P 1.11 [a] In Car A, the current $i$ is in the direction of the voltage drop across the 12 V battery (the current $i$ flows into the + terminal of the battery of Car A). Therefore using the passive sign convention,

$$p = vi = (30)(12) = 360 \text{ W}.$$  
Since the power is positive, the battery in Car A is absorbing power, so Car A must have the "dead" battery.

[b] $w(t) = \int_0^t p \, dx$; \hspace{1cm} 1 min = 60 s

$$w(60) = \int_0^{60} 360 \, dx$$

$$w = 360(60 - 0) = 360(60) = 21,600 \text{ J} = 21.6 \text{ kJ}$$

P 1.13 $p = vi$; \hspace{1cm} $w = \int_0^t p \, dx$

Since the energy is the area under the power vs. time plot, let us plot $p$ vs. $t$.

Note that in constructing the plot above, we used the fact that 40 hr = 144,000 s = 144 ks

$$p(0) = (1.5)(9 \times 10^{-3}) = 13.5 \times 10^{-3} \text{ W}$$

$$p(144 \text{ ks}) = (1)(9 \times 10^{-3}) = 9 \times 10^{-3} \text{ W}$$

$$w = (9 \times 10^{-3})(144 \times 10^3) + \frac{1}{2}(13.5 \times 10^{-3} - 9 \times 10^{-3})(144 \times 10^3) = 1620 \text{ J}$$

P 1.14 Assume we are standing at box A looking toward box B. Then, using the passive sign convention $p = -vi$, since the current $i$ is flowing into the - terminal of the voltage $v$. Now we just substitute the values for $v$ and $i$ into the equation for power. Remember that if the power is positive, B is absorbing power, so the power must be flowing from A to B. If the power is negative, B is generating power so the power must be flowing from B to A.
[a] \( p = -(125)(10) = -1250 \text{ W} \quad 1250 \text{ W from B to A} \)

[b] \( p = -(-240)(5) = 1200 \text{ W} \quad 1200 \text{ W from A to B} \)

[c] \( p = -(480)(-12) = 5760 \text{ W} \quad 5760 \text{ W from A to B} \)

[d] \( p = -(-660)(-25) = -16,500 \text{ W} \quad 16,500 \text{ W from B to A} \)

P 1.17  [a] \( p = vi = (0.05e^{-1000t})(75 - 75e^{-1000t}) = (3.75e^{-1000t} - 3.75e^{-2000t}) \text{ W} \)

\[
\frac{dp}{dt} = -3750e^{-1000t} + 7500e^{-2000t} = 0 \\
2 = e^{1000t} \quad \text{so} \quad \ln 2 = 1000t \quad \text{thus} \quad p \text{ is maximum at } t = 693.15 \mu s
\]

\( p_{\text{max}} = p(693.15 \mu s) = 937.5 \text{ mW} \)

[b] \( w = \int_0^\infty [3.75e^{-1000t} - 3.75e^{-2000t}] dt = \left[ \frac{3.75}{-1000}e^{-1000t} - \frac{3.75}{-2000}e^{-2000t} \right]_0^\infty \)

\[
= \frac{3.75}{1000} - \frac{3.75}{2000} = 1.875 \text{ mJ}
\]

P 1.24  [a] \( q = \text{ area under } i \text{ vs. } t \text{ plot} \)

\[
= \left[ \frac{1}{2}(5)(4) + (10)(4) + \frac{1}{2}(8)(4) + (8)(6) + \frac{1}{2}(3)(6) \right] \times 10^3 \\
= [10 + 40 + 16 + 48 + 9] \times 10^3 = 123,000 \text{ C}
\]
\[ w = \int p \, dt = \int v i \, dt \]

\[ v = 0.2 \times 10^{-3}t + 9 \quad 0 \leq t \leq 15 \text{ ks} \]

\[ 0 \leq i \leq 4000 s \]

\[ i = 15 - 1.25 \times 10^{-3}t \]

\[ p = 135 - 8.25 \times 10^{-3}t - 0.25 \times 10^{-6}t^2 \]

\[ w_1 = \int_0^{4000} (135 - 8.25 \times 10^{-3}t - 0.25 \times 10^{-6}t^2) \, dt \]

\[ = (540 - 66 - 5.3333) \times 10^3 = 468.667 \text{ kJ} \]

\[ 4000 \leq t \leq 12,000 \]

\[ i = 12 - 0.5 \times 10^{-3}t \]

\[ p = 108 - 2.1 \times 10^{-3}t - 0.1 \times 10^{-6}t^2 \]

\[ w_2 = \int_{4000}^{12,000} (108 - 2.1 \times 10^{-3}t - 0.1 \times 10^{-6}t^2) \, dt \]

\[ = (864 - 134.4 - 55.467) \times 10^3 = 674.133 \text{ kJ} \]

\[ 12,000 \leq t \leq 15,000 \]

\[ i = 30 - 2 \times 10^{-3}t \]

\[ p = 270 - 12 \times 10^{-3}t - 0.4 \times 10^{-6}t^2 \]

\[ w_3 = \int_{12,000}^{15,000} (270 - 12 \times 10^{-3}t - 0.4 \times 10^{-6}t^2) \, dt \]

\[ = (810 - 486 - 219.6) \times 10^3 = 104.4 \text{ kJ} \]

\[ w_T = w_1 + w_2 + w_3 = 468.667 + 674.133 + 104.4 = 1247.2 \text{ kJ} \]
$P_{1.27}$ 

\[ p_a = -v_a i_a = -(990)(-0.0225) = 22.275 \text{ W} \]
\[ p_b = -v_b i_b = -(600)(-0.03) = 18 \text{ W} \]
\[ p_c = v_c i_c = (300)(0.03) = 18 \text{ W} \]
\[ p_d = v_d i_d = (105)(0.0525) = 5.5125 \text{ W} \]
\[ p_e = -v_e i_e = -(-120)(0.03) = 3.6 \text{ W} \]
\[ p_f = v_f i_f = (165)(0.0825) = 13.6125 \text{ W} \]
\[ p_g = -v_g i_g = -(585)(0.0525) = -30.7125 \text{ W} \]
\[ p_h = v_h i_h = (-585)(0.0825) = -48.2625 \text{ W} \]

Therefore,

\[ \sum P_{\text{abs}} = 22.275 + 18 + 18 + 5.5125 + 3.6 + 13.6125 = 81 \text{ W} \]
\[ \sum P_{\text{del}} = 30.7125 + 48.2625 = 78.975 \text{ W} \]

\[ \sum P_{P_{\text{abs}}} \neq \sum P_{P_{\text{del}}} \]

Thus, the interconnection does not satisfy the power check.
From the diagram and the table we have

\[ p_a = -v_a i_a = -(46.16)(-6) = -276.96 \text{ W} \]
\[ p_b = v_{bi} = (14.16)(4.72) = 66.8352 \text{ W} \]
\[ p_c = v_{ci} = (-32)(-6.4) = 204.8 \text{ W} \]
\[ p_d = -v_d i_d = -(22)(1.28) = -28.16 \text{ W} \]
\[ p_e = -v_e i_e = -(33.6)(1.68) = -56.448 \text{ W} \]
\[ p_f = v_{fi} = (66)(-0.4) = -26.4 \text{ W} \]
\[ p_g = v_{gi} = (2.56)(1.28) = 3.2768 \text{ W} \]
\[ p_h = -v_h i_h = -(0.4)(0.4) = 0.16 \text{ W} \]

\[ \sum P_{del} = 276.96 + 28.16 + 56.448 + 26.4 = 387.968 \text{ W} \]
\[ \sum P_{abs} = 66.8352 + 204.8 + 3.2768 + 0.16 = 275.072 \text{ W} \]

Therefore, \( \sum P_{del} \neq \sum P_{abs} \) and the subordinate engineer is correct.

The difference between the power delivered to the circuit and the power absorbed by the circuit is

\[-387.968 + 275.072 = -112.896 \text{ W} \]

One-half of this difference is \(-56.448 \text{ W} \), so it is likely that \( p_a \) is in error. Either the voltage or the current probably has the wrong sign. (In Chapter 2, we will discover that using KCL at the node connecting components b, c, and e, the current \( i_e \) should be \(-1.68 \text{ A} \), not \( 1.68 \text{ A} \)!) If the sign of \( p_e \) is changed from negative to positive, we can recalculate the power delivered and the power absorbed as follows:

\[ \sum P_{del} = 276.96 + 28.16 + 26.4 = 331.52 \text{ W} \]
\[ \sum P_{abs} = 66.8352 + 204.8 + 56.448 + 3.2768 + 0.16 = 331.52 \text{ W} \]

Now the power delivered equals the power absorbed and the power balances for the circuit.
The interconnection is invalid. The voltage drop between the top terminal and the bottom terminal on the left hand side is due to the 6 V and 8 V sources, giving a total voltage drop between these terminals of 14 V. But the voltage drop between the top terminal and the bottom terminal on the right hand side is due to the 4 V and 12 V sources, giving a total voltage drop between these two terminals of 16 V. The voltage drop between any two terminals in a valid circuit must be the same, so the interconnection is invalid.

P 2.9  
[a] Yes, each of the voltage sources can carry the current required by the interconnection, and each of the current sources can carry the voltage drop required by the interconnection. (Note that \( i_\Delta = -8 \text{ A} \).)

[b] No, because the voltage drop between the top terminal and the bottom terminal cannot be determined. For example, define \( v_1 \), \( v_2 \), and \( v_3 \) as shown:

The voltage drop across the left branch, the center branch, and the right branch must be the same, since these branches are connected at the same two terminals. This requires that

\[ 20 + v_1 = v_2 + 100 = v_3 \]

But this equation has three unknown voltages, so the individual voltages cannot be determined, and thus the power of the sources cannot be determined.
The resistor value is the ratio of the power to the square of the current: 
\[ R = \frac{P}{I^2} \]. Using the values for power and current in Fig. P2.12(b),

\[
\frac{5.5 \times 10^{-3}}{(50 \times 10^{-6})^2} = \frac{22 \times 10^{-3}}{(100 \times 10^{-6})^2} = \frac{49.5 \times 10^{-3}}{(150 \times 10^{-6})^2} = \frac{88 \times 10^{-3}}{(200 \times 10^{-6})^2} = \frac{137.5 \times 10^{-3}}{(250 \times 10^{-6})^2} = \frac{198 \times 10^{-3}}{(300 \times 10^{-6})^2} = 2.2 \text{ M\Omega}
\]

Note that this is a value from Appendix H.
[b] $\Delta v = 25\text{V}; \quad \Delta i = 2.5\text{ mA}; \quad R = \frac{\Delta v}{\Delta i} = 10\text{ k}\Omega$

\[ \text{[c]} \quad 10,000i_1 = 2500i_s, \quad i_1 = 0.25i_s, \]
\[ 0.02 = i_1 + i_s = 1.25i_s, \quad i_s = 16\text{ mA} \]

\[ \text{[d]} \quad v_s(\text{open circuit}) = (20 \times 10^{-3})(10 \times 10^8) = 200\text{ V} \]

[e] The open circuit voltage can be found in the table of values (or from the plot) as the value of the voltage $v_s$ when the current $i_s = 0$. Thus,
\[ v_s(\text{open circuit}) = 140\text{ V} \text{ (from the table)} \]

[f] Linear model cannot predict the nonlinear behavior of the practical current source.
P 2.20  [a] Use KVL for the right loop to calculate the voltage drop across the right-hand branch \( v_\circ \). This is also the voltage drop across the middle branch, so once \( v_\circ \) is known, use Ohm’s law to calculate \( i_\circ \):

\[
v_\circ = 1000i_\alpha + 4000i_\alpha + 3000i_\alpha = 8000i_\alpha = 8000(0.002) = 16 \text{ V}
\]

\[
16 = 2000i_\circ
\]

\[
i_\circ = \frac{16}{2000} = 8 \text{ mA}
\]

[b] KCL at the top node: \( i_\circ = i_\alpha + i_\circ = 0.002 + 0.008 = 0.010 \text{ A} = 10 \text{ mA} \).

[c] The voltage drop across the source is \( v_\circ \), seen by writing a KVL equation for the left loop. Thus,

\[
p_\circ = -v_\circ i_\circ = -(16)(0.01) = -0.160 \text{ W} = -160 \text{ mW}.
\]

Thus the source delivers 160 mW.