

4- Ohm's law and power

1st law

Ohm's law

INTRODUCTION

Ohm's Law is The first equation to be described is without question one of the most important to be learned in this field. It is not particularly difficult mathematically, but it is very powerful because it can be applied to any network in any time frame. That is, it is applicable to dc circuits, ac circuits, digital and microwave circuits, and, in fact, any type of applied signal.

continue

OHM'S LAW

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

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

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

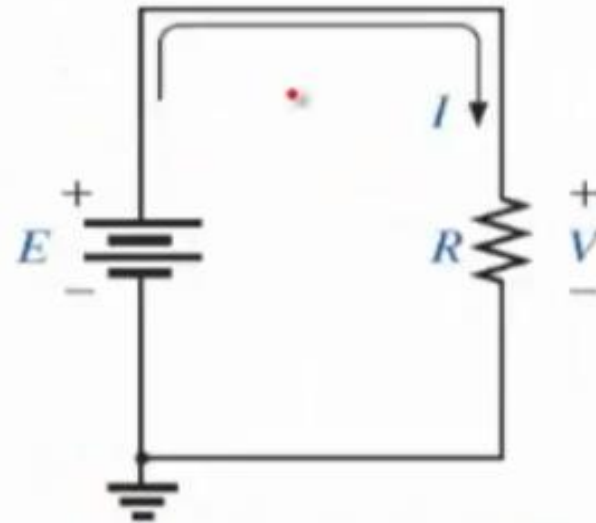


FIG. 4.1 *Basic circuit.*

continue

Voltage polarity

OHM'S LAW

For any resistor, in any network, the direction of current through a resistor will define the polarity of the voltage drop across the resistor

$$I = \frac{V_R}{R} = \frac{E}{R}$$

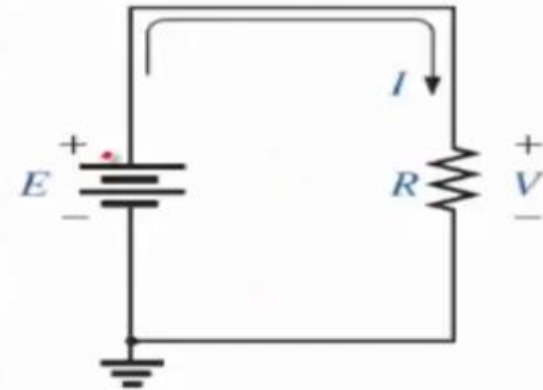
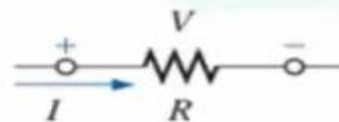
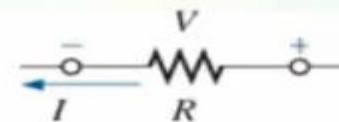


FIG. 4.1 *Basic circuit.*



(a)



(b)

FIG. 4.2 *Defining polarities.*

Examples

OHM'S LAW

EXAMPLE 1 Determine the current resulting from the application of a 9 V battery across a network with a resistance of $2.2\ \Omega$.

Solution: Eq. (2):

$$I = \frac{V_R}{R} = \frac{E}{R} = \frac{9\ \text{V}}{2.2\ \Omega} = \mathbf{4.09\ \text{A}}$$

EXAMPLE 2 Calculate the resistance of a 60 W bulb if a current of 500 mA results from an applied voltage of 120 V.

Solution: Eq. (4):

$$R = \frac{V_R}{I} = \frac{E}{I} = \frac{120\ \text{V}}{500 \times 10^{-3}\ \text{A}} = \mathbf{240\ \Omega}$$

Examples

OHM'S LAW

EXAMPLE 3 Calculate the current through the 2 k Ω resistor in Fig. 4 if the voltage drop across it is 16 V.

Solution:

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

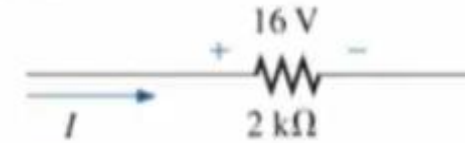


FIG. 4

Example 3.

EXAMPLE 4 Calculate the voltage that must be applied across the dering iron in Fig. 5 to establish a current of 1.5 A through the iron if its internal resistance is 80 Ω .

Solution:

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

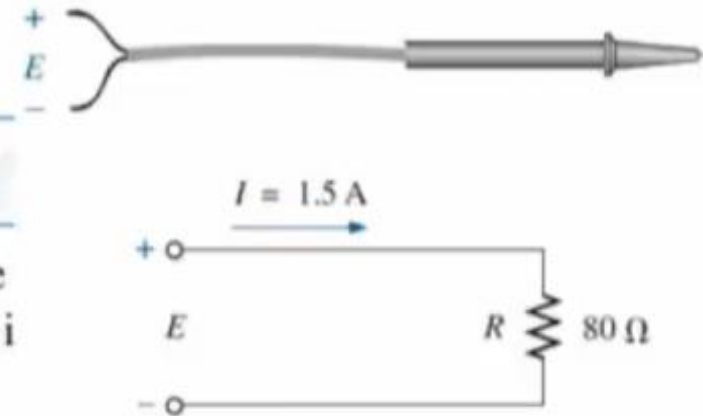


FIG. 5

Plotting ohm's law

PLOTTING OHM'S LAW

- Graphs, characteristics, plots, and the like play an important role in every technical field as modes through which the broad picture of the behavior or response of a system can be conveniently displayed.
- It is therefore critical to develop the skills necessary both to read data and to plot them in such a manner that they can be interpreted easily.

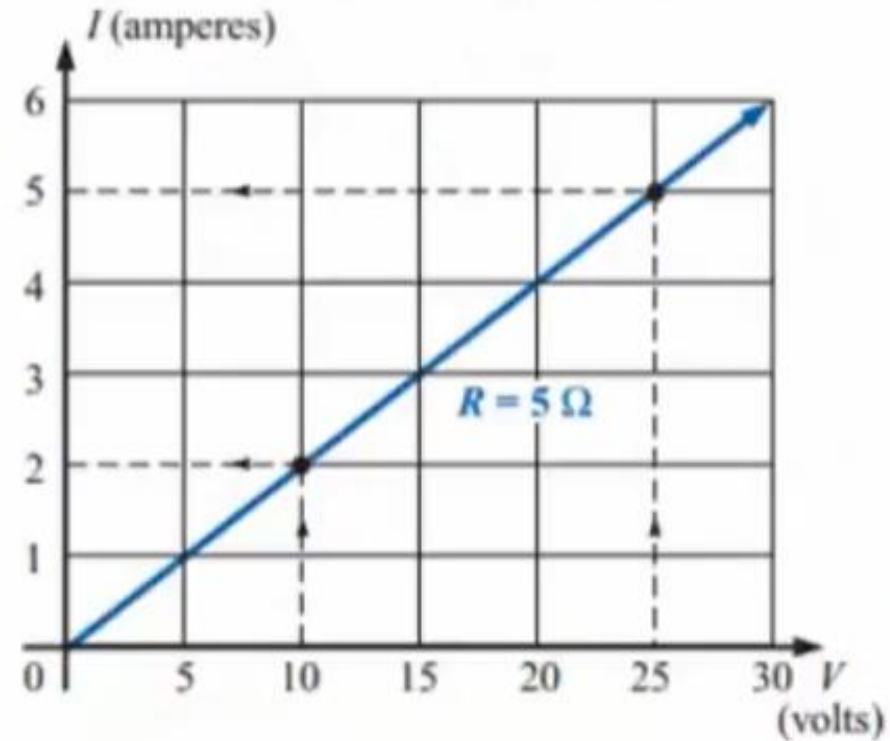
continue

PLOTTING OHM'S LAW

$$I = \frac{1}{R} \cdot E + 0$$

↓ ↓ ↓ ↓

$$y = m \cdot x + b$$



Plotting Ohm's Law

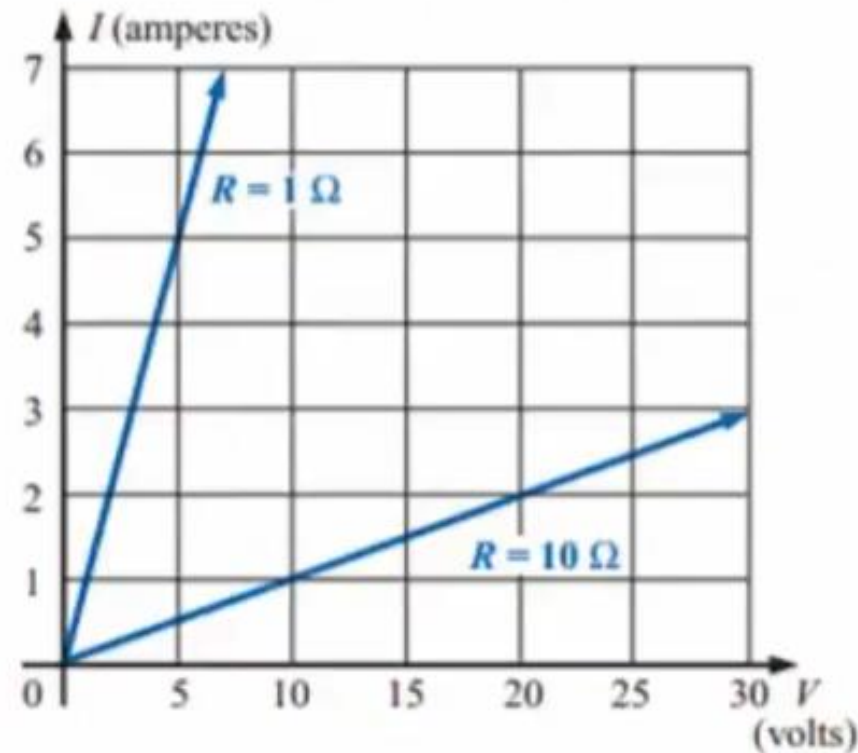
continue

PLOTTING OHM'S LAW

$$I = \frac{1}{R} \cdot E + 0$$

↓ ↓ ↓ ↓

$$y = m \cdot x + b$$



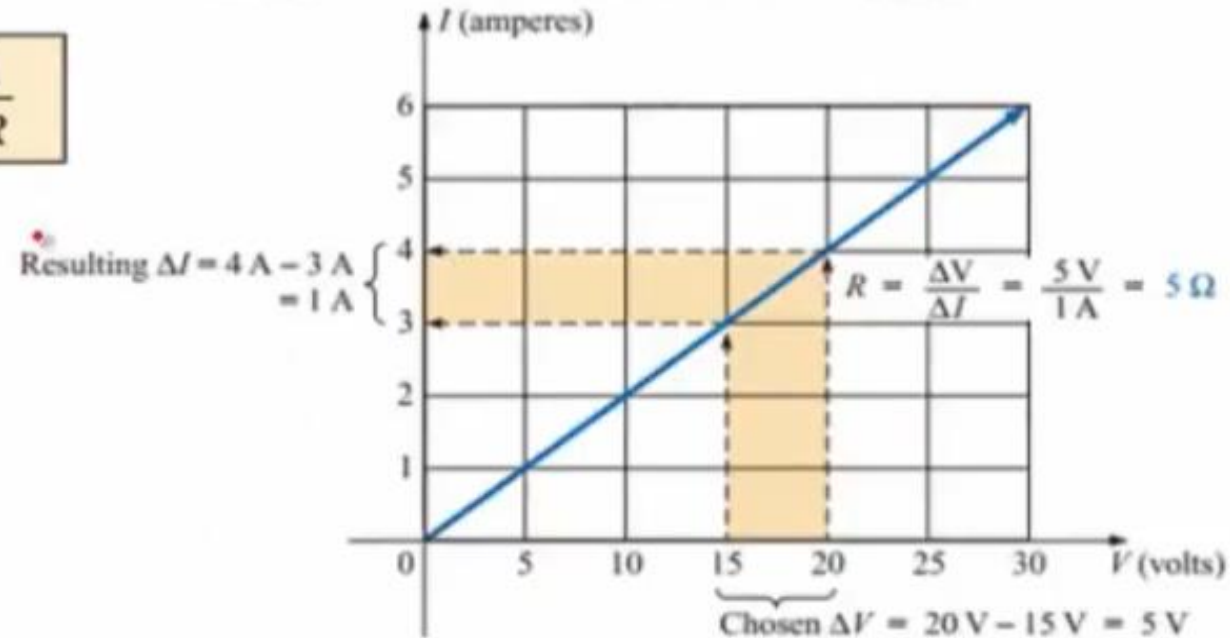
Demonstrating on an I-V plot that the lower the resistance, the steeper is the slope.

Continue

PLOTTING OHM'S LAW

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

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



Apply OHM'S LAW to calculate unknown resistance

Continue

PLOTTING OHM'S LAW

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 $V = 6\text{ V}$, $I = 3\text{ mA}$, 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.

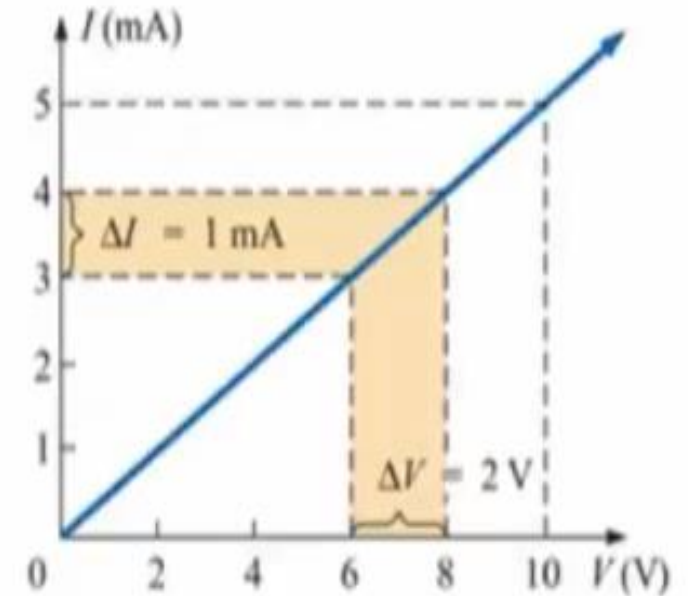


FIG. 4.9

Example 4.5.

Power

POWER

- In general, *the term power is applied to provide an indication of how much work (energy conversion) can be accomplished in a specified amount of time; that is, power is a rate of doing work.*

$$1 \text{ watt (W)} = 1 \text{ joule/second (J/s)}$$

In equation form, power is determined by

$$P = \frac{W}{t}$$

(watts, W, or joules/second, J/s)

continue

POWER

$$P = \frac{W}{t}$$

(watts, W, or joules/second, J/s)

- Since energy is measured in joules (J) and time in seconds (s), power is measured in joules/second (J/s).
- The electrical unit of measurement for power is the watt (W), defined by:

$$1 \text{ watt (W)} = 1 \text{ joule/second (J/s)}$$

continue

POWER

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

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

$$P = VI$$

(watts, W)

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

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

(watts, W)

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

$$P = I^2 R$$

(watts)

The magnitude of the power delivered or absorbed by a battery is given by :

$$P = EI$$

(watts)

Examples

POWER

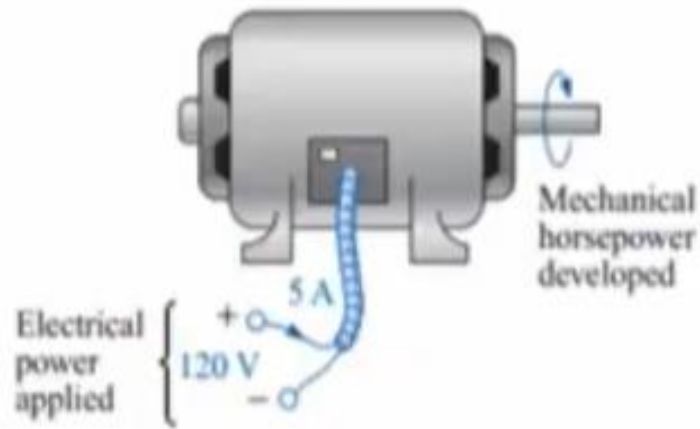


FIG. 4.14
Example 4.6.

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:

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

Energy

5 ENERGY

For power, which is the rate of doing work, to produce an energy conversion of any form, it must be *used over a period of time*. For example, a motor may have the horsepower to run a heavy load, but unless the motor is *used* over a period of time, there will be no energy conversion. In addition, the longer the motor is used to drive the load, the greater will be the energy expended.

The **energy** (W) lost or gained by any system is therefore determined by

$$W = Pt$$

(wattseconds, Ws, or joules)

(16)

continue

Since power is measured in watts (or joules per second) and time in seconds, the unit of energy is the *wattsecond* or *joule* (note Fig. 15). The wattsecond, however, is too small a quantity for most practical purposes, so the *watthour* (Wh) and the *kilowatthour* (kWh) are defined, as follows:

$$\text{Energy (Wh)} = \text{power (W)} \times \text{time (h)} \quad (17)$$

$$\text{Energy (kWh)} = \frac{\text{power (W)} \times \text{time (h)}}{1000} \quad (18)$$

Note that the energy in kilowatthours is simply the energy in watthours divided by 1000. To develop some sense for the kilowatthour energy level, consider that *1 kWh is the energy dissipated by a 100 W bulb in 10 h.*

Examples

EXAMPLE 11 How much energy (in kilowatthours) is required to light a 60 W bulb continuously for 1 year (365 days)?

Solution:

$$W = \frac{Pt}{1000} = \frac{(60 \text{ W})(24 \text{ h/day})(365 \text{ days})}{1000} = \frac{525,600 \text{ Wh}}{1000} \\ = \mathbf{525.60 \text{ kWh}}$$

EXAMPLE 12 How long can a 340 W plasma TV be on before it uses more than 4 kWh of energy?

Solution:

$$W = \frac{Pt}{1000} \Rightarrow t \text{ (hours)} = \frac{(W)(1000)}{P} = \frac{(4 \text{ kWh})(1000)}{340 \text{ W}} = \mathbf{11.76 \text{ h}}$$

EXAMPLE 13 What is the cost of using a 5 hp motor for 2 h if the rate is 11¢ per kilowatthour?

Solution:

$$W \text{ (kilowatthours)} = \frac{Pt}{1000} = \frac{(5 \text{ hp} \times 746 \text{ W/hp})(2 \text{ h})}{1000} = 7.46 \text{ kWh} \\ \text{Cost} = (7.46 \text{ kWh})(11\text{¢/kWh}) = \mathbf{82.06\text{¢}}$$

Conclusion

OHM'S LAW

Conclusion

This chapter reveals how the three important quantities of an electric circuit are interrelated. The most important equation in the study of electric circuits is introduced, and various other equations that allow us to find power and energy levels are discussed in detail. It is the chapter where we tie things together and develop a feeling for the way an electric circuit behaves and what affects its response.