



Ohm's Law

2.1 Ohm's Law

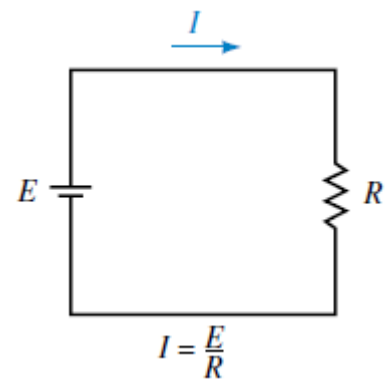
Ohm determined experimentally that current in a resistive circuit is directly proportional to its applied voltage and inversely proportional to its resistance. In equation form, Ohm's law states

$$I = \frac{E}{R} \quad [\text{Amps, } A]$$

where E is the voltage in volts (V)

R is the resistance in ohms (Ω)

I is the current in amperes (A)

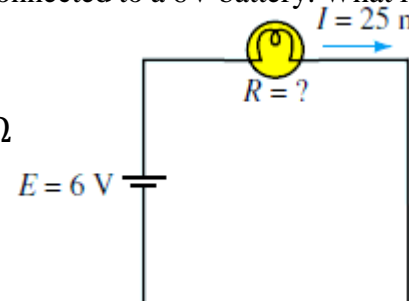


Example 1: A 27Ω resistor is connected to a 12V battery. What is the current?

$$I = \frac{E}{R} = \frac{12}{27} = 0.444A$$

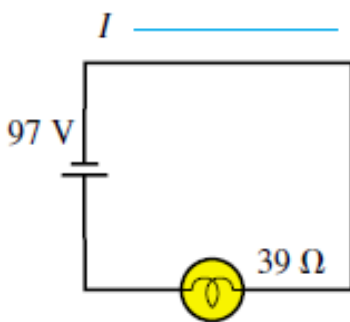
Example 2: The lamp of the following circuit draws 25mA when connected to a 6V battery. What is its resistance?

$$R = \frac{E}{I} = \frac{6}{25 \times 10^{-3}} = 240\Omega$$

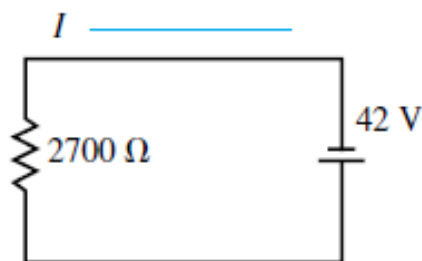


H.W 1: Determine the current for each circuit, including its current direction

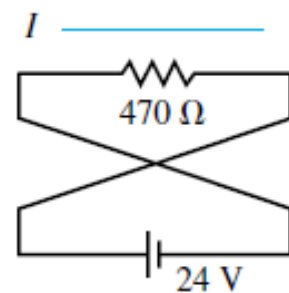
(Ans. (a) 2.49 A, left (b) 15.6 mA, right (c) 51.1 mA, left)



(a)



(b)

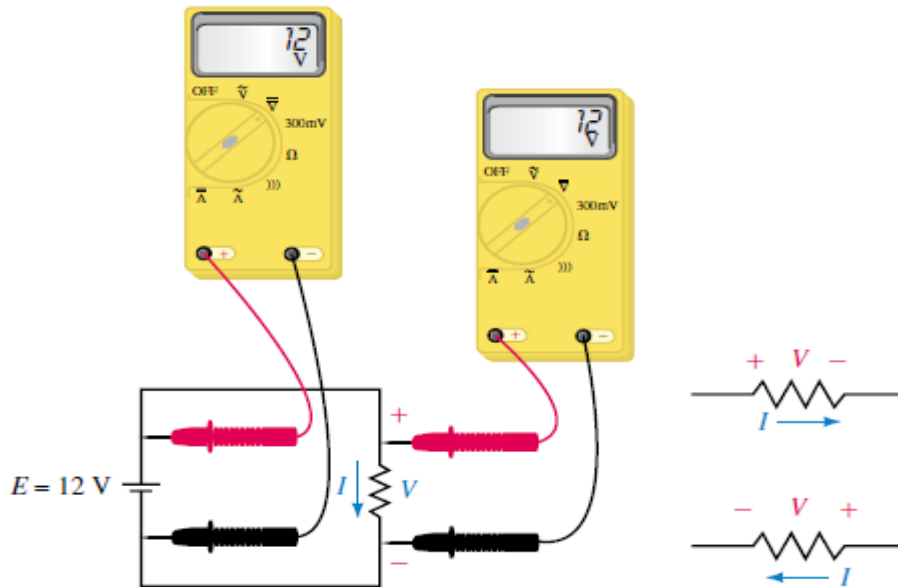


(c)



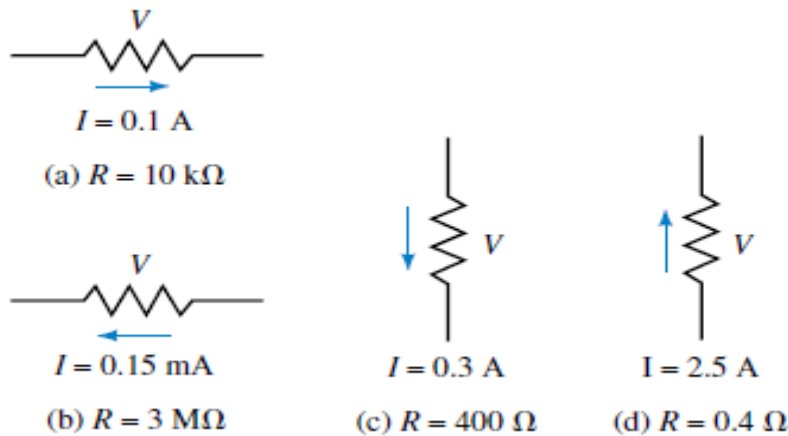
2.2 Voltage Polarity and Current Direction

There is a simple relationship between current direction and voltage polarity. For resistive element, the polarity of the voltage drop for the indicated current direction is shown in the following Figure. For voltage across a resistor, always place the plus sign at the tail of the current reference arrow



H.W 3: for each resistor of the following Figure, compute V and show its polarity

(Ans. (a) 1000 V, + at left (b) 450 V, + at right (c) 120 V, + at top (d) 1 V, at bottom)



H.W4: A certain resistive circuit has voltage E and resistance R . If $I=2.5 \text{ A}$, what will be the current if:

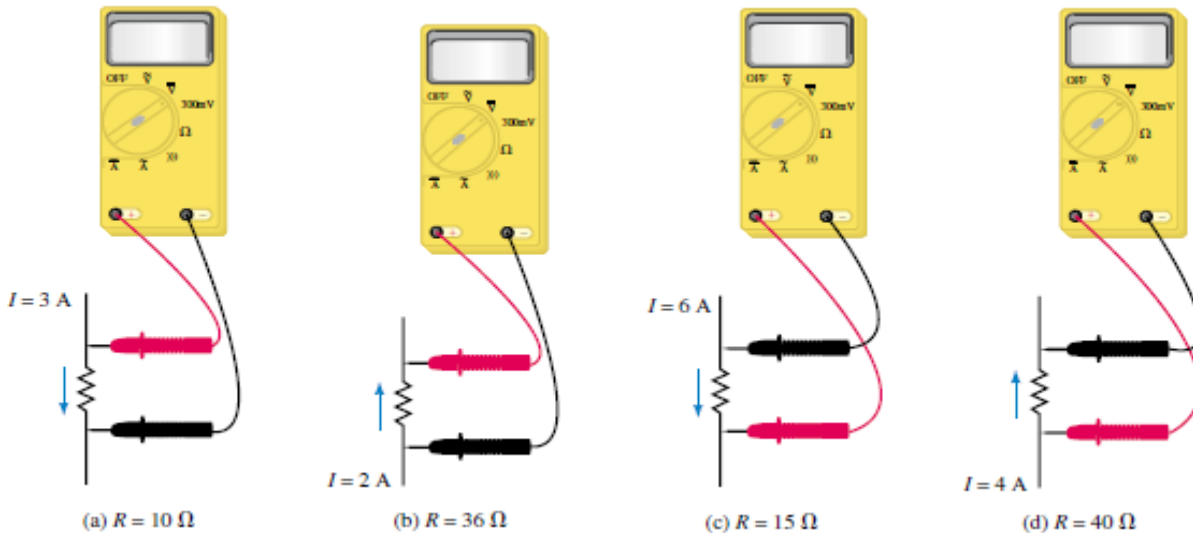
- E remains unchanged but R is doubled?
- E remains unchanged but R is quadrupled?
- E remains unchanged but R is reduced to 20% of its original value?
- R is doubled and E is quadrupled?

(Ans. (a) 1.25 A (b) 0.625 A (c) 12.5 A (d) 5 A)



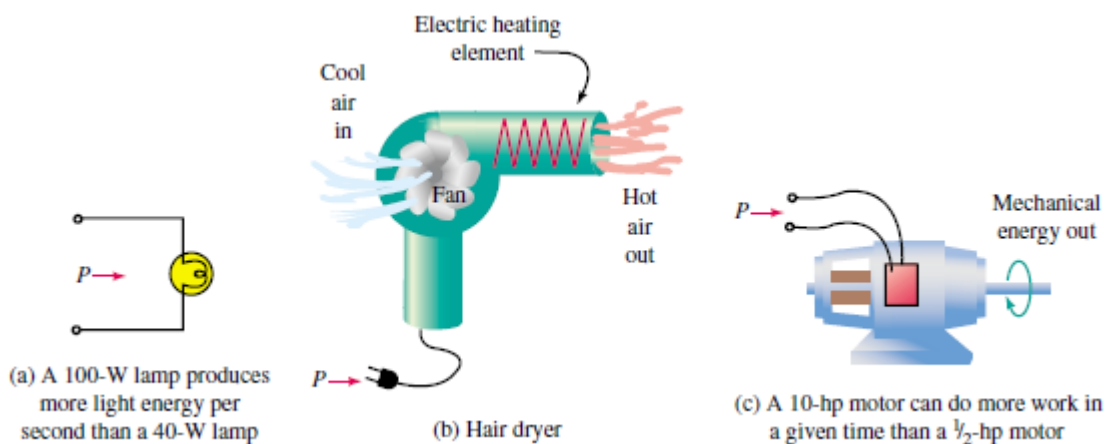
H.W 5: The voltmeters of the following Figure have autopolarity. Determine the reading of each meter, its magnitude and sign.

(Ans. (a) 30 V (b) -72 V (c) -90 V (d) 160 V)



2.3 Power

Power is familiar to all of us, at, for example, that electric heaters and light bulbs are rated in watts (W) and that motors are rated in horsepower (or watts). The higher the watt rating of a device, the more energy we can get out of it per unit time. In the following Figure illustrates that In (a), the greater the power rating of the light, the more light energy that it can produce per second. In (b), the greater the power rating of the heater, the more heat energy it can produce per second. In (c), the larger the power rating of the motor, the more mechanical work that it can do per second.



Power is related to energy, which is the capacity to do work.



$$P = \frac{W}{t} \quad [\text{Watts}, W]$$

where W is the work (or energy) in joules and t is the corresponding time interval of t seconds.

Power in horsepower (hp) is $1 \text{ hp} = 746 \text{ watts}$.

2.4 Power in Electrical and Electronic Systems

The power delivered to, or absorbed by, an electrical device or system can be found in terms of the voltage and the current. The unit of power is the watt and horsepower (hp) where the $1 \text{ hp} = 746 \text{ watts}$

$$P = VI \quad [\text{watts}, W]$$

and, for a source,

$$P = EI \quad [\text{watts}, W]$$

By direct substitution of ohm's law the equation for power can be obtained in two other forms:

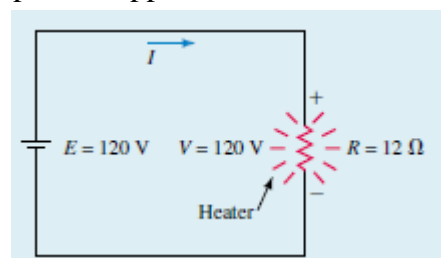
$$P = \frac{V^2}{R} \quad [\text{watts}, W]$$

$$P = I^2R \quad [\text{watts}, W]$$

Example 3: Compute the power absorbed by the heater and the power supplied to the electric heater.

$$P_{\text{absorbed}} = \frac{V^2}{R} = 1200 \text{ W}$$

$$P_{\text{supplied}} = EI = E * \frac{V}{R} = (120) * \left(\frac{120}{12}\right) = 1200 \text{ W}$$



H.W 6: A 100Ω resistor dissipates 169 W . What is its current? (Ans. 1.3 A)

H.W 7 : A 3Ω resistor dissipates 243 W . What is the voltage across it? (Ans. 27 V)



2.5 Energy

The energy lost or gained by any system is determined by

$$W = Pt \quad (\text{wattsecond, } Ws \text{ or } \text{joules})$$

If the power is measured in kilowatts and the time in hours then the unit of energy is **kilowatt-hours (kWh)**, often called the ‘**unit of electricity**’. The electricity meter in the home records the number of kilowatt-hours used and is thus an energy meter.

$$W (kWh) = \frac{P (W) * t (h)}{1000} \quad (kWh)$$

Example 4: Determine the total energy used by a 100-W lamp for 12 hours and a 1.5-kW heater for 45 minutes.

$$W (kWh) = \left(\frac{100}{1000} kW\right) (12 h) + (1.5 kW) \left(\frac{45}{60} h\right) = 2.325 kWh$$

Example 5: Suppose you use the following electrical appliances: a 1.5- kW heater for 7½ hours; a 3.6- kW broiler for 17 minutes; three 100-W lamps for 4 hours; a 900-W toaster for 6 minutes. At \$0.09 per kilowatthour, how much will this cost you?

$$\begin{aligned} W (kWh) &= (1.5 kW)(7.5 h) + (3.6 kW) \left(\frac{17}{60} h\right) + (3) \left(\frac{100}{1000} kW\right) (4 h) + \left(\frac{900}{1000}\right) \left(\frac{6}{60}\right) \\ &= 13.56 kWh \end{aligned}$$

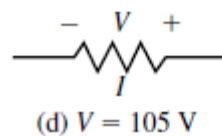
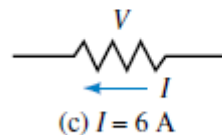
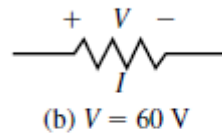
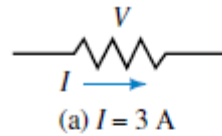
$$\text{cost} = (13.56 kWh) \left(\$ \frac{0.09}{kWh}\right) = \$ 1.22$$

Exercises

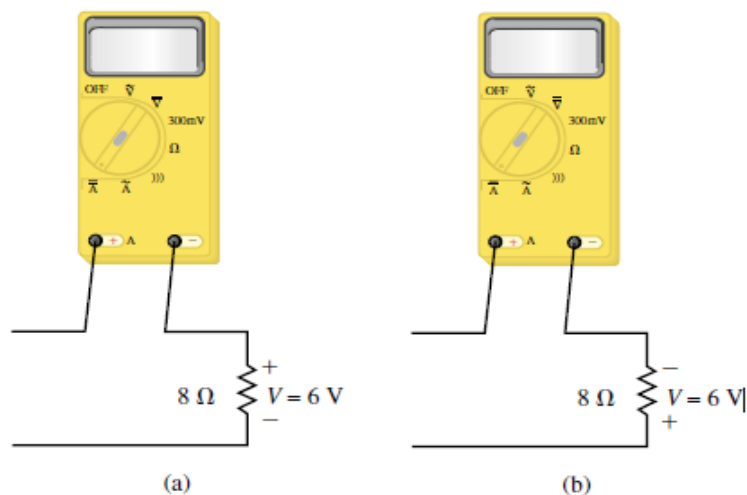
1. If $E = 30 \text{ V}$ and the conductance of the resistor is 0.2 S , what is I ? (Ans. 6A)
2. A resistive circuit element is made from 100 m of 0.5-mm-diameter aluminum wire. If the current at 20°C is 200 mA, what is the applied voltage? (Resistivity of aluminum is 2.825×10^{-8}). (Ans. 2.88V)
3. For a resistive circuit, $E = 100 \text{ V}$. If R is doubled and E is changed so that the new current is double the original current, what is the new value of E ? (Ans. 400 V)



4. For each resistor (All resistors are 15Ω) of the following Figure, determine voltage V and its polarity or current I and its direction as applicable. (Ans. (a) $+45$ - (b) $4A$ (\rightarrow) (c) $-90V$ + (d) $7A$ (\leftarrow))



5. The ammeters of the following Figure have autopolarity. Determine their readings, magnitude, and polarity. (Ans. (a) $+0.75\text{ A}$ (b) -0.75 A)



6. A resistor dissipates 723 joules of energy in 3 minutes and 47 seconds. What is its power dissipation in watts? (Ans. 3.19 W)

7. A resistor draws 3 A from a 12-V battery. How much power does the battery deliver to the resistor? (Ans. 36 W)



Chemical and Petroleum Refining Engineering
Electrical Technology/ 2nd stage



8. A 1.2-kW electric heater has a resistance of $6\ \Omega$. How much current does it draw? (Ans. 14.1 A)
9. How many volts must be applied to a $3\text{-}\Omega$ resistor to result in a power dissipation of 752 W? (Ans. 47.5 V)
10. Determine the total cost of using the following at \$0.11 per kWh: 900-W toaster for 5 minutes, 120-V, 8-A heater for 1.7 hours, 1100-W dishwasher for 36 minutes, and 120-V, 288- Ω soldering iron for 24 minutes. (Ans. \$ 0.26)