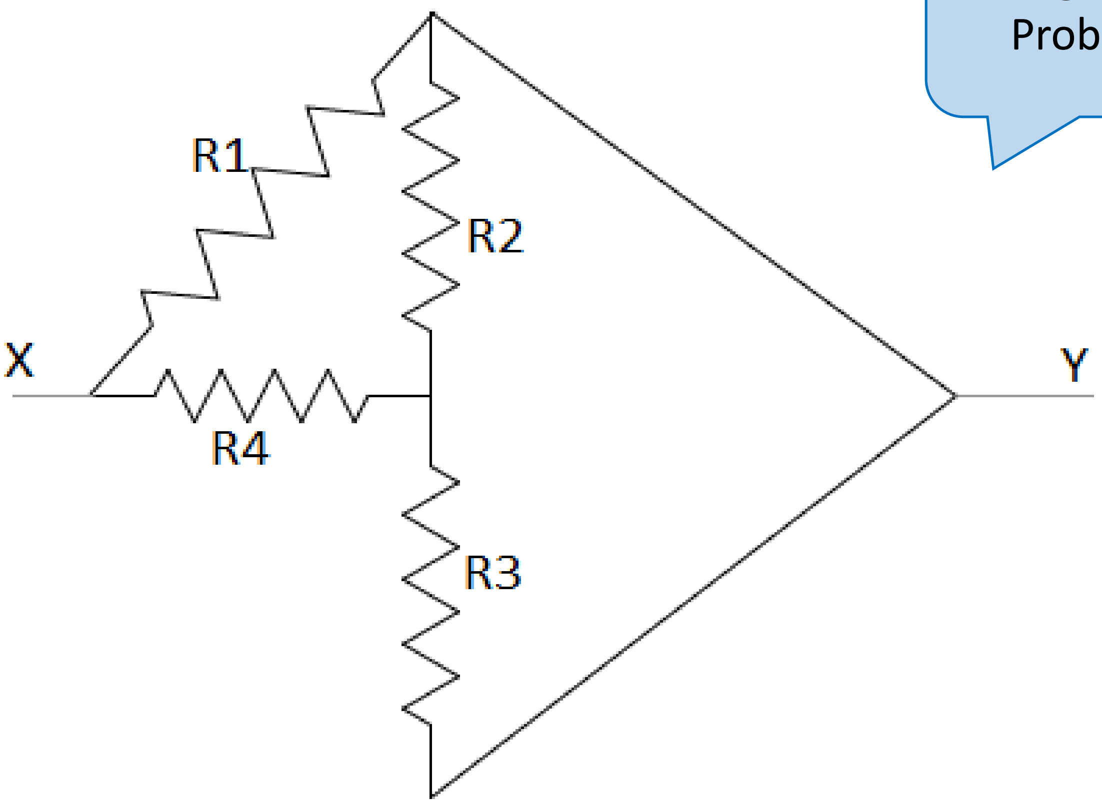




$$R_{eq} = \{(R_4 + R_3) \| R_2\} + R_1$$

Find equivalent resistance between X and Y

Assignment 1
Problem 1



Circuit Analysis Using Series/Parallel Equivalents

1. Begin by locating a combination of resistances that are in series or parallel. Often the place to start with is the farthest from the source.

2. Redraw the circuit with the equivalent resistance for the combination found in step 1.

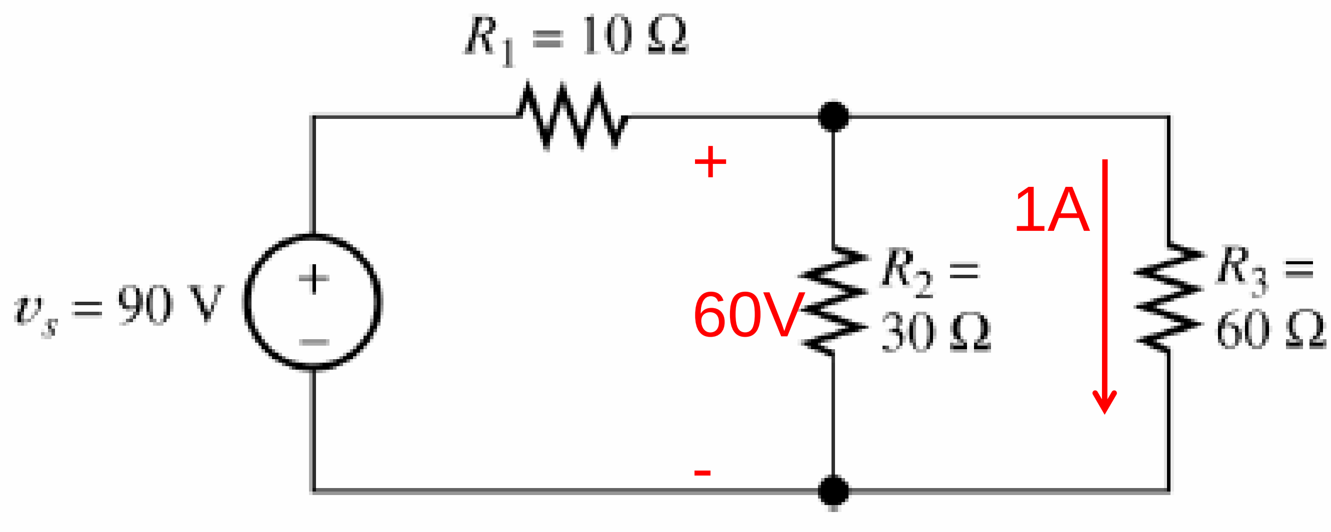
3. Repeat steps 1 and 2 until the circuit is reduced as far as possible. Often (but not always) we end up with a single source and a single resistance.

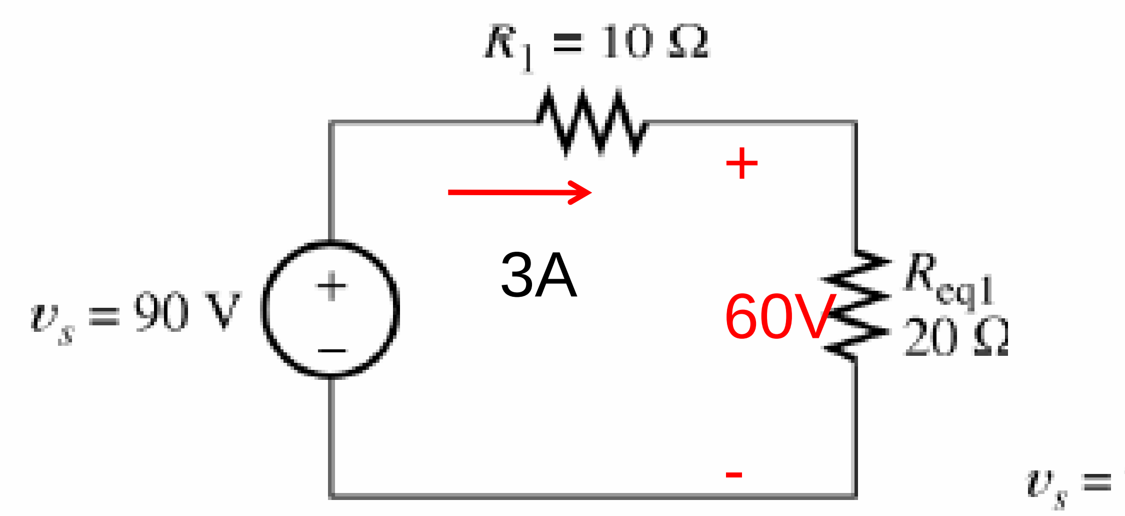
4. Solve for the currents and voltages in the final equivalent circuit. Then go back one step and solve for unknown voltages and current.

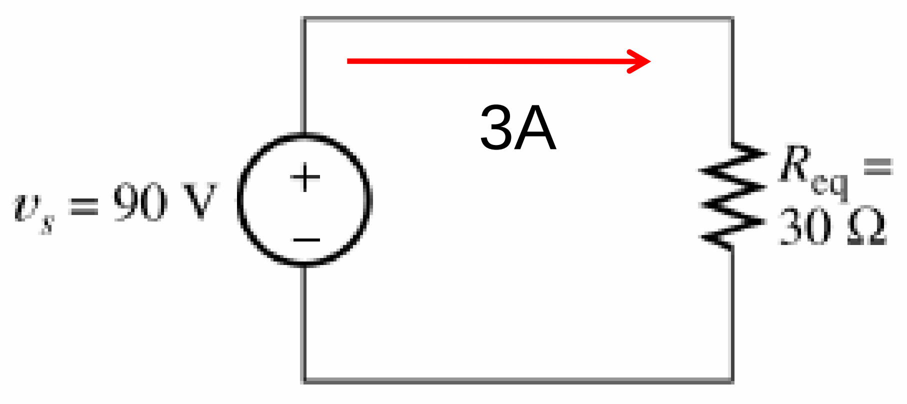
5. Repeat step 4 until the required current or voltage in the original circuit is found.

Example

Find current in R_3

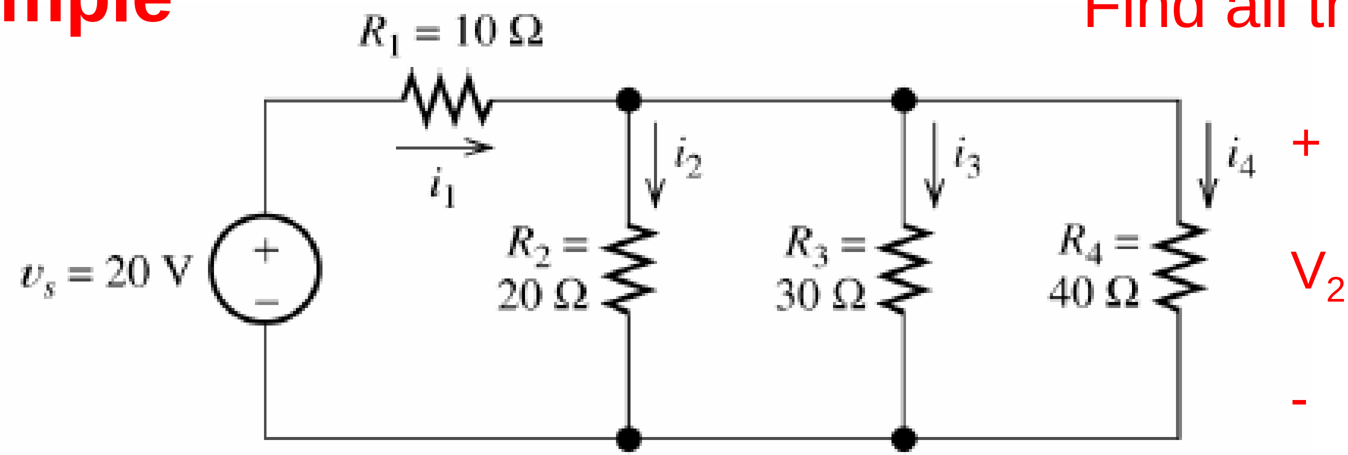




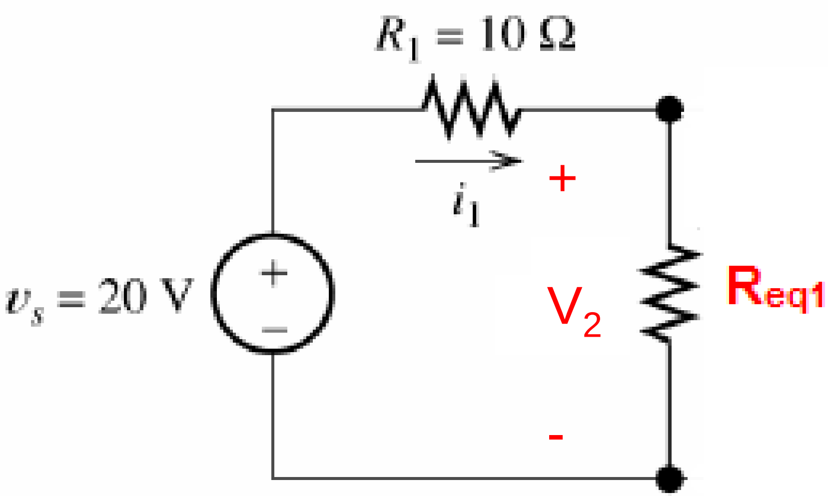


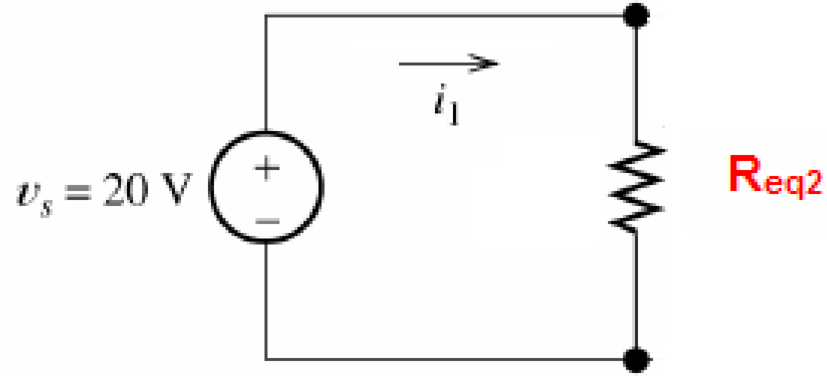
Example

Find all the currents



Solve for i_2, i_3 and i_4





$$\mathrm{R}_{eq1} = R_2 \| R_3 \| R_4$$

Solve for V_2

$$\mathrm{R}_{eq2} = R_1 + R_{eq1}$$

Solve for i_1

Ans. i_1=1.04 A, i_2=0.48 A, i_3=0.32, i_4=0.24 A

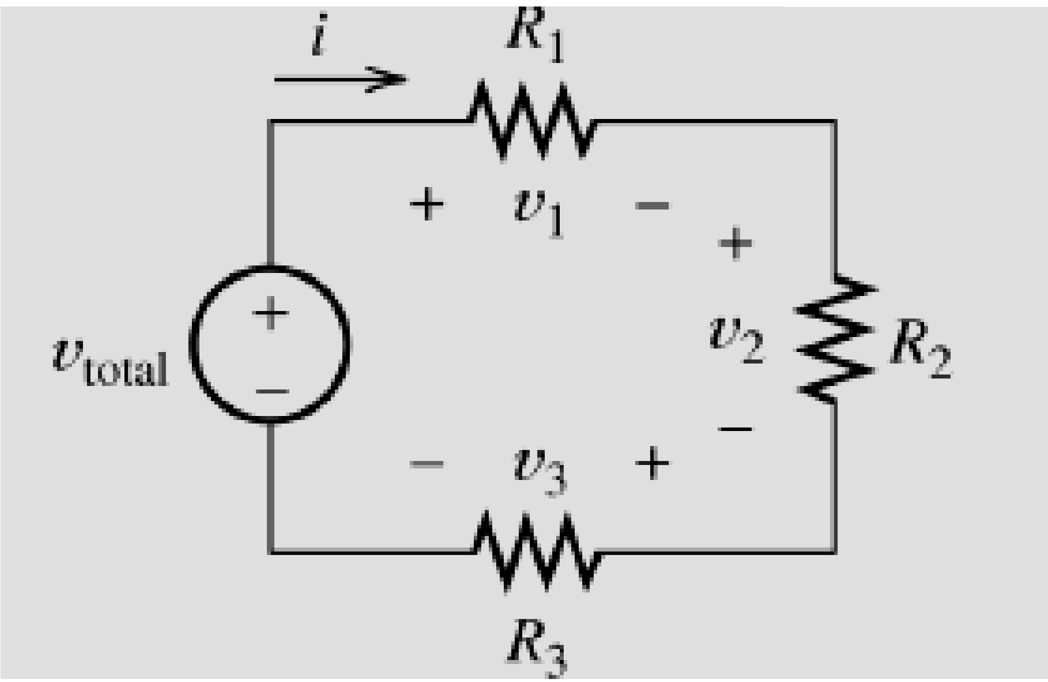
Voltage division

A voltage applied to resistors connected in series will be divided among them

$$i = \frac{v_{total}}{R_1 + R_2 + R_3}$$

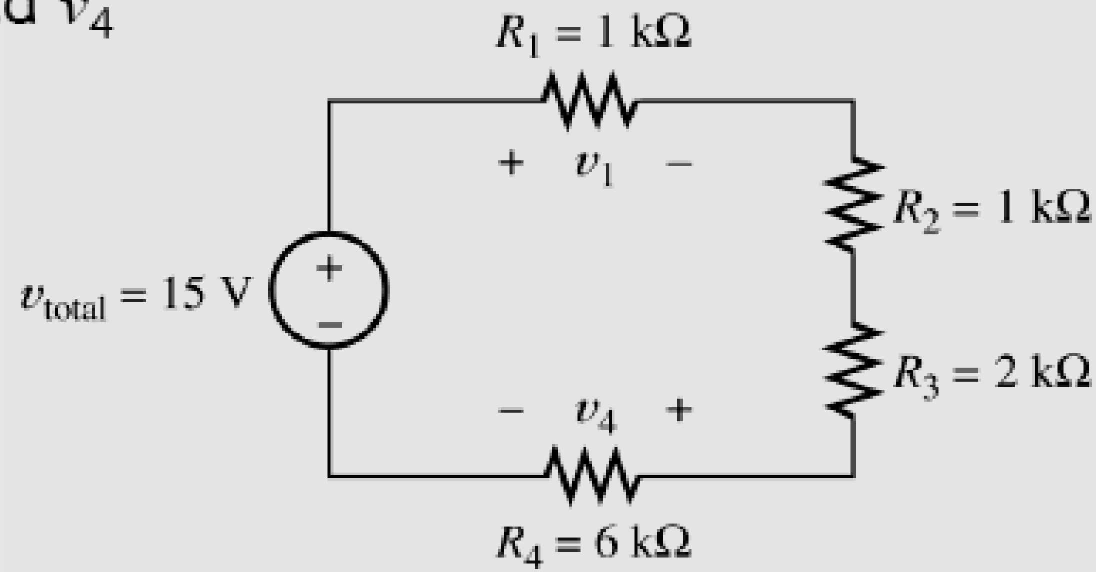
$$v_1 = R_1 i = \frac{R_1}{R_1 + R_2 + R_3} v_{\text{total}}$$

$$v_2 = R_2 i = \frac{R_2}{R_1 + R_2 + R_3} v_{\text{total}}$$



Example

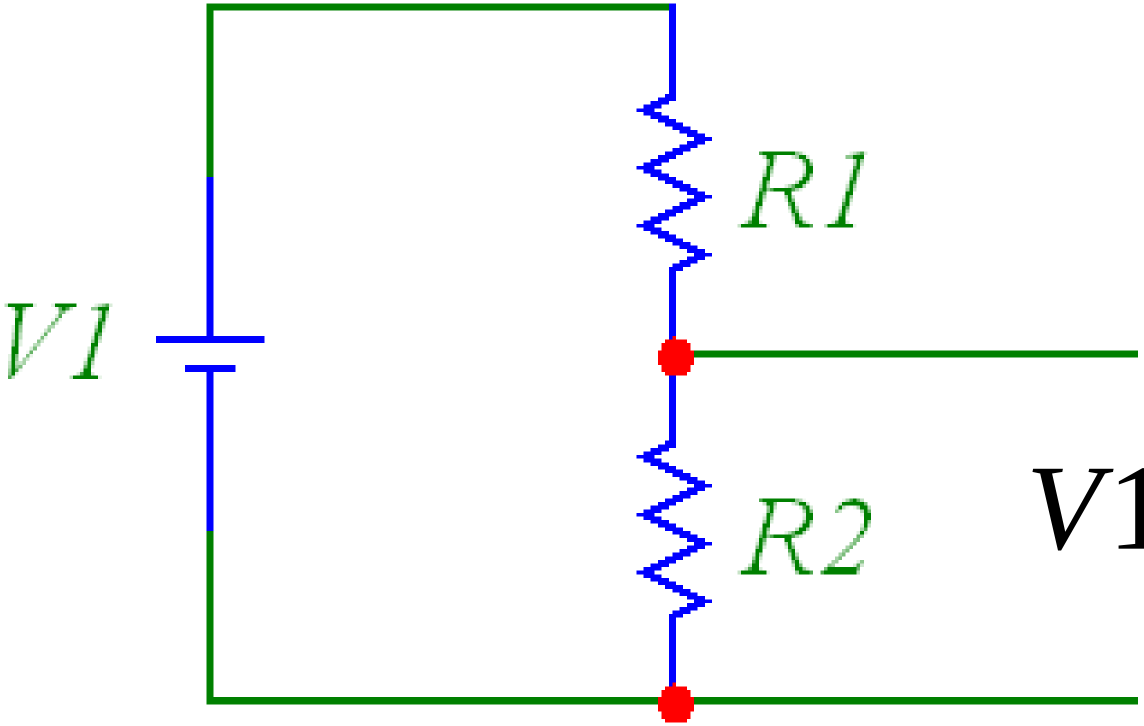
Find v_1 and v_4



$$v_1 = \frac{1000}{1000+1000+2000+6000} \times 15 = 1.5V$$

$$v_4 = \frac{6000}{1000+1000+2000+6000} \times 15 = 9V$$

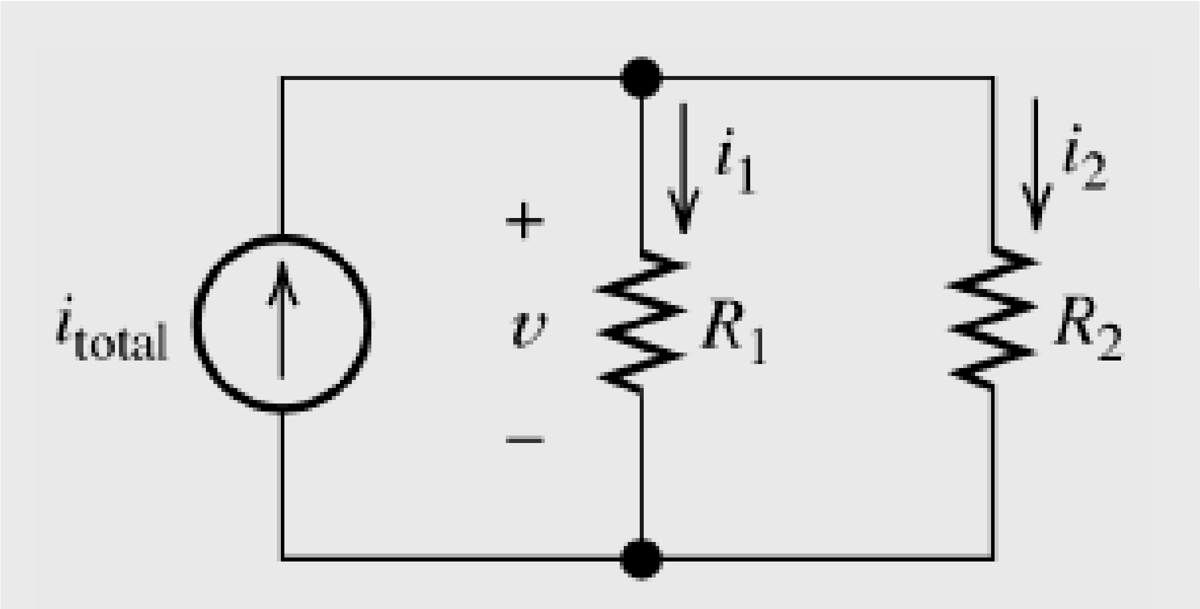
Potential Divider



$$V1\frac{R2}{R1+R2}$$

Current Division

The total current flowing into a parallel combination of resistors will be divided among them



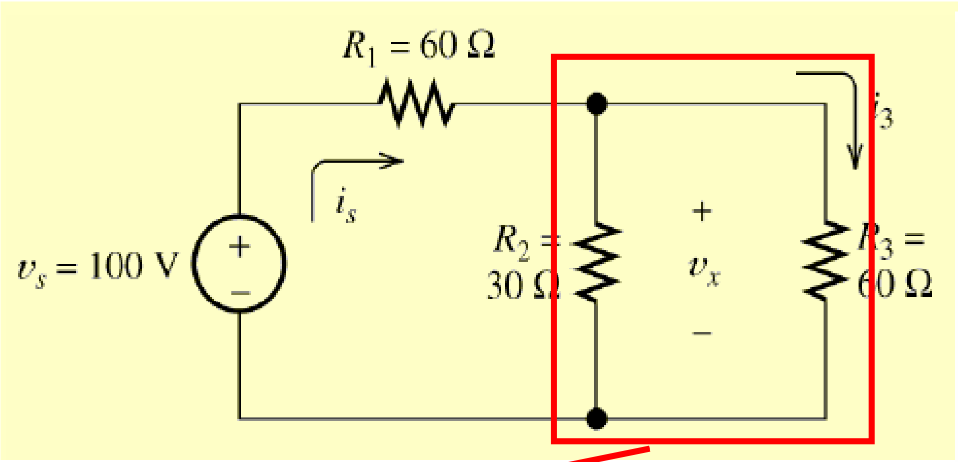
$$v = \frac{R_1 R_2}{R_1 + R_2} i_{total}$$

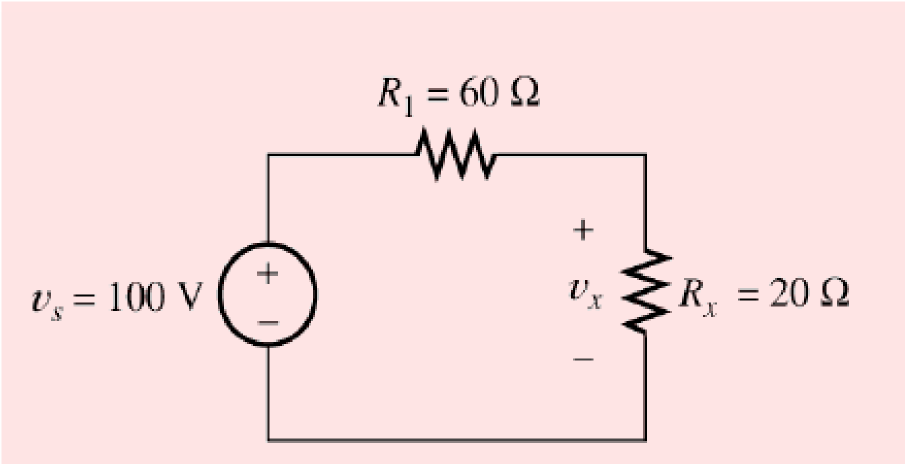
$$i_1 = \frac{v}{R_1} = \frac{R_2}{R_1 + R_2} i_{total}$$

$$i_2 = \frac{v}{R_2} = \frac{R_1}{R_1 + R_2} i_{total}$$

Example

Find v_x *using voltage division and then find* i_s *and use it to find* i_3 *using* current division





$$R_x = \frac{R_2 R_3}{R_2 + R_3} = \frac{30 \times 60}{30 + 60} = 20\Omega$$

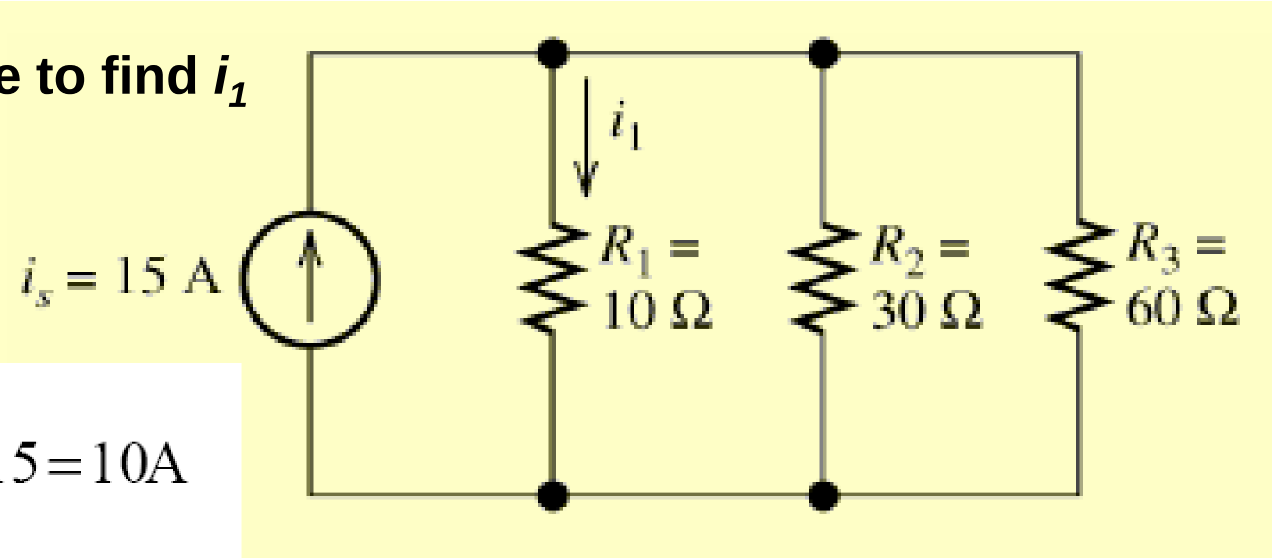
$$v_x = \frac{R_x}{R_1 + R_x} v_s = \frac{20}{60 + 20} 100 = 25V$$

$$i_3 = \frac{R_2}{R_2 + R_3} i_s = \frac{30}{30+60} \times 1.25 = 0.417A$$

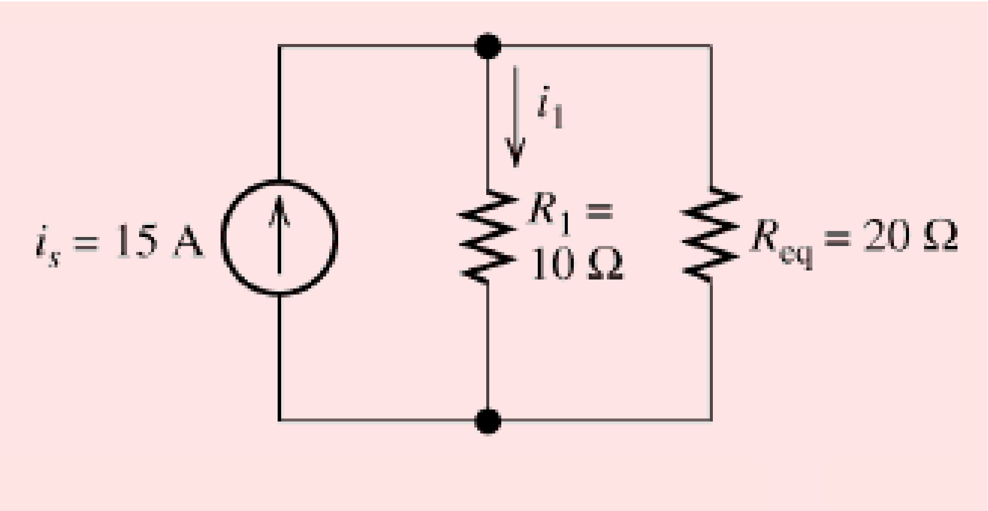
$$i_s = \frac{v_s}{R_1 + R_x} = \frac{100}{60 + 20} = 1.25A$$

Example

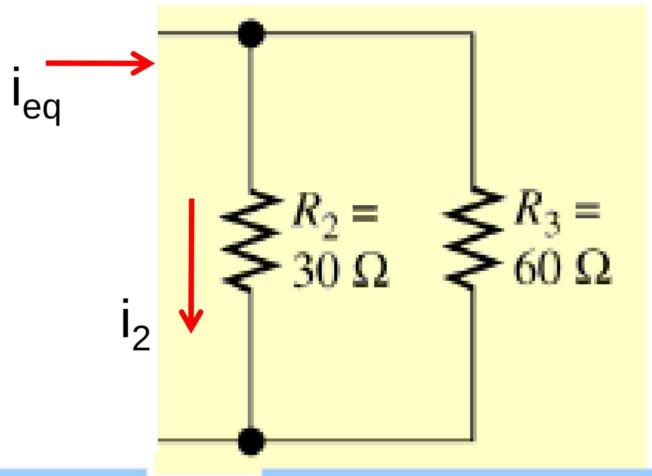
Use current division rule to find *i_1*



$$i_1 = \frac{R_{eq}}{R_1 + R_{eq}} i_s = \frac{20}{10+20} 15 = 10\text{A}$$



Suppose we want to find i_2 also



$$i_{eq} = \frac{R_1}{R_1 + R_{eq}} i_s$$

$$i_2 = \frac{R_3}{R_2 + R_3} i_{eq}$$

In Fig. 2a and Fig. 2b, R1=50Ω, R2=500Ω, R3=100Ω, R4=50Ω, R5=25Ω and R6=50Ω.
(a) Use current division to find current through R5 in Fig. 2a. I=5mA.
(b) Use voltage division to find voltage across R2 in Fig. 2b. V=10V.

Assignment 1
Problem 2

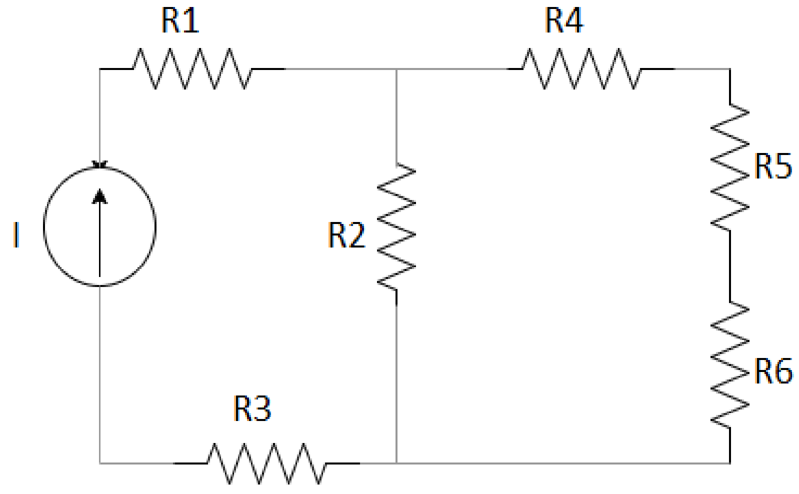


Fig. 2a

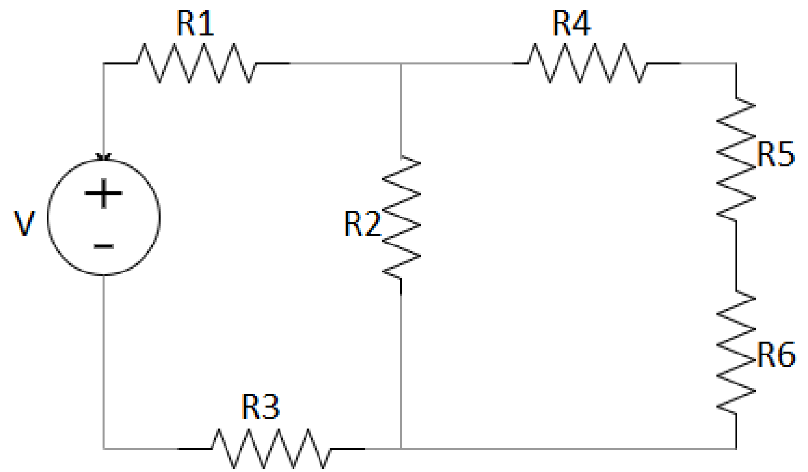


Fig. 2b

The digital multi-meter (DMM) is a device commonly used to measure voltages. It is equipped with two leads (usually red for the positive reference and black for the negative reference) and an LCD display. Let's suppose a DMM is connected to the circuit of Fig.3 with the positive lead at the top node and the negative lead on the bottom node. Using KCL, explain why we would ideally want a DMM used in this way to have an infinite resistance as opposed to zero resistance.

Assignment 1
Problem 3

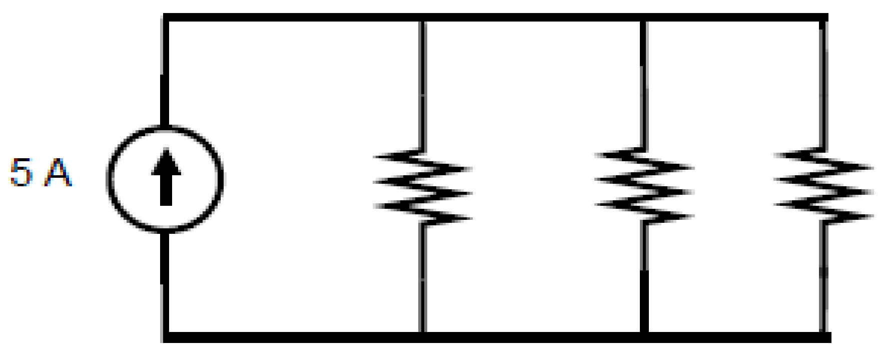


Fig. 3

You will often use DMM in ESc201 lab!

Assignment 1
Problem 5

Three appliances --- an 850W coffee maker, a 1200W microwave oven, and a 900W toaster --- are connected in parallel to a 120V circuit with a 15A circuit breaker.

(a) Draw a schematic diagram of this circuit.

(b) Which of these appliances can be operated simultaneously without tripping the circuit breaker?

Limitations

Although series/parallel equivalents and the current/voltage division principles are very important concepts, yet they are not sufficient to solve all circuits !!