Section 2-6 Voltmeters and Ammeters

P 2.6-1 For the circuit of Figure P 2.6-1:

(a) What is the value of the resistance *R*?

(b) How much power is delivered by the voltage source?

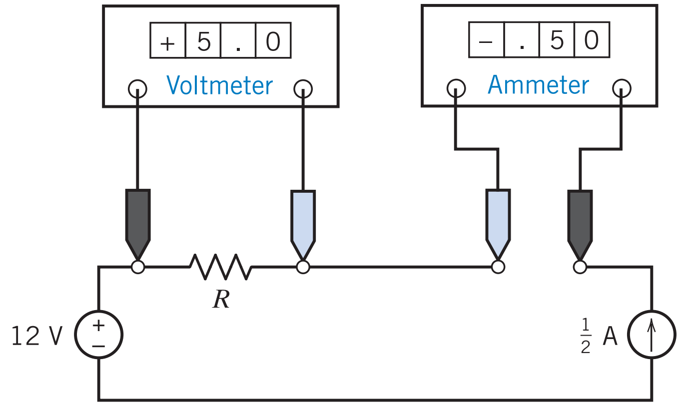

Figure P 2.6-1

Solution:

(a) $R = \frac{v}{i} = \frac{5}{0.5} = 10\ \Omega$

(b) The voltage, 12 V, and the current, 0.5 A, of the voltage source adhere to the passive convention so the power

$$P = 12\,(0.5) = 6\text{ W}$$

is the power received by the source. The voltage source delivers -6 W.

P 2.6-2 The current source in Figure P 2.6-2 supplies 40 W. What values do the meters in Figure P 2.6-2 read?

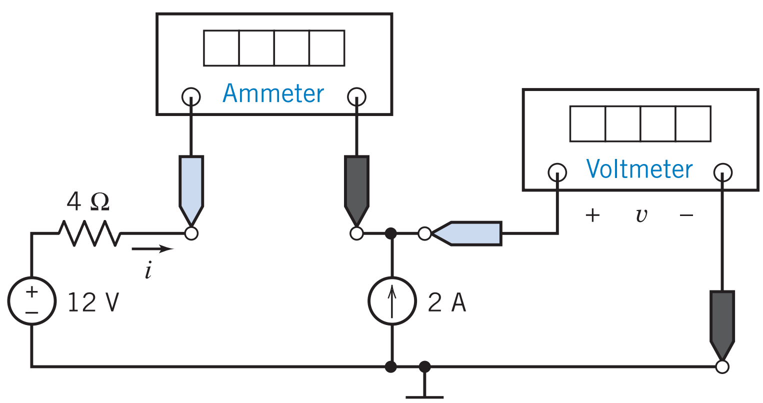

Figure P 2.6-2

Solution:

The voltmeter current is zero so the ammeter current is equal to the current source current except for the reference direction:

$$i = -2\text{ A}$$

The voltage v is the voltage of the current source. The power supplied by the current source is 40 W so

$$40 = 2\,v \quad \Rightarrow \quad v = 20\text{ V}$$

P 2.6-3 An ideal voltmeter is modeled as an open circuit. A more realistic model of a voltmeter is a large resistance. Figure P 2.6-3*a* shows a circuit with a voltmeter that measures the voltage v_m. In Figure P 2.6-3*b* the voltmeter is replaced by the model of an ideal voltmeter, an open circuit. Ideally, there is no current in the 100-Ω resistor and the voltmeter measures v_{mi} = 12 V, the ideal value of v_m. In Figure P 2.6-3*c* the voltmeter is modeled by the resistance R_m. Now the voltage measured by the voltmeter is

$$v_m = \left(\frac{R_m}{R_m + 100}\right)12$$

As $R_m \to \infty$, the voltmeter becomes an ideal voltmeter and $v_m \to v_{mi} = 12$ V. When $R_m < \infty$, the voltmeter is not ideal and $v_m < v_{mi}$. The difference between v_m and v_{mi} is a measurement error caused by the fact that the voltmeter is not ideal.

(a) Express the measurement error that occurs when R_m = 900 Ω as a percent of v_{mi}.

(b) Determine the minimum value of R_m required to ensure that the measurement error is smaller than 2 percent of v_{mi}.

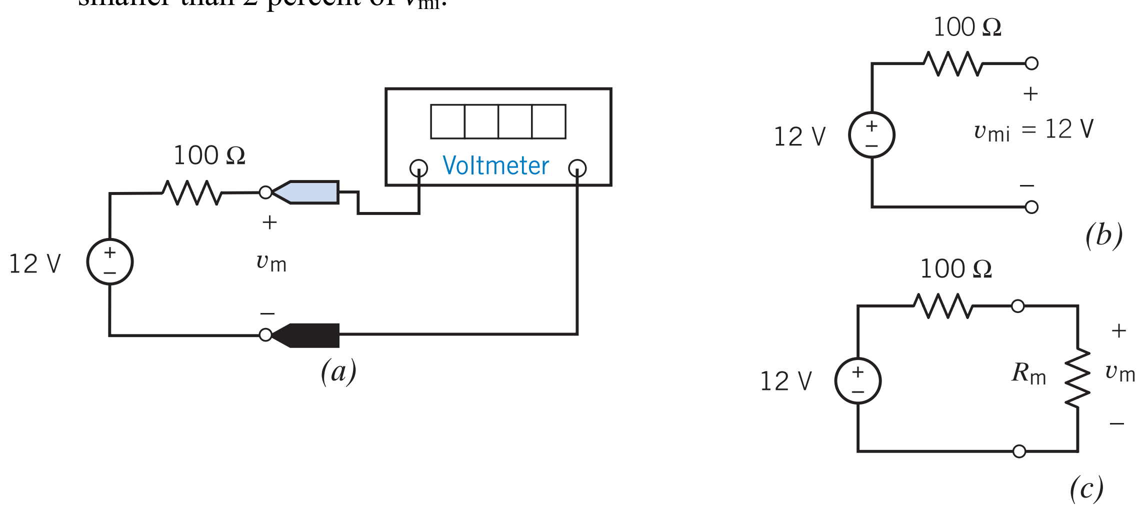

Figure P 2.6-3

Solution:

(a)
$$v_m = \left(\frac{900}{900+100}\right)12 = 10.8 \text{ V}$$

$$\frac{12-10.8}{12} = 0.1 = 10\%$$

(b) We require

$$0.02 \ge \frac{12 - \left(\frac{R_m}{R_m+100}\right)12}{12} \quad \Rightarrow \quad \frac{R_m}{R_m+100} \ge 0.98 \quad \Rightarrow \quad R_m \ge 4900\ \Omega$$

(checked: LNAP 6/16/04)

2.6-4 An ideal ammeter is modeled as a short circuit. A more realistic model of an ammeter is a small resistance. Figure P 2.6-4*a* shows a circuit with an ammeter that measures the current i_m. In Figure P 2.6-4*b* the ammeter is replaced by the model of an ideal ammeter, a short circuit. Ideally, there is no voltage across the 1-kΩ resistor and the ammeter measures $i_{mi} = 2$ A, the ideal value of i_m. In Figure P 2.6-4*c* the ammeter is modeled by the resistance R_m. Now the current measured by the ammeter is

$$i_m = \left(\frac{1000}{1000+R_m}\right)2$$

As $R_m \rightarrow 0$, the ammeter becomes an ideal ammeter and $i_m \rightarrow i_{mi} = 2$ A. When $R_m > 0$, the ammeter is not ideal and $i_m < i_{mi}$. The difference between i_m and i_{mi} is a measurement error caused by the fact that the ammeter is not ideal.

(a) Express the measurement error that occurs when $R_m = 10\ \Omega$ as a percent of i_{mi}.

(b) Determine the maximum value of R_m required to ensure that the measurement error is smaller than 5 percent.

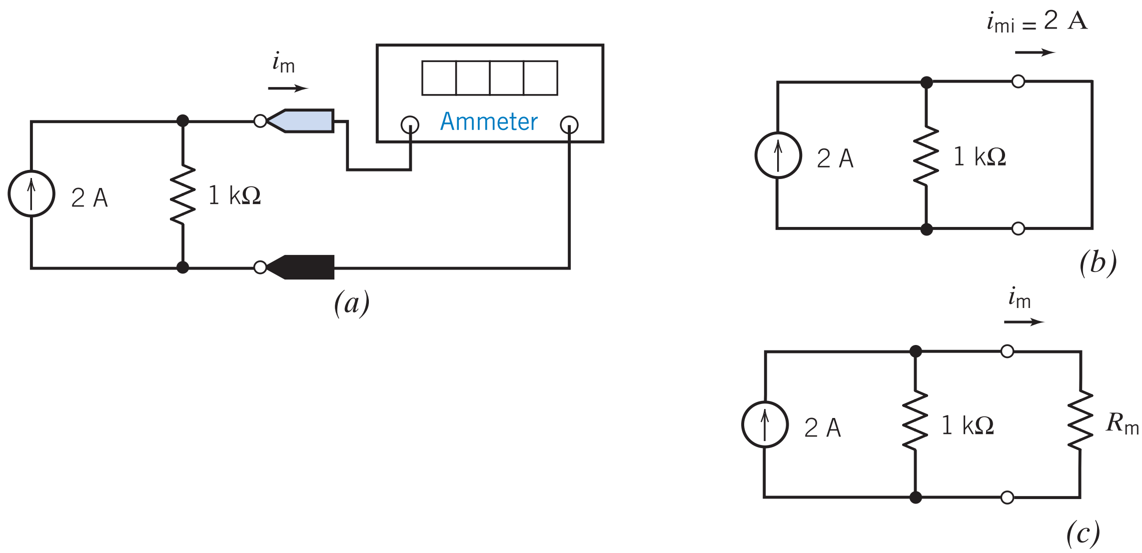

Figure P 2.6-4

Solution:

(a)

$$i_m = \left(\frac{1000}{1000+10}\right)2 = 1.98 \text{ A}$$

$$\% \text{ error} = \frac{2-1.98}{2} \times 100 = 0.99\%$$

(b)

$$0.05 \geq \frac{2-\left(\dfrac{1000}{1000+R_m}\right)2}{2} \quad \Rightarrow \quad \frac{1000}{1000+R_m} \geq 0.95 \quad \Rightarrow \quad R_m \leq 52.63\ \Omega$$

(checked: LNAP 6/17/04)

P 2.6-5 The voltmeter in Figure P 2.6-5*a* measures the voltage across the current source. Figure P 2.6-5*b* shows the circuit after removing the voltmeter and labeling the voltage measured by the voltmeter as v_m. Also, the other element voltages and currents are labeled in Figure P 2.6-5*b*.

Given that

$$12 = v_R + v_m \text{ and} - i_R = i_s = 2\text{ A}$$

and $$v_R = 25\, i_R$$

(a) Determine the value of the voltage measured by the meter.

(b) Determine the power supplied by each element.

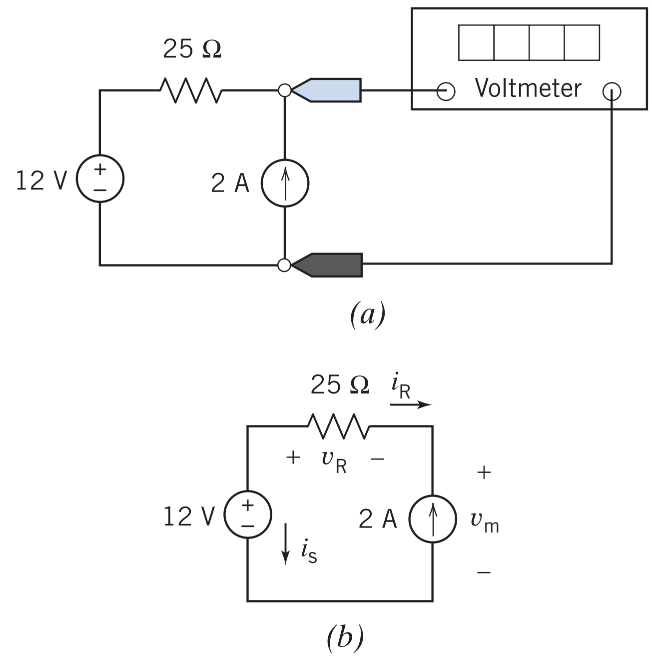

Figure P 2.6-5

Solution:

a.)

$$v_R = 25\, i_R = 25(-2) = -50 \text{ V}$$

$$v_m = 12 - v_R = 12 - (-50) = 62 \text{ V}$$

b.)

Element	**Power supplied**
voltage source	$-12(i_s) = -12(2) = -24$ W
current source	$62(2) = 124$ W
resistor	$-v_R \times i_R = -(-50)(-2) = -100$ W
total	0

P 2.6-6 The ammeter in Figure P 2.6-6*a* measures the current in the voltage source. Figure P 2.6-6*b* shows the circuit after removing the ammeter and labeling the current measured by the ammeter as i_m. Also, the other element voltages and currents are labeled in Figure P 2.6-6*b*.

Given that

$$2 + i_m = i_R \text{ and } v_R = v_s = 12\text{ V}$$

and

$$v_R = 25 i_R$$

(a) Determine the value of the current measured by the meter.

(b) Determine the power supplied by each element.

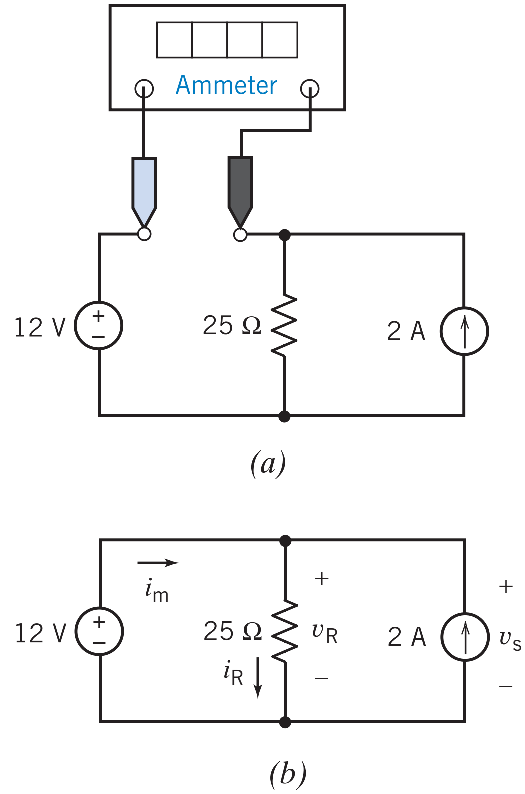

Figure P 2.6-6

Solution:

a.)

$$i_R = \frac{v_R}{25} = \frac{12}{25} = 0.48 \text{ A}$$

$$i_m = i_R - 2 = 0.48 - 2 = -1.52 \text{ A}$$

b.)

Element	**Power supplied**
voltage source	$12(i_m) = 12(-1.52) = -18.24$ W
current source	$v_s(2) = 12(2) = 24$ W
resistor	$-v_R \times i_R = -(12)(0.48) = -5.76$ W
total	0