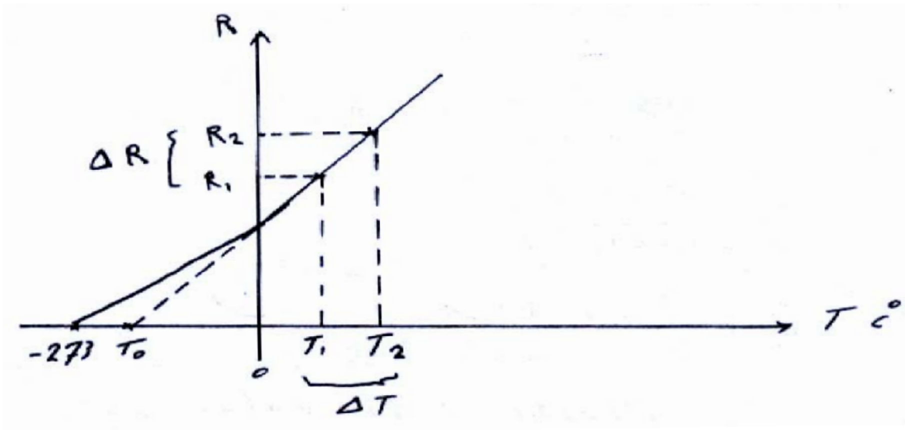
Continue ➔ The Effect of Temperature



$$\text{slop} = \frac{\Delta R}{\Delta T} = \text{constant} = \frac{R_2 - R_1}{T_2 - T_1} = \frac{R_2 - R}{T_2 - T} = \frac{R - R_1}{T - T_1}$$

Example: The resistance of material is 300 Ω at 10C°, and 400 Ω at 60C°. Find its resistance at 50 C° ?

Solution:

$$\text{slop} = \frac{R_2 - R_1}{T_2 - T_1} = \frac{400 - 300}{60 - 10} = 2\Omega / C^o$$

$$2 = \frac{R - R_1}{T - T_1} = \frac{R - 300}{50 - 10} = \frac{R - 300}{40}$$

$$R - 300 = 80 \Rightarrow R = 80 + 300 \Rightarrow R = 380\Omega$$

Also from the above figure we can sea

$$\frac{R_2 - 0}{T_2 - T_0} - \frac{R_1 - 0}{T_1 - T_0}$$

$$\frac{R_2}{T_2 - T_0} = \frac{R_1}{T_1 - T_0}$$

$$\therefore \frac{R_2}{R_1} = \frac{T_2 - T_0}{T_1 - T_0} \text{ , hence } \frac{\rho_2 \frac{\ell}{A}}{\rho_1 \frac{\ell}{A}} = \frac{T_2 - T_0}{T_1 - T_0} \Rightarrow \frac{\rho_2}{\rho_1} = \frac{T_2 - T_0}{T_1 - T_0}$$

Example: Aluminum conductor with length of 75 cm and 1.5 mm^2 cross section area. Find its resistance at 90 C^o ?

Solution:

$$R = \frac{\rho \ell}{A} = \frac{\left(2.83\times10^{-8}\right)\times\left(75\times10^{-2}\right)}{1.5\times10^{\ 6}}$$

$$= 2.83\times50\times10^{\ 4} = 141.5\times10^{\ 4} = 14.15m\Omega$$

$$\frac{R_2}{R_1} = \frac{T_2 - T_0}{T_1 - T_0}$$

$$R_2 = 14.15\left[\frac{90 - (-236)}{20 - (-236)}\right]$$

$$= 14.15\left[\frac{90 + 236}{20 + 236}\right] = 18\, m\Omega.$$

Another method

$$\frac{\rho_2}{\rho_1} = \frac{T_2 - T_0}{T_1 - T_0} \Rightarrow \rho_{90} = \rho_{20}\left(\frac{90+236}{20+236}\right)$$

$$R = \frac{\rho_{90}\ell}{A} = \frac{\rho_{20}\left(\frac{90+236}{20+236}\right)\times\left(75\times10^{-2}\right)}{1.5\times10^{-6}}$$

$$\rho_{20} = 2.83\times10^{-8}$$

$$\therefore \rho_{90} = 14.15m\Omega$$

Deriving the temperature coefficient

It can be started by using the previous relationship of the resistance and temperature

$$\frac{R_2}{R_1} = \frac{T_2 - T_0}{T_1 - T_0}$$

$$R_2 = R_1\left(\frac{T_2 - T_0}{T_1 - T_0}\right)$$

$$R_2 = R_1\left(\frac{T_2 - T_0}{T_1 - T_0} + 1 - 1\right)$$

$$R_2 = R_1\left(1 + \frac{T_2 - T_0}{T_1 - T_0} - 1\right)$$

$$R_2 = R_1\left(1 + \frac{T_2 - T_0 - (T_1 - T_0)}{T_1 - T_0}\right)$$

$$R_2 = R_1\left(1 + \frac{T_2 - T_1}{T_1 - T_0}\right)$$

$$R_2 = R_1\left[1 + \left(\frac{1}{T_1 - T_0}\right)(T_2 - T_1)\right]$$

Let $\alpha_1 = \frac{1}{T_1 - T_0}$ temperature coefficient of resistance at a temperature T_1

$$\therefore R_2 = R_1[1 + \alpha_1(T_2 - T_1)]$$

Where T_0 for copper = -234.5

In some resource, T_0 take an absolute value, which means $|T_0|$ = 234.5, hence we can sea

$$\alpha_1 = \frac{1}{|T| + T_1} \qquad \& \qquad \frac{R_2}{R_1} = \frac{|T_0| + T_2}{|T_0| + T_1}$$

Example:

a) Find the value of α_1 at (T_1 = 40 C^o) for copper wire.

b) Using the result of (a), find the resistance of a copper wire at 75 C^o if its resistance is 30 Ω at 40 C^o ?

Solution:

a) $$\alpha_1 = \frac{1}{T_1 - T_0} = \frac{1}{40 - (-234.5)} = \frac{1}{274.5} = 0.00364 \qquad 1/K$$

Or $$\alpha_1 = \frac{1}{|T| + T_1} = \frac{1}{234.5 + 40} = \frac{1}{274.5} = 0.00364 \qquad 1/K$$

b) $$R_2 = R_1[1 + \alpha_1(T_2 - T_1)]$$

$$= 30[1 + 0.00364(75 - 40)] = 33.8\Omega$$

Exercise*/ A coil has a resistance of 18 Ohm when its mean temperature is 20°C and of 20 Ohm temperature is 50°C. Find its mean temperature rise when its resistance is 21 Ohm and the surrounding temperature is 15°* C.

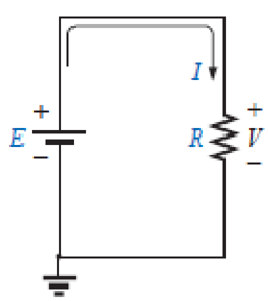
OHM'S LAW

Consider the following relationship: $$\text{Effect} = \frac{\text{cause}}{\text{opposition}}$$

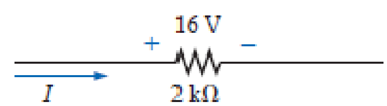
Every conversion of energy from one form to another can be related to this equation. In electric circuits, the *effect* we are trying to establish is the flow of charge, or *current.* The *potential difference,* or voltage, between two points is the *cause* ("pressure"), and the opposition is the *resistance* encountered.

when its mean

$$\text{Current} = \frac{\text{potential difference}}{\text{resistance}}$$



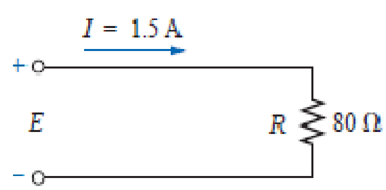
$$I = \frac{E}{R} \qquad \text{(amperes, A)}$$



$$E = IR \qquad \text{(volts, V)}$$

$$I = \frac{V}{R} = \frac{16\text{ V}}{2 \times 10^3\ \Omega} = \mathbf{8\ mA}$$

$$R = \frac{E}{I} \qquad \text{(ohms, } \Omega\text{)}$$



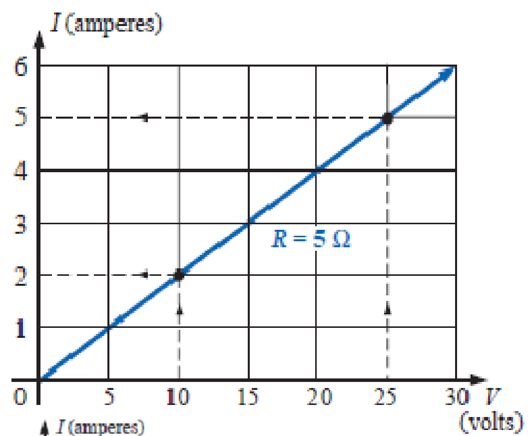
$$E = IR = (1.5\text{ A})(80\ \Omega) = \mathbf{120\ V}$$

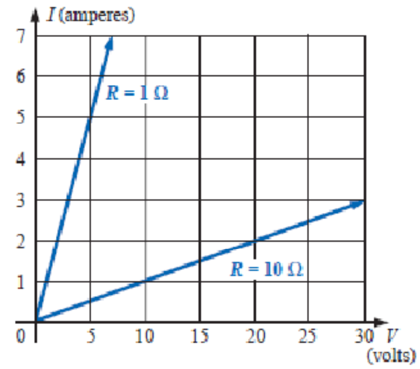
PLOTTING OHM'S LAW

If we write Ohm's law in the following manner and relate it to the basic straight-line equation

$$I = \frac{1}{R} \cdot E + 0$$
$$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$$
$$y = m \cdot x + b$$

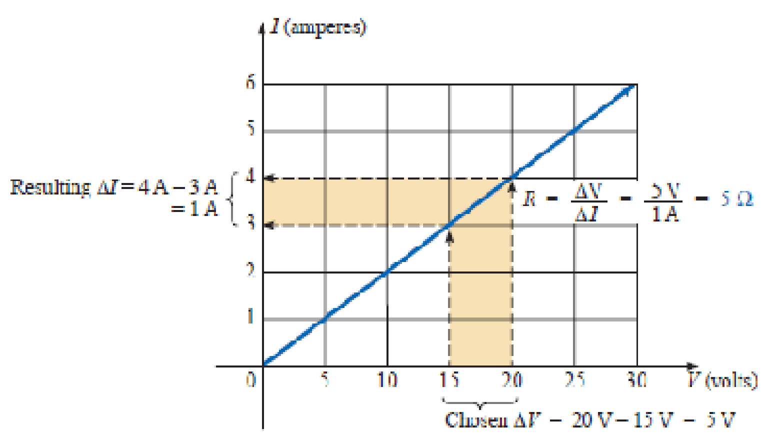
we find that the slope is equal to 1 divided by the resistance value, as indicated by the following:





$$m = \text{slope} = \frac{\Delta y}{\Delta x} = \frac{\Delta I}{\Delta V} = \frac{1}{R}$$

$$R = \frac{\Delta V}{\Delta I} \quad \text{(ohms)}$$



EXAMPLE 4.5 Determine the resistance associated with the curve of Fig. 4.9 using Eqs. (4.5) and (4.7), and compare results.

Solution: At $V = 6$ V, $I = 3$ mA, and

$$R_{dc} = \frac{V}{I} = \frac{6\text{ V}}{3\text{ mA}} = 2\text{ k}\Omega$$

For the interval between 6 V and 8 V,

$$R = \frac{\Delta V}{\Delta I} = \frac{2\text{ V}}{1\text{ mA}} = 2\text{ k}\Omega$$

The results are equivalent.

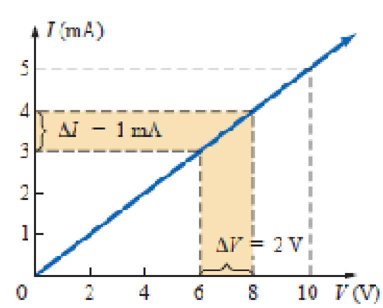


FIG. 4.9

Semiconductor diode characteristic

At $V = +1$ V,

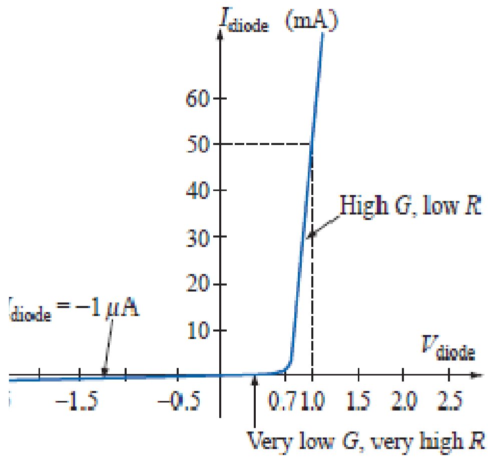
$$R_{diode} = \frac{V}{I} = \frac{1\text{ V}}{50\text{ mA}} = \frac{1\text{ V}}{50 \times 10^{-3}\text{ A}}$$

$= 20\ \Omega$
(a relatively low value for most applications)

At $V = -1$ V,

$$R_{diode} = \frac{V}{I} = \frac{1\text{ V}}{1\ \mu\text{A}}$$

$= 1\text{ M}\Omega$
(which is often represented by an open-circuit equivalent)



POWER

Power is an indication of how much work (the conversion of energy from one form to another) can be done in a specified amount of time, that is, a *rate* of doing work.

1 watt (W) = 1 joule/second (J/s)

In equation form, power is determined by

$$P = \frac{W}{t} \quad \text{(watts, W, or joules/second, J/s)}$$

1 horsepower ≅ 746 watts

The power delivered to, or absorbed by, an electrical device or system can be found in terms of the current and voltage by first substituting Eq.

$$P = \frac{W}{t} = \frac{QV}{t} = V\frac{Q}{t}$$

But $$I = \frac{Q}{t}$$

so that $$P = VI \quad \text{(watts)}$$

$$P = VI = V\left(\frac{V}{R}\right)$$

and $$P = \frac{V^2}{R} \quad \text{(watts)}$$

or $$P = VI = (IR)I$$

and $$P = I^2R \quad \text{(watts)}$$

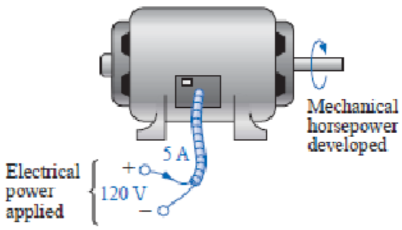


FIG. 4.14
Example 4.6.

EXAMPLE 4.6 Find the power delivered to the dc motor of Fig. 4.14.

Solution:

$$P = VI = (120\text{ V})(5\text{ A}) = 600\text{ W} = \mathbf{0.6\text{ kW}}$$

EXAMPLE 4.7 What is the power dissipated by a 5-Ω resistor if the current is 4 A?

Solution:

$$P = I^2R = (4\text{ A})^2(5\ \Omega) = \mathbf{80\text{ W}}$$

Sometimes the power is given and the current or voltage must be determined. Through algebraic manipulations, an equation for each variable is derived as follows:

$$P = I^2R \Rightarrow I^2 = \frac{P}{R}$$

and

$$I = \sqrt{\frac{P}{R}} \quad \text{(amperes)} \qquad \mathbf{(4.14)}$$

$$P = \frac{V^2}{R} \Rightarrow V^2 = PR$$

and

$$V = \sqrt{PR} \quad \text{(volts)} \qquad \mathbf{(4.15)}$$

EXAMPLE Determine the current through a 5-k_ resistor when the power dissipated by the element is 20 mW.

Solution

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{20 \times 10^{-3}\text{ W}}{5 \times 10^{3}\ \Omega}} = \sqrt{4 \times 10^{-6}} = 2 \times 10^{-3}\text{ A}$$
$$= \mathbf{2\text{ mA}}$$

EFFICIENCY

Conservation of energy requires that

Energy input(W_{in}) = energy output (W_{out}) + energy lost or stored in the system

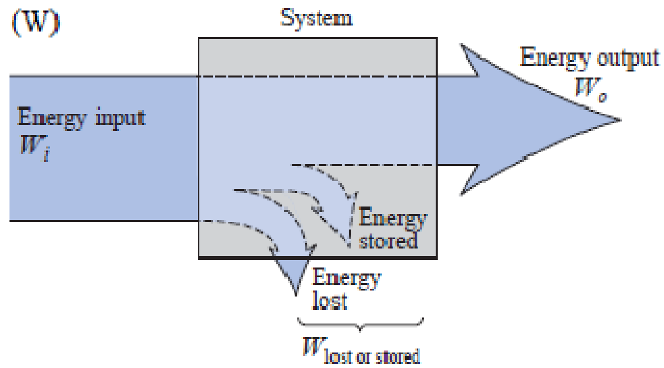
Dividing both sides of the relationship by ***t*** gives

$$\frac{W_{in}}{t} = \frac{W_{out}}{t} + \frac{W_{\text{lost or stored by the system}}}{t}$$

Energy flow through a system.

Since $P = W/t$, we have the following:

$$P_i = P_o + P_{\text{lost or stored}}$$



The **efficiency** (η) of the system is then determined by the following equation:

$$\text{Efficiency} = \frac{\text{power output}}{\text{power input}}$$

$$\eta = \frac{P_o}{P_i} \quad \text{(decimal number)}$$

$$\eta\% = \frac{P_o}{P_i} \times 100\% \quad \text{(percent)}$$

$$\eta\% = \frac{W_o}{W_i} \times 100\% \quad \text{(percent)}$$

EXAMPLE A 2-hp motor operates at an efficiency of 75%. What is the power input in watts? If the applied voltage is 220 V, what is the input current?

$$\eta\% = \frac{P_o}{P_i} \times 100\%$$

$$0.75 = \frac{(2\text{ hp})(746\text{ W/hp})}{P_i}$$

and

$$P_i = \frac{1492\text{ W}}{0.75} = \mathbf{1989.33\text{ W}}$$

$$P_i = EI \quad \text{or} \quad I = \frac{P_i}{E} = \frac{1989.33\text{ W}}{220\text{ V}} = \mathbf{9.04\text{ A}}$$

EXAMPLE 4.11 What is the output in horsepower of a motor with an efficiency of 80% and an input current of 8 A at 120 V?

Solution:

$$\eta\% = \frac{P_o}{P_i} \times 100\%$$

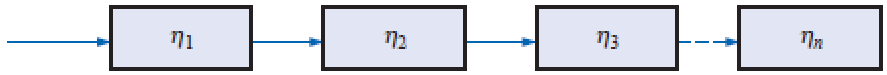
$$0.80 = \frac{P_o}{(120\text{ V})(8\text{ A})}$$

and $$P_o = (0.80)(120\text{ V})(8\text{ A}) = 768\text{ W}$$

with $$768\text{ W}\left(\frac{1\text{ hp}}{746\text{ W}}\right) = \mathbf{1.029\text{ hp}}$$

Efficiency for Cascade Systems

$$\eta_1 = \frac{P_{o_1}}{P_{i_1}} \qquad \eta_2 = \frac{P_{o_2}}{P_{i_2}} \qquad \eta_3 = \frac{P_{o_3}}{P_{i_3}}$$



If we form the product of these three efficiencies,

$$\eta_1 \cdot \eta_2 \cdot \eta_3 = \frac{P_{o_1}}{P_{i_1}} \cdot \frac{P_{o_2}}{P_{i_2}} \cdot \frac{P_{o_3}}{P_{i_3}}$$

and substitute the fact that $P_{i_2} = P_{o_1}$ and $P_{i_3} = P_{o_2}$, we find that the quantities indicated above will cancel, resulting in P_{o_3}/P_{i_1}, which is a measure of the efficiency of the entire system. In general, for the representative cascaded system of Fig. 4.20,

$$\eta_{\text{total}} = \eta_1 \cdot \eta_2 \cdot \eta_3 \cdots \eta_n \qquad \textbf{(4.20)}$$

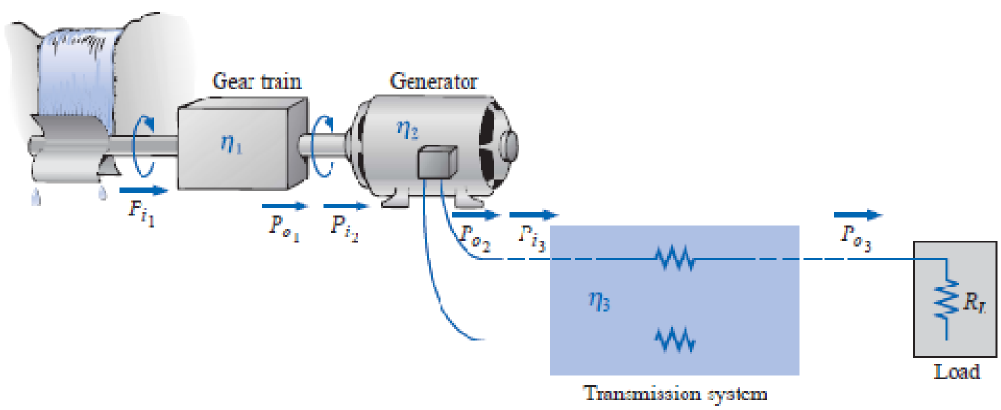


FIG. 4.19
Basic components of a generating system.

EXAMPLE 4.13 Find the overall efficiency of the system of Fig. 4.19 if $\eta_1 = 90\%$, $\eta_2 = 85\%$, and $\eta_3 = 95\%$.

Solution:

$$\eta_T = \eta_1 \cdot \eta_2 \cdot \eta_3 = (0.90)(0.85)(0.95) = 0.727, \text{ or } 72.7\%$$

Energy

$$\text{Energy (Wh)} = \text{power (W)} \times \text{time (h)}$$

$$\text{Energy (kWh)} = \frac{\text{power (W)} \times \text{time (h)}}{1000}$$

EXAMPLE 4.16 How much energy (in kilowatthours) is required to light a 60-W bulb continuously for 1 year (365 days)?

Solution:

$$W = \frac{Pt}{1000} = \frac{(60\text{ W})(24\text{ h/day})(365\text{ days})}{1000} = \frac{525{,}600\text{ Wh}}{1000}$$

$$= \mathbf{525.60\ kWh}$$

EXAMPLE 4.17 How long can a 205-W television set be on before using more than 4 kWh of energy?

Solution:

$$W = \frac{Pt}{1000} \Rightarrow t\text{ (hours)} = \frac{(W)(1000)}{P}$$

$$= \frac{(4\text{ kWh})(1000)}{205\text{ W}} = \mathbf{19.51\ h}$$

TABLE 4.1
Typical wattage ratings of some common household items.

Appliance	Wattage Rating	Appliance	Wattage Rating
Air conditioner	860	Lap-top computer:	
Blow dryer	1,300	Sleep	< 1 W (Typically 0.3 W to 0.5 W)
Cassette player/recorder	5	Normal	10–20 W
Cellular phone:		High	25–35 W
Standby	≅ 35 mW	Microwave oven	1,200
Talk	≅ 4.3 W	Pager	1–2 mW
Clock	2	Phonograph	75
Clothes dryer (electric)	4,800	Projector	1,200
Coffee maker	900	Radio	70
Dishwasher	1,200	Range (self-cleaning)	12,200
Fan:		Refrigerator (automatic defrost)	1,800
Portable	90	Shaver	15
Window	200	Stereo equipment	110
Heater	1,322	Sun lamp	280
Heating equipment:		Toaster	1,200
Furnace fan	320	Trash compactor	400
Oil-burner motor	230	TV (color)	200
Iron, dry or steam	1,100	Videocassette recorder	110
		Washing machine	500
		Water heater	4,500

Courtesy of General Electric Co.

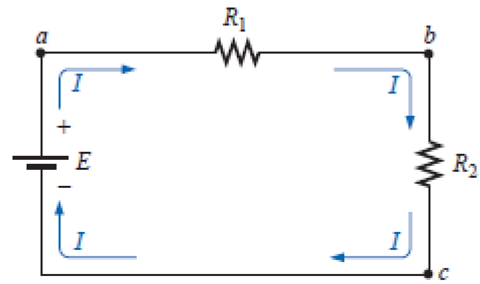
Problems in pages 125-----126 ➔ the reference is Boylestad

SERIES CIRCUITS

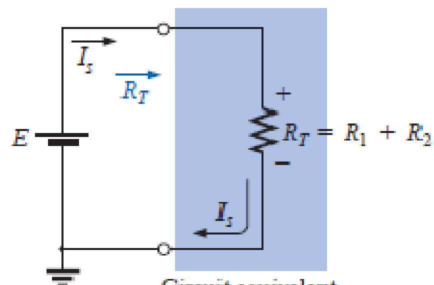
Two elements are in series if
1. They have only one terminal in common (i.e., one lead of one is connected to only one lead of the other).
2. The common point between the two elements is not connected to another current-carrying element.
The total resistance of a series circuit is the sum of the resistance levels.

$$R_T = R_1 + R_2 + R_3 + \cdots + R_N \qquad \text{(ohms, } \Omega\text{)}$$

$$I_s = \frac{E}{R_T} \qquad \text{(amperes, A)}$$



$$V_1 = IR_1,\ V_2 = IR_2,\ V_3 = IR_3,\ \ldots,\ V_N = IR_N \qquad \text{(volts, V)}$$



Circuit equivalent

$$P_1 = V_1 I_1 = I_1^2 R_1 = \frac{V_1^2}{R_1} \qquad \text{(watts, W)}$$

The power delivered by the source is

$$P_{\text{del}} = EI \qquad \text{(watts, W)}$$

The total power delivered to a resistive circuit is equal to the total power dissipated by the resistive elements.
That is,

$$P_{\text{del}} = P_1 + P_2 + P_3 + \cdots + P_N$$

EXAMPLE 5.1

a. Find the total resistance for the series circuit of Fig. 5.7.
b. Calculate the source current I_s.
c. Determine the voltages V_1, V_2, and V_3.
d. Calculate the power dissipated by R_1, R_2, and R_3.
e. Determine the power delivered by the source, and compare it to the sum of the power levels of part (d).

Solutions:

a. $R_T = R_1 + R_2 + R_3 = 2\ \Omega + 1\ \Omega + 5\ \Omega = \mathbf{8\ \Omega}$

b. $I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{8\ \Omega} = \mathbf{2.5\ A}$

c. $V_1 = IR_1 = (2.5\text{ A})(2\ \Omega) = \mathbf{5\ V}$
$V_2 = IR_2 = (2.5\text{ A})(1\ \Omega) = \mathbf{2.5\ V}$
$V_3 = IR_3 = (2.5\text{ A})(5\ \Omega) = \mathbf{12.5\ V}$

d. $P_1 = V_1I_1 = (5\text{ V})(2.5\text{ A}) = \mathbf{12.5\ W}$
$P_2 = I_2^2R_2 = (2.5\text{ A})^2(1\ \Omega) = \mathbf{6.25\ W}$
$P_3 = V_3^2/R_3 = (12.5\text{ V})^2/5\ \Omega = \mathbf{31.25\ W}$

e. $P_{del} = EI = (20\text{ V})(2.5\text{ A}) = \mathbf{50\ W}$
$P_{del} = P_1 + P_2 + P_3$
$50\text{ W} = 12.5\text{ W} + 6.25\text{ W} + 31.25\text{ W}$
$50\text{ W} = 50\text{ W}$ (checks)

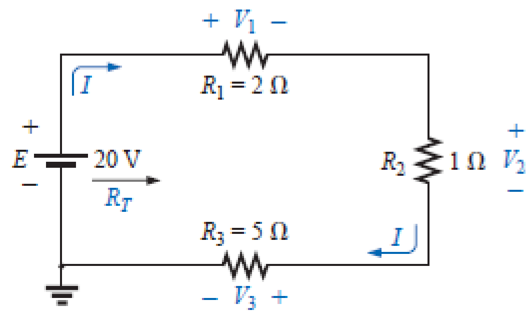


FIG. 5.7
Example 5.1.

EXAMPLE 5.2 Determine R_T, I, and V_2 for the circuit of Fig. 5.8.

Solution: Note the current direction as established by the battery and the polarity of the voltage drops across R_2 as determined by the current direction. Since $R_1 = R_3 = R_4$,

$$R_T = NR_1 + R_2 = (3)(7\ \Omega) + 4\ \Omega = 21\ \Omega + 4\ \Omega = \mathbf{25\ \Omega}$$
$$I = \frac{E}{R_T} = \frac{50\text{ V}}{25\ \Omega} = \mathbf{2\ A}$$
$$V_2 = IR_2 = (2\text{ A})(4\ \Omega) = \mathbf{8\ V}$$

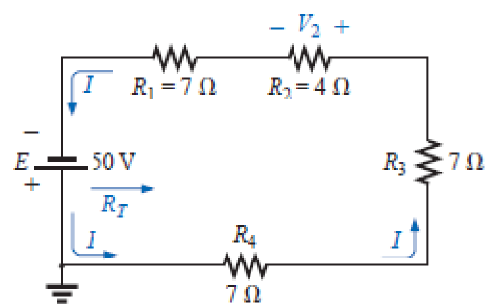


FIG. 5.8
Example 5.2.

EXAMPLE 5.3 Given R_T and I, calculate R_1 and E for the circuit of Fig. 5.9.

$$R_T = R_1 + R_2 + R_3$$
$$12\text{ k}\Omega = R_1 + 4\text{ k}\Omega + 6\text{ k}\Omega$$
$$R_1 = 12\text{ k}\Omega - 10\text{ k}\Omega = \mathbf{2\ k\Omega}$$
$$E = IR_T = (6 \times 10^{-3}\text{ A})(12 \times 10^{3}\ \Omega) = \mathbf{72\ V}$$

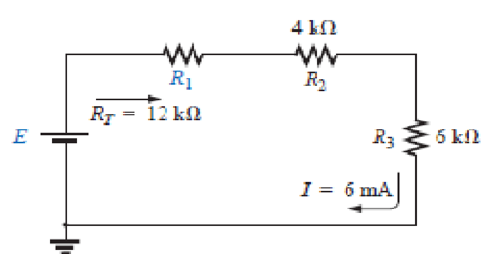
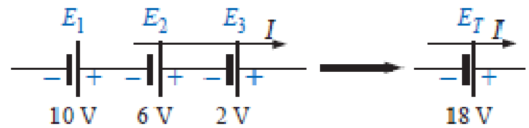


FIG. 5.9
Example 5.3.

VOLTAGE SOURCES IN SERIES

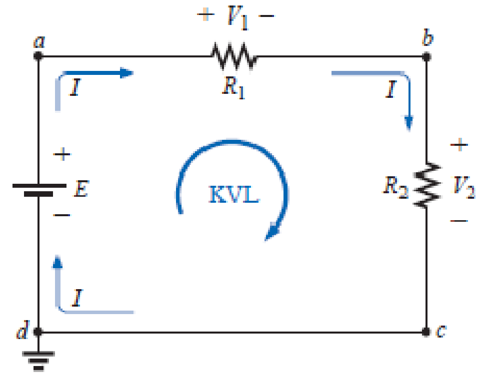
$$E_T = E_1 + E_2 + E_3 = 10\text{ V} + 6\text{ V} + 2\text{ V} = 18\text{ V}$$



KIRCHHOFF'S VOLTAGE LAW

Kirchhoff's voltage law ***(KVL) states that the algebraic sum of the potential rises and drops around a closed loop (or path) is zero.***

$$\Sigma_C V = 0$$ (Kirchhoff's voltage law in symbolic form)



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

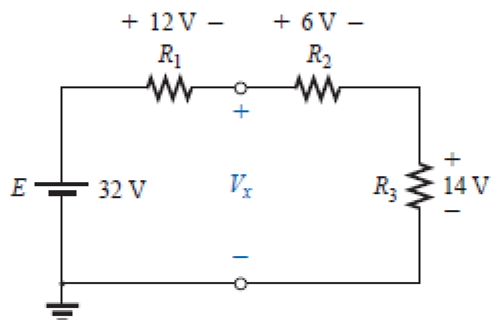
$$E = V_1 + V_2$$

revealing that

the applied voltage of a series circuit equals the sum of the voltage drops across the series elements.

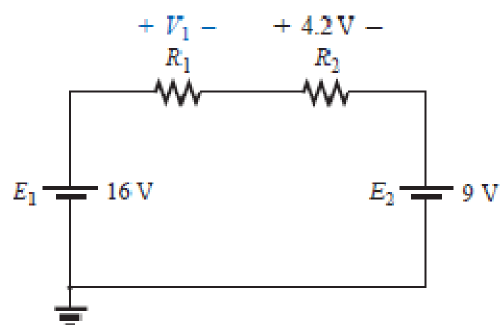
$$\Sigma_C V_{rises} = \Sigma_C V_{drops}$$

Example/ Determine the unknown voltages for the networks



$$+E - V_1 - V_x = 0$$

$$V_x = E - V_1 = 32\text{ V} - 12\text{ V} = \mathbf{20\text{ V}}$$



$$+E_1 - V_1 - V_2 - E_2 = 0$$

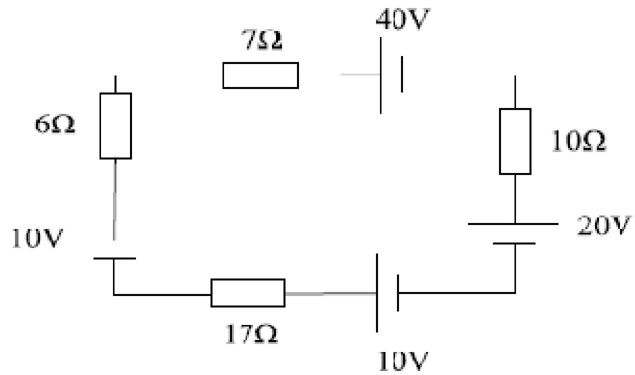
$$V_1 = E_1 - V_2 - E_2 = 16\text{ V} - 4.2\text{ V} - 9\text{ V} = \mathbf{2.8\text{ V}}$$

Example: For the following circuit diagram, Find I using:-

a) Ohm's law.

b) K.V.L.

Solution:



a) By applying ohm's law :-

$$I = \frac{E_T}{R} = \frac{20 + 40 - 10 - 10}{10 + 7 + 6 + 17} = \frac{40}{40} = 1A$$

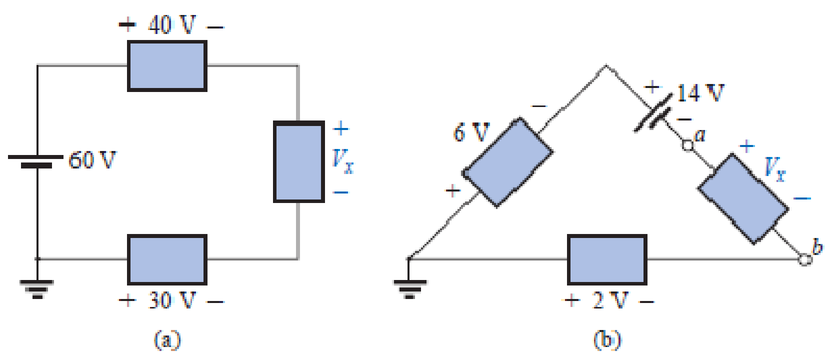
b) By applying K.V.L. :-

$$10 + 6I + 7I - 40 + 10I - 20 + 10 + 17I = 0$$

$$10 - 40 - 20 + 10 + I (6 + 7 + 10 + 17) = 0$$

$$-40 = -I (40) \Rightarrow I = \frac{40}{40} = 1A$$

EXAMPLE 5.6 Using Kirchhoff's voltage law, determine the unknown voltages for the network of Fig. 5.16.



$$60\text{ V} - 40\text{ V} - V_x + 30\text{ V} = 0$$

$$V_x = 60\text{ V} + 30\text{ V} - 40\text{ V} = 90\text{ V} - 40\text{ V}$$
$$= \mathbf{50\ V}$$

$$-6\text{ V} - 14\text{ V} - V_x + 2\text{ V} = 0$$

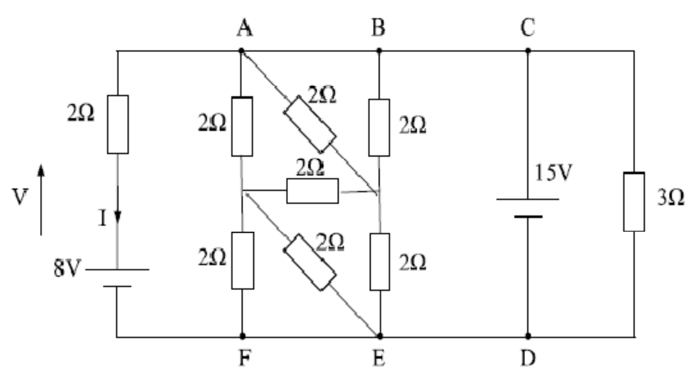
$$V_x = -20\text{ V} + 2\text{ V}$$
$$= \mathbf{-18\ V}$$

Example :- For the following circuit diagram , find the current ?

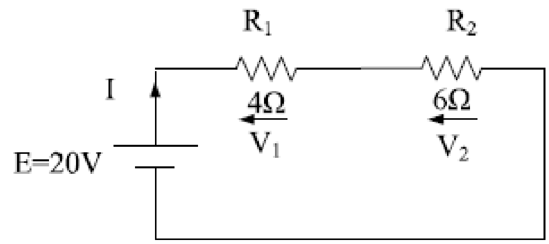
Take the loop FABCDEF

$$+8 + V - 15 = 0 \Rightarrow +V - 7 = 0 \Rightarrow V = +7\text{ volt}$$

$$V = IR \Rightarrow I = \frac{7}{2} = 3.5A$$



Example :- For the following circuit diagram , find ; R_T , I , V_1 , V_2 , $P_{4\Omega}$, $P_{6\Omega}$, P_E , verify by K.V.L. ?



Solution :-

$R_T = R_1 + R_2 = 4 + 6 = 10$

$$I = \frac{E}{R_T} = \frac{20}{10} = 2A$$

$$V_1 = IR_1 = 2 \times 4 = 8V$$

$$V_2 = IR_2 = 2 \times 6 = 12V$$

$$P_{4\Omega} = I^2 R_1 = (2)^2 \times 4 = 16W \quad ; \text{ or } \quad P_{4\Omega} = \frac{V_1^2}{R_1} = \frac{(8)^2}{4} = 16w$$

$$P_{6\Omega} = I^2 R_2 = (2)^2 \times 6 = 24W \quad ; \text{ or } \quad P_{6\Omega} = \frac{V_2^2}{R_2} = \frac{(12)^2}{6} = 24w$$

$$P_E = IE = 2 \times 20 = 40W \quad ; \text{ or } \quad P_E = P_{4\Omega} + P_{6\Omega} = 16 + 24 = 40W$$

To verify results by using K.V.L. ; then

$$\sum_{i=1}^{N} V_i = 0$$

$E - V_1 - V_2 = 0$

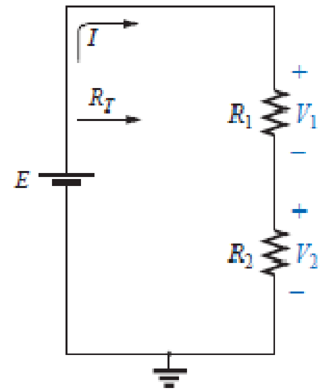
$E = V_1 + V_2$

$20 = 8 + 12$

$20 = 20$ checks

VOLTAGE DIVIDER RULE

In a series circuit,
the voltage across the resistive elements will divide as the magnitude of the resistance levels.



$$R_T = R_1 + R_2$$

and
$$I = \frac{E}{R_T}$$

Applying Ohm's law:

$$V_1 = IR_1 = \left(\frac{E}{R_T}\right)R_1 = \frac{R_1E}{R_T}$$

with
$$V_2 = IR_2 = \left(\frac{E}{R_T}\right)R_2 = \frac{R_2E}{R_T}$$

Note that the format for V_1 and V_2 is

$$V_x = \frac{R_xE}{R_T} \quad \text{(voltage divider rule)}$$

EXAMPLE 5.10 Determine the voltage V_1 for the network of Fig. 5.27.

Solution: Eq. (5.10):

$$V_1 = \frac{R_1E}{R_T} = \frac{R_1E}{R_1 + R_2} = \frac{(20\ \Omega)(64\ \text{V})}{20\ \Omega + 60\ \Omega} = \frac{1280\ \text{V}}{80} = \mathbf{16\ V}$$

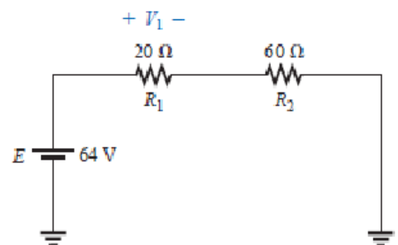


FIG. 5.27
Example 5.10.

EXAMPLE 5.11 Using the voltage divider rule, determine the voltages V_1 and V_3 for the series circuit of Fig. 5.28.

Solution:

$$V_1 = \frac{R_1E}{R_T} = \frac{(2\ \text{k}\Omega)(45\ \text{V})}{2\ \text{k}\Omega + 5\ \text{k}\Omega + 8\ \text{k}\Omega} = \frac{(2\ \text{k}\Omega)(45\ \text{V})}{15\ \text{k}\Omega}$$
$$= \frac{(2 \times 10^3\ \Omega)(45\ \text{V})}{15 \times 10^3\ \Omega} = \frac{90\ \text{V}}{15} = \mathbf{6\ V}$$

$$V_3 = \frac{R_3E}{R_T} = \frac{(8\ \text{k}\Omega)(45\ \text{V})}{15\ \text{k}\Omega} = \frac{(8 \times 10^3\ \Omega)(45\ \text{V})}{15 \times 10^3\ \Omega}$$
$$= \frac{360\ \text{V}}{15} = \mathbf{24\ V}$$

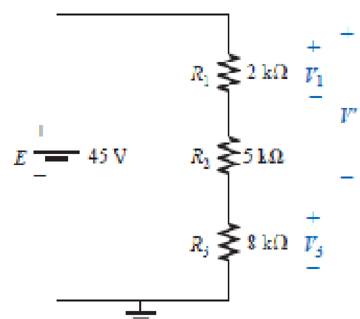


FIG. 5.28
Example 5.11.

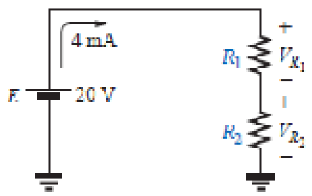


FIG. 5.30
Example 5.13.

EXAMPLE 5.13 Design the voltage divider of Fig. 5.30 such that $V_{R1} = 4V_{R2}$.

Solution: The total resistance is defined by

$$R_T = \frac{E}{I} = \frac{20\text{ V}}{4\text{ mA}} = 5\text{ k}\Omega$$

Since $V_{R_1} = 4V_{R_2}$,

$$R_1 = 4R_2$$

Thus $$R_T = R_1 + R_2 = 4R_2 + R_2 = 5R_2$$

and $$5R_2 = 5\text{ k}\Omega$$
$$R_2 = \mathbf{1\text{ k}\Omega}$$

and $$R_1 = 4R_2 = \mathbf{4\text{ k}\Omega}$$

Voltage Sources and Ground

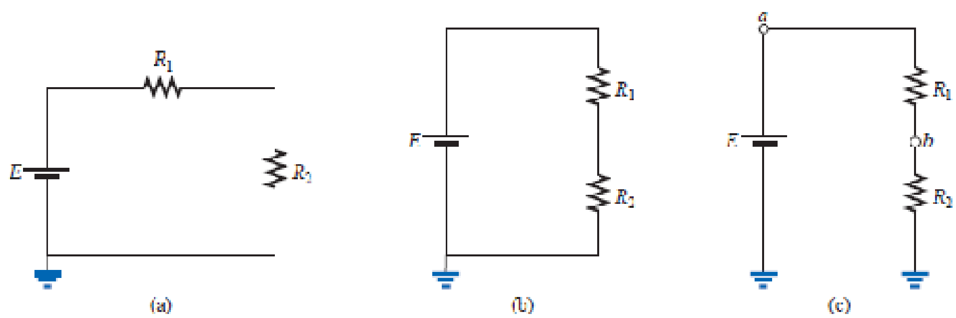


FIG. 5.32
Three ways to sketch the same series dc circuit.

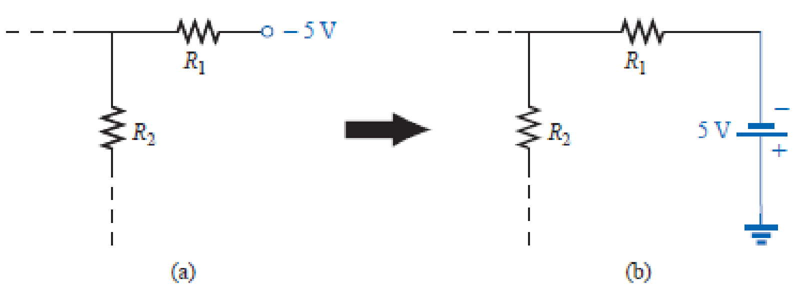


FIG. 5.34
Replacing the notation for a negative dc supply with the standard notation.

EXAMPLE 5.20 For the network of Fig. 5.50:

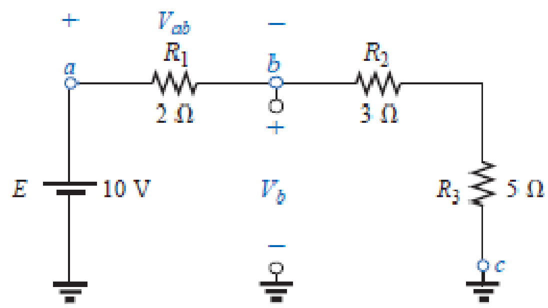


FIG. 5.50
Example 5.20.

a. Calculate V_{ab}.
b. Determine V_b.
c. Calculate V_c.

Solutions:

a. Voltage divider rule:

$$V_{ab} = \frac{R_1 E}{R_T} = \frac{(2\ \Omega)(10\ \text{V})}{2\ \Omega + 3\ \Omega + 5\ \Omega} = \mathbf{+2\ V}$$

b. Voltage divider rule:

$$V_b = V_{R_2} + V_{R_3} = \frac{(R_2 + R_3)E}{R_T} = \frac{(3\ \Omega + 5\ \Omega)(10\ \text{V})}{10\ \Omega} = \mathbf{8\ V}$$

or $\quad V_b = V_a - V_{ab} = E - V_{ab} = 10\ \text{V} - 2\ \text{V} = \mathbf{8\ V}$

c. V_c = ground potential = **0 V**

EXAMPLE 5.19 Using the voltage divider rule, determine the voltages V_1 and V_2 of Fig. 5.48.

Solution: Redrawing the network with the standard battery symbol will result in the network of Fig. 5.49. Applying the voltage divider rule,

$$V_1 = \frac{R_1 E}{R_1 + R_2} = \frac{(4\ \Omega)(24\ \text{V})}{4\ \Omega + 2\ \Omega} = \mathbf{16\ V}$$

$$V_2 = \frac{R_2 E}{R_1 + R_2} = \frac{(2\ \Omega)(24\ \text{V})}{4\ \Omega + 2\ \Omega} = \mathbf{8\ V}$$

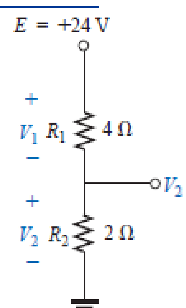


FIG. 5.48

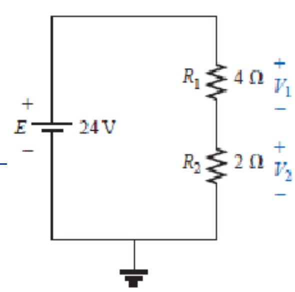


FIG. 5.49
Circuit of Fig. 5.48 redrawn.