EEE 1131 : Basic Electrical Circuits

Ohm’s Law, KCL, KVL, VDR, CDR

Courtesy: Md. Sarwar Pervez

OHM'S LAW

Ohm's law states that the voltage v across a resistor is directly proportional to the current i flowing through the resistor.

at a constant temperature, the electrical current flowing through a fixed linear resistance is directly proportional to the voltage applied across it, and also inversely proportional to the resistance.

Ohms Law Relationship

$$Current, (I) = \frac{Voltage, (V)}{Resistance, (R)} \text{ in Amperes, } (A)$$

Courtesy: Md. Sarwar Pervez

OHM'S LAW

To find the Voltage, (V)

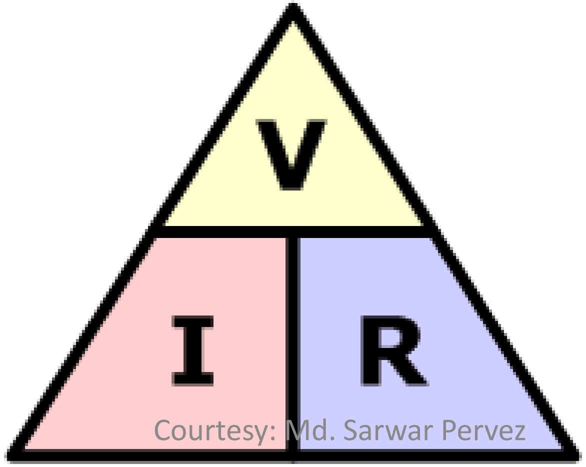
[V = I x R] V (volts) = I (amps) x R (Ω)

To find the Current, (I)

[I = V ÷ R] I (amps) = V (volts) ÷ R (Ω)

To find the Resistance, (R)

[R = V ÷ I] R (Ω) = V (volts) ÷ I (amps)



SERIES RESISTORS

Series Circuit, Parallel Circuit

In Fig. 5.4, one terminal of resistor R2 is connected to resistor R1 on one side, and the remaining terminal is connected to resistor R3 on the other side, resulting in one, and only one, connection between adjoining resistors. When connected in this manner, the resistors have established a series connection.

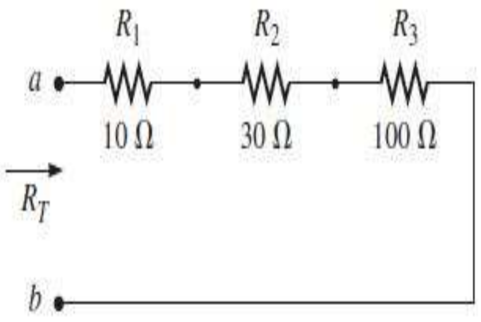


FIG. 5.4
Series connection of resistors.

For resistors in series,
The total resistance of a series configuration is the sum of the resistance levels. In equation form for any number (N) of resistors,

$$\boxed{R_T = R_1 + R_2 + R_3 + R_4 + \cdots + R_N} \qquad (5.1)$$

SERIES RESISTORS

A result of Eq. (5.1) is that the more resistors we add in series, the greater the resistance, no matter what their value.

Further, the largest resistor in a series combination will have the most impact on the total resistance.

For the configuration in Fig. 5.4, the total resistance would be

$$R_T = R_1 + R_2 + R_3$$
$$= 10\ \Omega + 30\ \Omega + 100\ \Omega$$

and $$R_T = 140\ \Omega$$

SERIES RESISTORS

EXAMPLE 5.1 Determine the total resistance of the series connection in Fig. 5.6. Note that all the resistors appearing in this network are standard values.

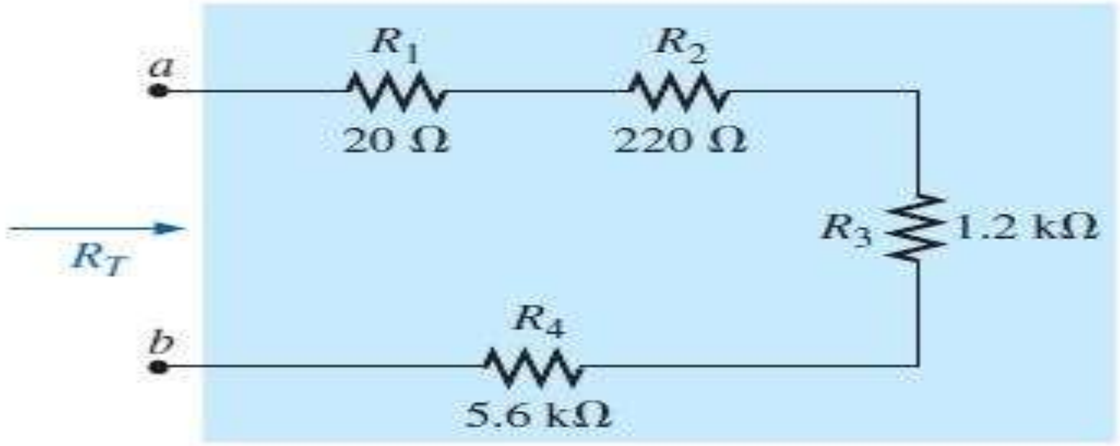


FIG. 5.6
Series connection of resistors for Example 5.1.

VOLTAGE DIVISION IN A SERIES CIRCUIT

The voltage across series resistive elements will divide as the magnitude of the resistance levels.

In other words, ***in a series resistive circuit, the larger the resistance, the more of the applied voltage it will capture.***

In addition, ***the ratio of the voltages across series resistors will be the same as the ratio of their resistance levels***

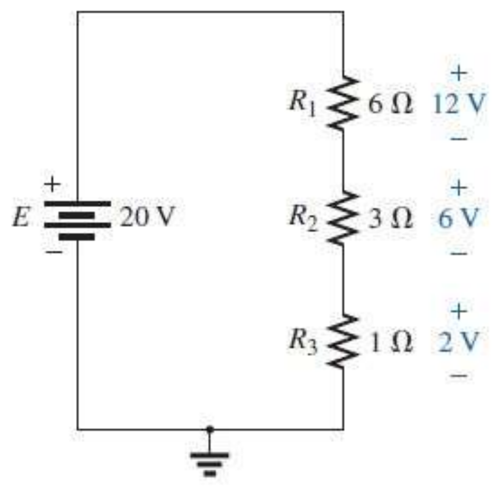


FIG. 5.33
Revealing how the voltage will divide across series resistive elements.

Simulate the above example using PSpice software and find values.

VOLTAGE DIVIVER RULE (VDR)

First, determine the total resistance as follows:

$$R_T = R_1 + R_2$$

Then $$I_s = I_1 = I_2 = \frac{E}{R_T}$$

Apply Ohm's law to each resistor:

$$V_1 = I_1R_1 = \left(\frac{E}{R_T}\right)R_1 = R_1\frac{E}{R_T}$$

$$V_2 = I_2R_2 = \left(\frac{E}{R_T}\right)R_2 = R_2\frac{E}{R_T}$$

The resulting format for V_1 and V_2 is

$$\boxed{V_x = R_x\frac{E}{R_T}} \quad \text{(voltage divider rule)} \qquad \textbf{(5.10)}$$

where V_x is the voltage across the resistor R_x, E is the impressed voltage across the series elements, and R_T is the total resistance of the series circuit.

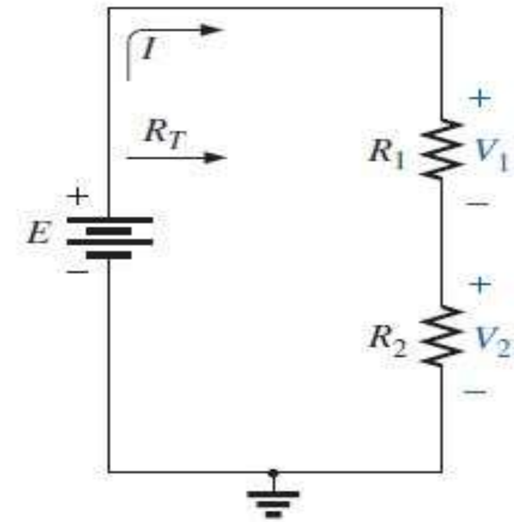


FIG. 5.36
Developing the voltage divider rule.

VOLTAGE DIVIVER RULE (VDR)

The voltage divider rule **states that**
the voltage across a resistor in a series circuit is equal to the value of that resistor times the total applied voltage divided by the total resistance of the series configuration.

Although Eq. (5.10) was derived using a series circuit of only two elements, it can be used for series circuits with any number of series resistors.

VOLTAGE DIVIVER RULE (VDR)

EXAMPLE 5.15 For the series circuit in Fig. 5.37.

a. Without making any calculations, how much larger would you expect the voltage across R2 to be compared to that across R1?

b. Find the voltage V1 using only the voltage divider rule.

c. Using the conclusion of part (a), determine the voltage across R2.

d. Use the voltage divider rule to determine the voltage across R2, and compare your answer to your conclusion in part (c).

e. How does the sum of V1 and V2 compare to the applied voltage?

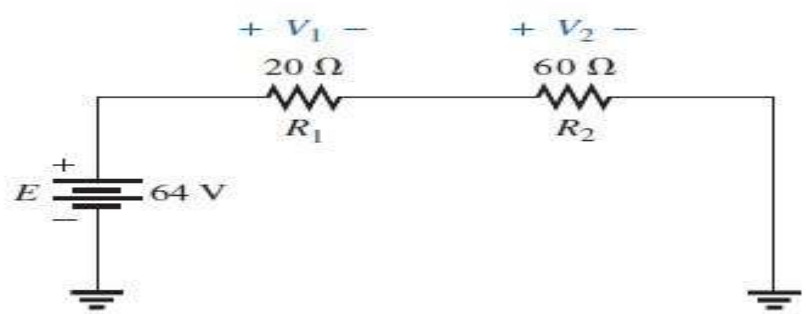


FIG. 5.37
Series circuit to be examined using the voltage divider rule in Example 5.15.

Simulate the above example using PSpice software and find values.

PARALLEL RESISTORS

In general, two elements, branches, or circuits are in parallel if they have two points in common.

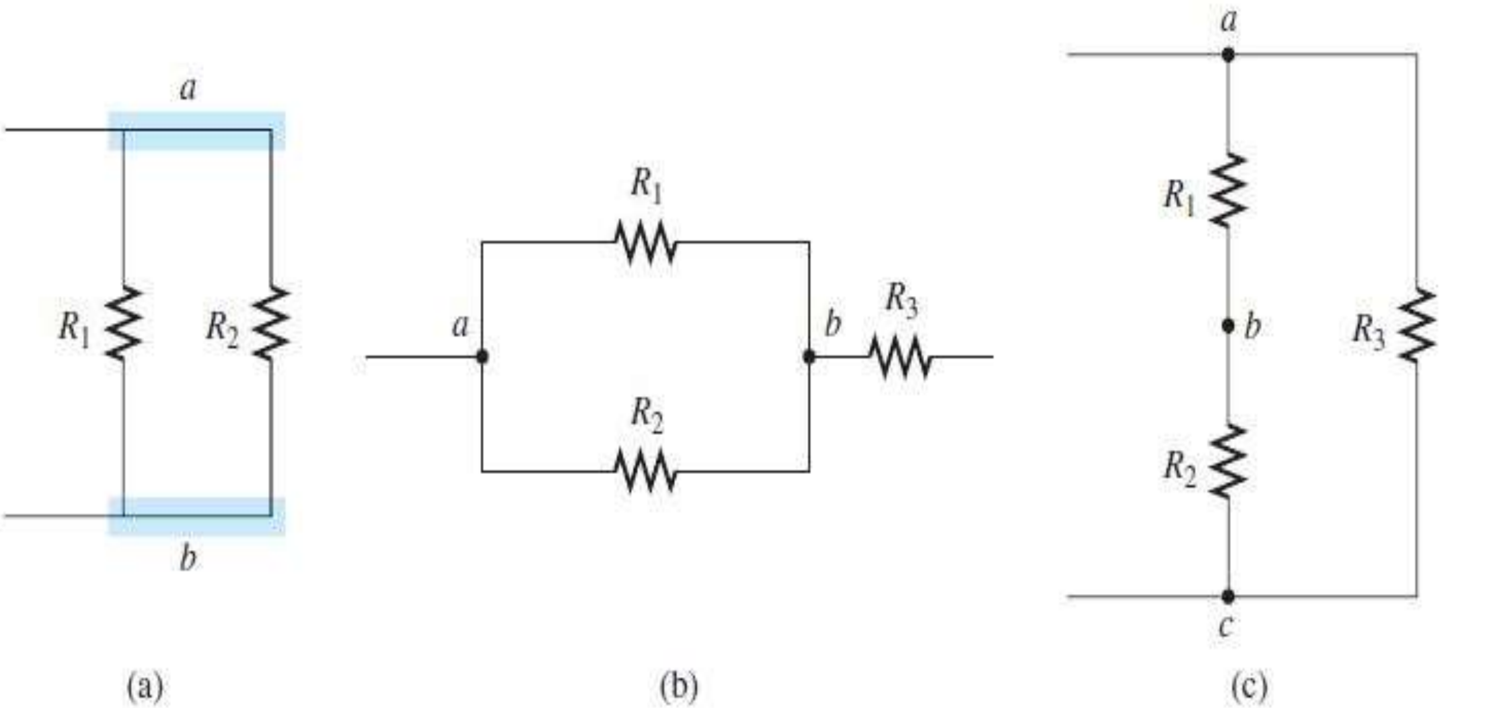


FIG. 6.1

(a) Parallel resistors; (b) R_1 and R_2 are in parallel; (c) R_3 is in parallel with the series combination of R_1 and R_2.

PARALLEL RESISTORS

For resistors in parallel as shown in Fig. 6.3, the total resistance is determined from the following equation:

$$\boxed{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N}} \qquad \textbf{(6.1)}$$

Since $G = 1/R$, the equation can also be written in terms of conductance levels as follows:

$$\boxed{G_T = G_1 + G_2 + G_3 + \cdots + G_N} \qquad \text{(siemens, S)} \qquad \textbf{(6.2)}$$

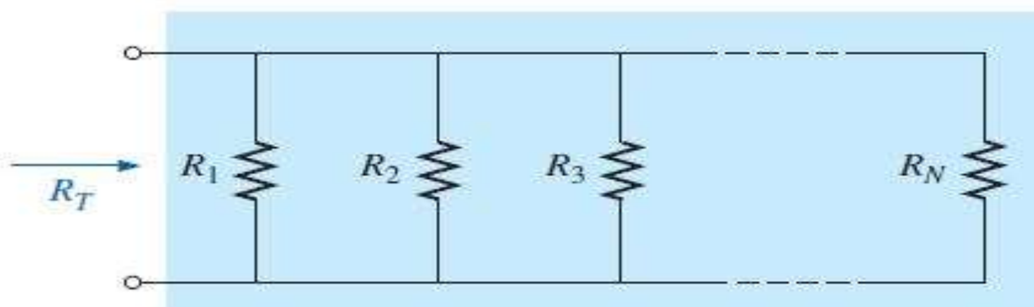


FIG. 6.3
Parallel combination of resistors.

KIRCHHOFF’S CURRENT LAW

The algebraic sum of the currents entering and leaving a junction (or region) of a network is zero.

The law can also be stated in the following way:

The sum of the currents entering a junction (or region) of a network must equal the sum of the currents leaving the same junction (or region).

In equation form, the above statement can be written as follows:

$$\boxed{\Sigma I_i = \Sigma I_o} \tag{6.13}$$

$$
\begin{aligned}
\Sigma I_i &= \Sigma I_o \\
I_1 + I_4 &= I_2 + I_3 \\
4\text{ A} + 8\text{ A} &= 2\text{ A} + 10\text{ A} \\
12\text{ A} &= 12\text{ A} \quad \text{(checks)}
\end{aligned}
$$

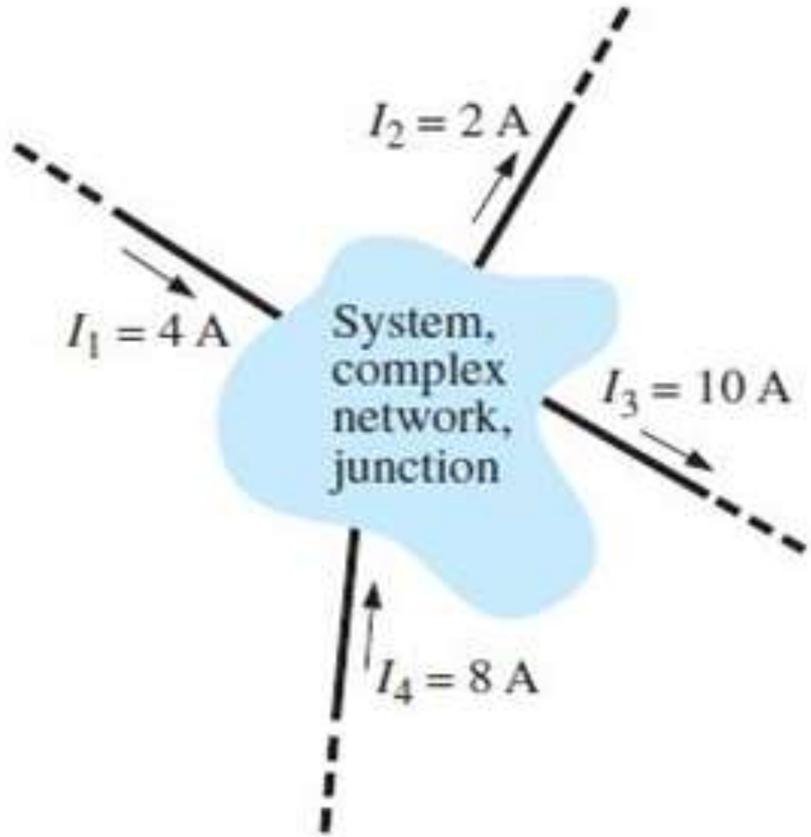


FIG. 6.31
Introducing Kirchhoff's current law.

KIRCHHOFF'S CURRENT LAW

EXAMPLE 6.16 Determine currents I3 and I4 in Fig. 6.33 using Kirchhoff's current law.

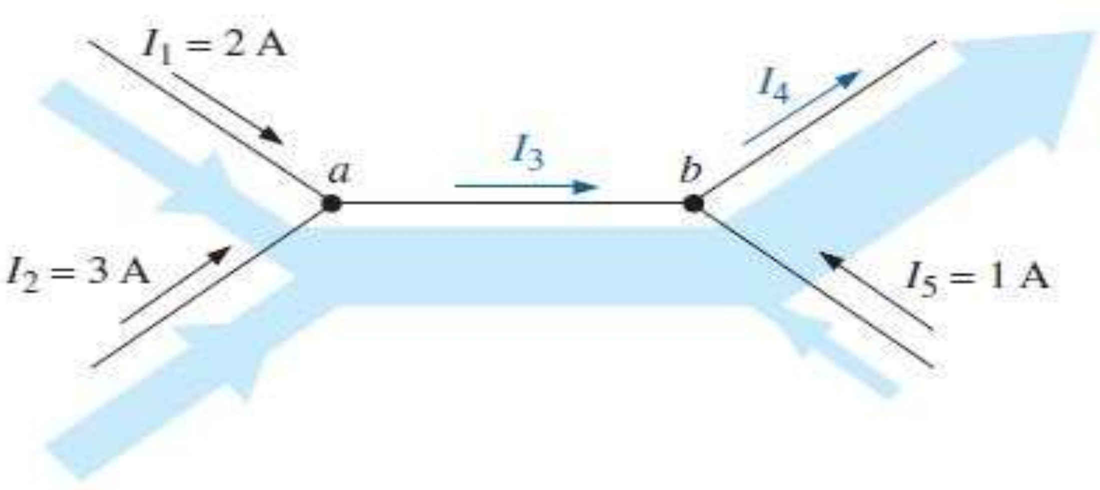


FIG. 6.33
Two-node configuration for Example 6.16.

CURRENT DIVIDER RULE

In general,

For two parallel elements of equal value, the current will divide equally. For parallel elements with different values, the smaller the resistance, the greater the share of input current. For parallel elements of different values, the current will split with a ratio equal to the inverse of their resistor values.

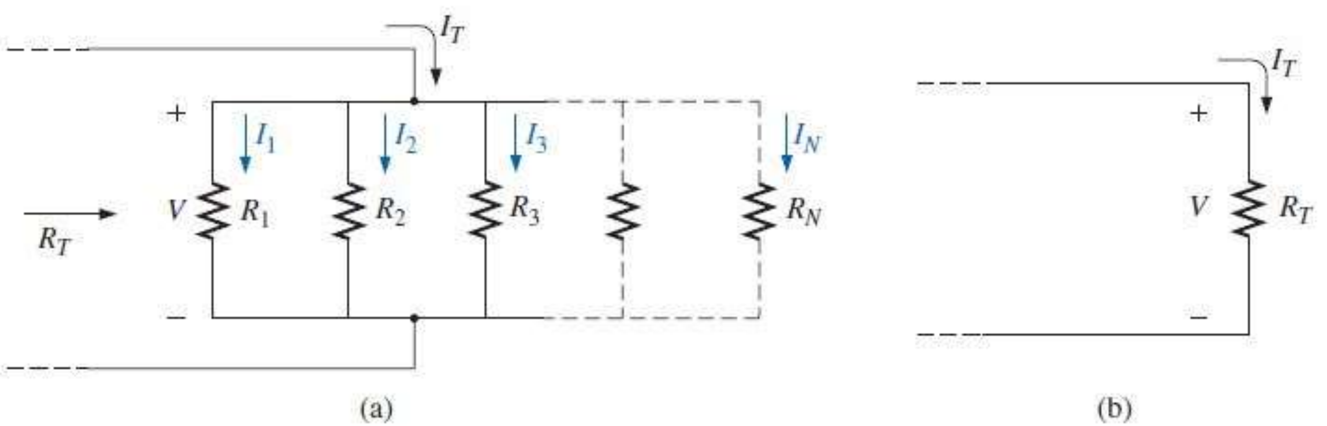


FIG. 6.41

Deriving the current divider rule: (a) parallel network of N parallel resistors; (b) reduced equivalent of part (a).

CURRENT DIVIDER RULE

The current I_T can then be determined using Ohm's law:

$$I_T = \frac{V}{R_T}$$

Since the voltage V is the same across parallel elements, the following is true:

$$V = I_1R_1 = I_2R_2 = I_3R_3 = \cdots = I_xR_x$$

where the product I_xR_x refers to any combination in the series.

Substituting for V in the above equation for I_T, we have

$$I_T = \frac{I_xR_x}{R_T}$$

Solving for I_x, the final result is the **current divider rule:**

$$\boxed{I_x = \frac{R_T}{R_x}I_T} \qquad \textbf{(6.14)}$$

CURRENT DIVIDER RULE

States that ***the current through any branch of a parallel resistive network is equal to the total resistance of the parallel network divided by the resistor of interest and multiplied by the total current entering the parallel configuration.***

Special Case: **Two Parallel Resistors**

For two parallel resistors, the current through one is equal to the other resistor times the total entering current divided by the sum ofthe two resistors.

$$I_1 = \left(\frac{R_2}{R_1 + R_2}\right) I_T \quad (6.15a)$$

$$I_2 = \left(\frac{R_1}{R_1 + R_2}\right) I_T \quad (6.15b)$$

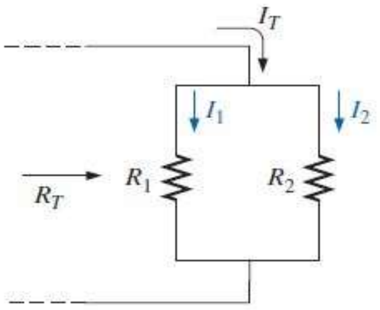


FIG. 6.43
Deriving the current divider rule for the special case of only two parallel resistors.

CURRENT DIVIDER RULE

EXAMPLE 6.22 For the parallel network in Fig. 6.42, determine currentI1 using Eq. (6.14).

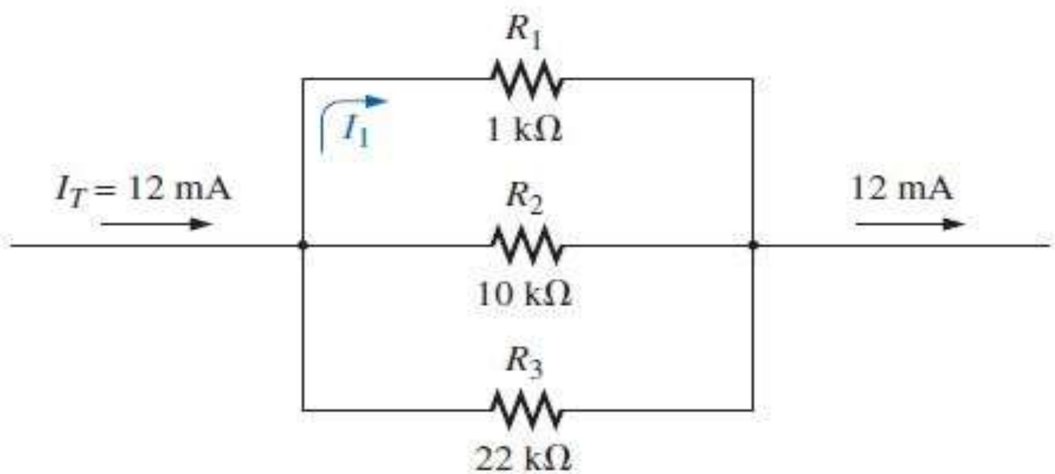


FIG. 6.42
Using the current divider rule to calculate current I_1 in Example 6.22.

KIRCHHOFF’S VOLTAGE LAW

The algebraic sum of the potential rises and drops around a closed path (or closed loop) is zero.

In symbolic form it can be written as

$$\boxed{\Sigma_C V = 0} \quad \text{(Kirchhoff's voltage law in symbolic form)} \quad (5.8)$$

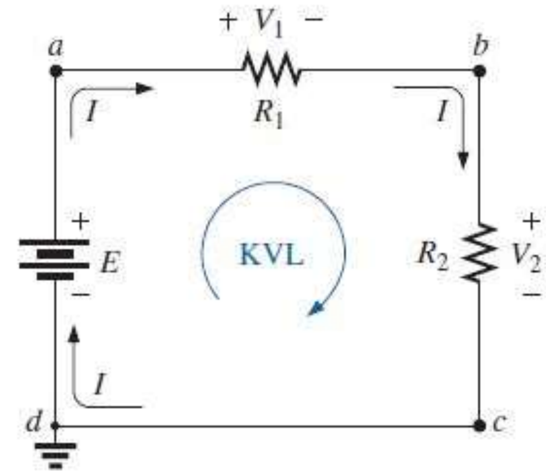


FIG. 5.26
Applying Kirchhoff’s voltage law to a series dc circuit.

KIRCHHOFF'S VOLTAGE LAW

Writing out the sequence with the voltages and the signs results in the following:

$$+E - V_1 - V_2 = 0$$

which can be rewritten as $E = V_1 + V_2$

The result is particularly interesting because it tells us that

the applied voltage of a series dc circuit will equal the sum of the voltage drops of the circuit.

Kirchhoff's voltage law can also be written in the following form:

$$\boxed{\Sigma_{\circlearrowright} V_{\text{rises}} = \Sigma_{\circlearrowright} V_{\text{drops}}} \qquad \textbf{(5.9)}$$

revealing that

the sum of the voltage rises around a closed path will always equal the sum of the voltage drops.

To demonstrate that the direction that you take around the loop has no effect on the results, let's take the counterclockwise path and compare results. The resulting sequence appears as

$$-E + V_2 + V_1 = 0$$

yielding the same result of $E = V_1 + V_2$

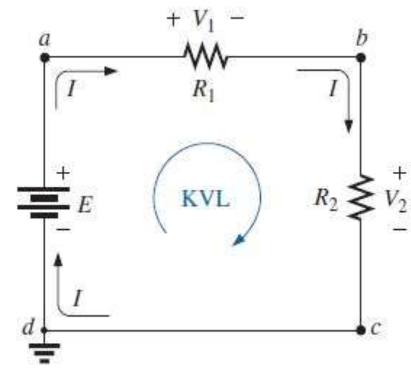


FIG. 5.26
Applying Kirchhoff's voltage law to a series dc circuit.

KIRCHHOFF’S VOLTAGE LAW

EXAMPLE 5.8 Use Kirchhoff’s voltage law to determine the Unknown voltage for the circuit in Fig. 5.27.

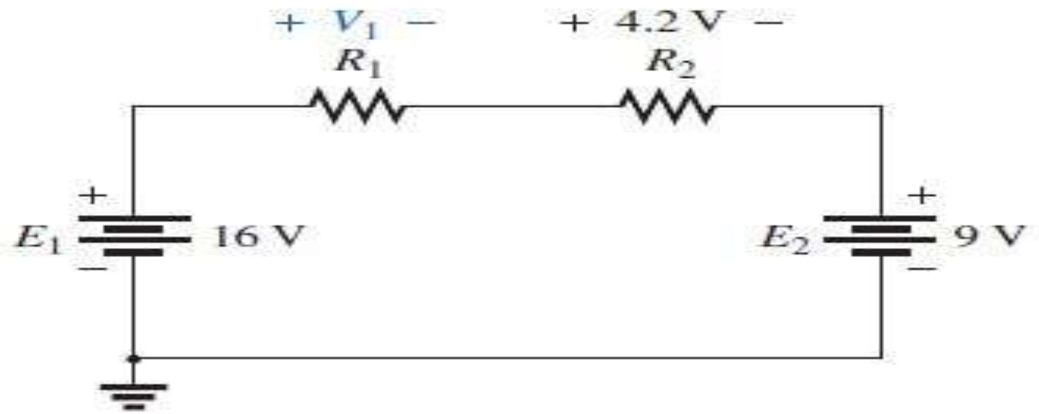


FIG. 5.27
Series circuit to be examined in Example 5.8.

Where are Parallel Circuit used

Parallel circuit are used in wiring almost everything in buildings. You use them to turn on the lights in a room. Use a blow dryer or to plug anything into an outlet.

A parallel circuit is used when the current through several components needs to be independent to each other.

Where are series circuit used.

In resistive circuit , when you need the same current in the whole circuit, you use series circuit because in series circuit current remains the same.

Series circuits are used in areas where the operation of t he circuit is required to be linear.

PRACTICAL APPLICATIONS OF SERIES CIRCUIT

Series Control

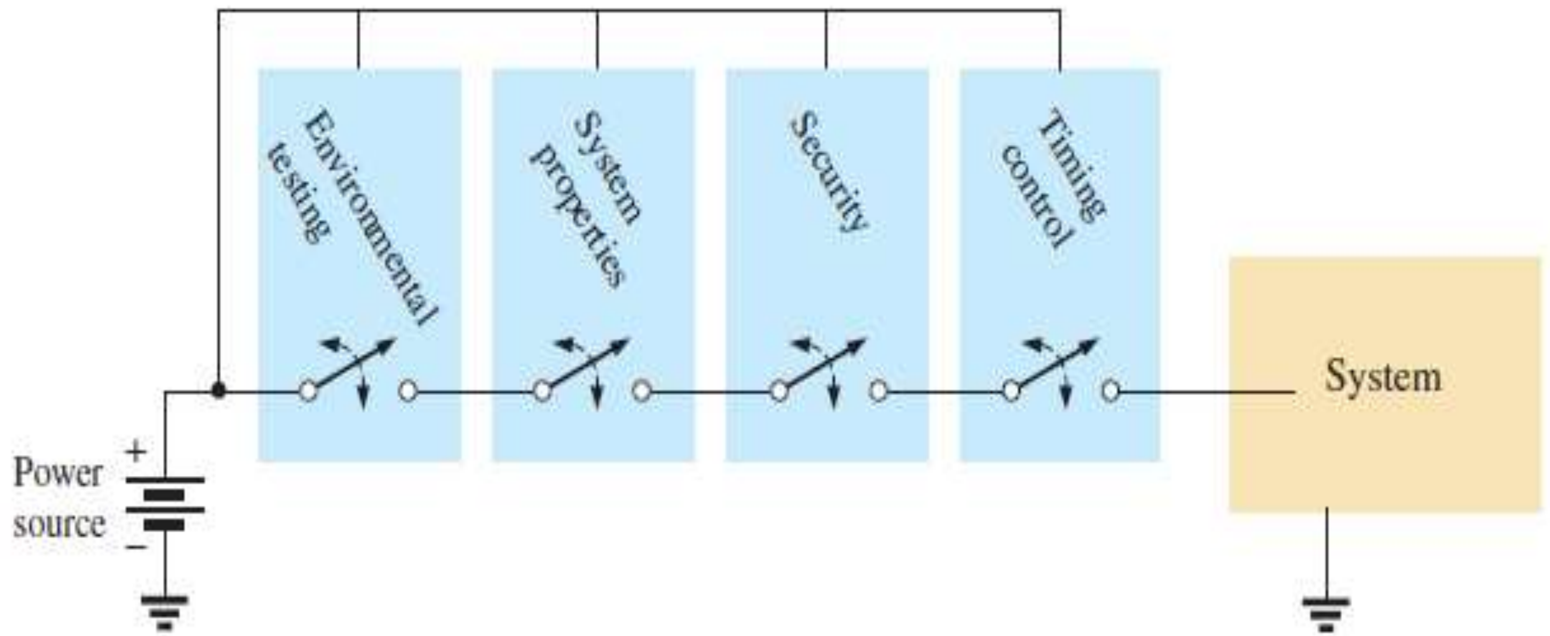


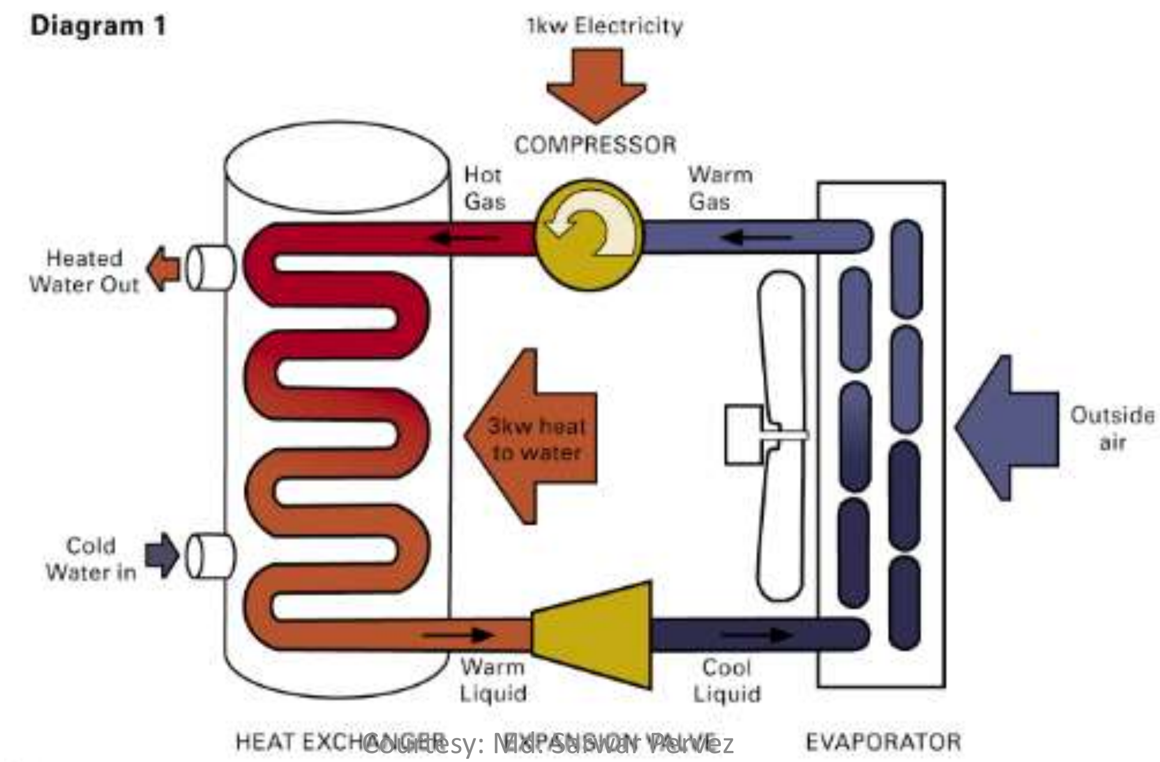
FIG. 5.77

Series control over an operating system.

PRACTICAL APPLICATIONS OF SERIES CIRCUIT

Water Heaters

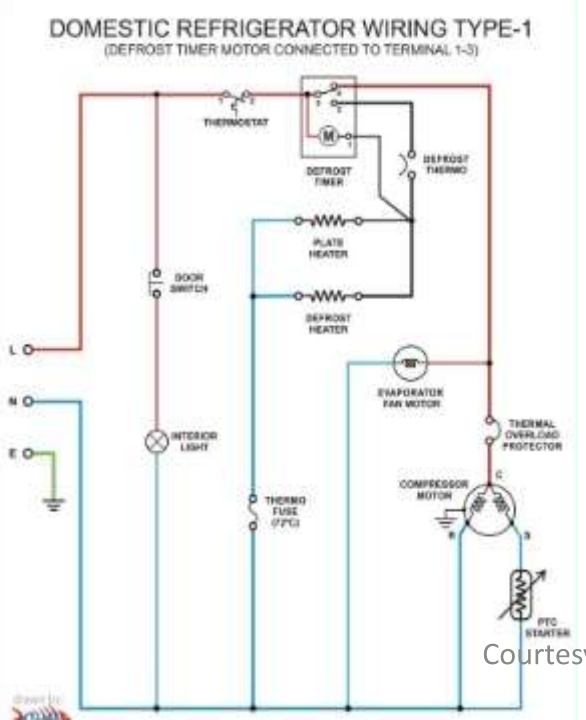
Water heaters use a series circuit. Power through the thermostat, which is a temperature control switch. When the water reaches the correct temperature, the thermostat will cut off the current to the heating element, leaving the current with no other paths to follow.

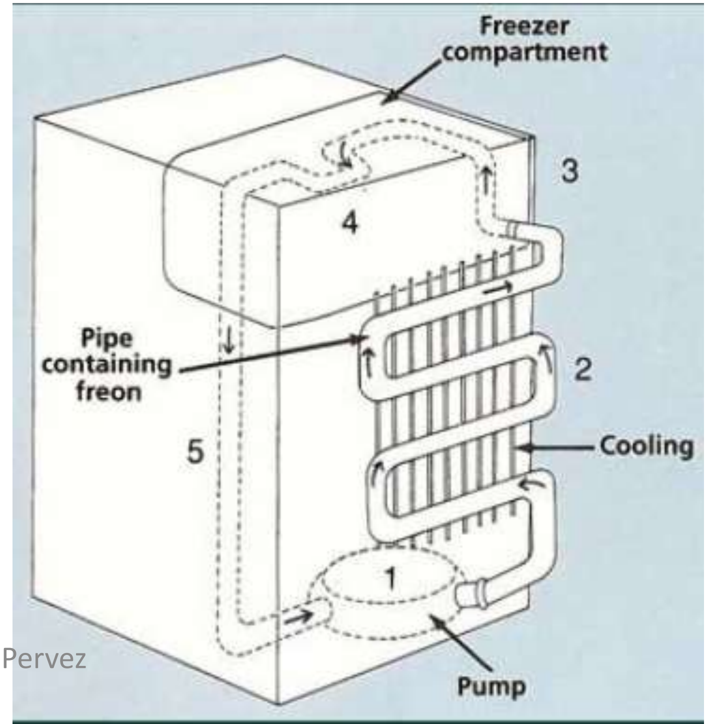


PRACTICAL APPLICATIONS OF SERIES CIRCUIT

Freezers and Refrigerators

Freezers and refrigerators both use series circuits. The elements in this circuit are the compressor and the temperature control switch. If the temperature inside the freezer or refrigerator gets too hot, the temperature control switch will turn the compressor on until the temperature drops. Ones the correct temperature is reached, the switch will then turn the compressor off again.





Courtesy: Md. Sarwar Pervez

PRACTICAL APPLICATIONS OF SERIES CIRCUIT

Microwave Oven

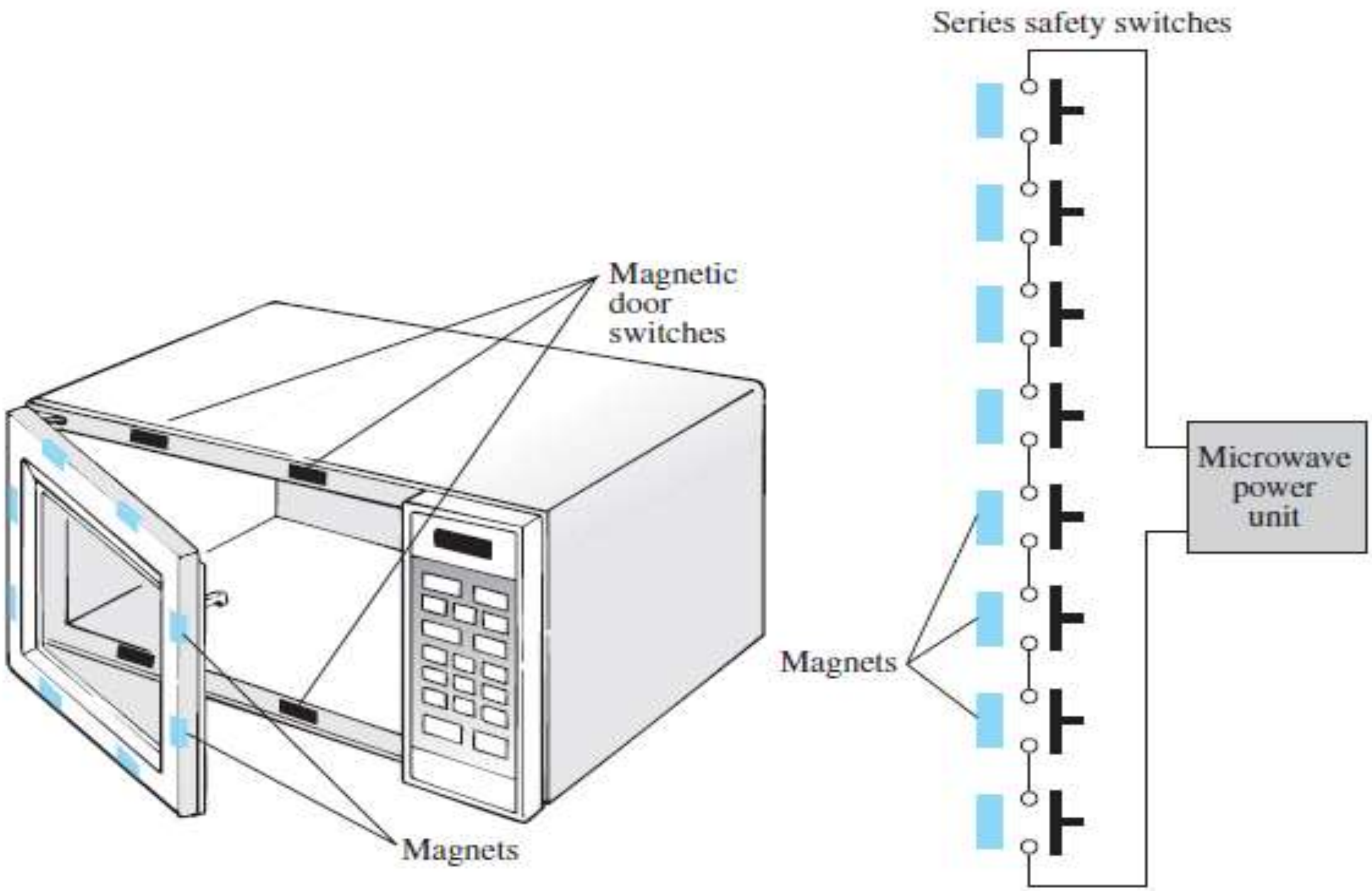
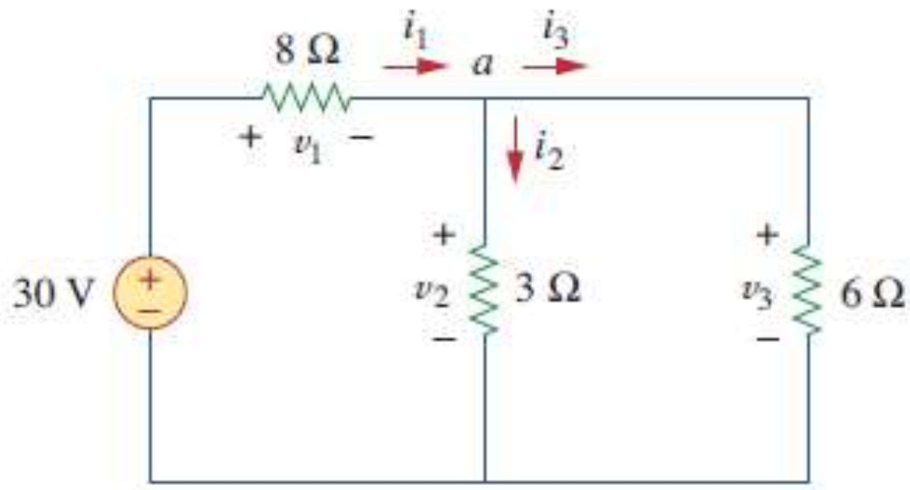


FIG. 5.80
Series safety switches in a microwave oven.

Courtesy: Md. Sarwar Pervez

HOME WORK

1. Find currents and voltages in the following circuit



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