PROBLEM SOLUTIONS CHAPTER 5.

Solution 5.1. (a) $V_s = 10$ V, $P = 20$ W and $P = V_s \times I_s$ implies $I_s = 2$ A.

(b) $R_{in} = V_s/I_s = 10/2 = 5\ \Omega$

(c) By the linearity/proportionality property: $\dfrac{V_s^{new}}{V_s^{old}} = \dfrac{I_s^{new}}{I_s^{old}}$ which implies $\dfrac{2}{10} = \dfrac{I_s^{new}}{2}$ implies

$I_s^{new} = 0.4$ A.

(d) $P^{new} = V_s^{new} \times I_s^{new} = 2 \times 0.4 = 0.8$ watts. Observe that

$$\frac{P^{new}}{P^{old}} = \frac{0.8}{20} \neq \frac{V_s^{new}}{V_s^{old}} = \frac{2}{10}$$

It follows that the proportionality property does not hold for power calculations.

Solution 5.2 First note that the ratio I_R/V_S is constant. With the given values of voltage and current, this ratio is:

$$I_R/V_S = 0.25/25 = 0.01$$

Power dissipated in the resistor is

$$P = I_R^2 R = 2.5 \Rightarrow I_R^2 = 2.5/R = 0.25 \Rightarrow I_R = 0.5$$

Since I_R is always $0.01 \times V_S$, it follows that $V_S = 50$V.

Solution 5.3 Label the resistances R_1, R_2, and so on in the manner shown in Example 5.11. In this problem, we have R_1 to R_{10} (the last being the 2 Ohm resistance at the voltage source). First, assume that V_1 (the voltage across R_1) is 1V. Then evaluate the rest of the currents and voltages until you deduce the resulting V_S. It should be noted that the equivalent resistance looking into R_3, R_5, R_7, and R_9 is always 2Ω.

$$V_1 = 1 \qquad I_1 = \frac{V_1}{4} = 0.25 \qquad I_2 = 0.25 \qquad V_2 = I_2 \times 2 = 0.5 \text{ V}$$

$$V_3 = V_1 + V_2 = 1.5 \Rightarrow I_3 = \frac{V_3}{3} = 0.5 \Rightarrow I_4 = I_3 + I_2 = 0.75 \Rightarrow V_4 = I_4 \times 4 = 3$$

$$V_5 = V_3 + V_4 = 4.5 \Rightarrow I_5 = \frac{V_5}{3} = 1.5 \Rightarrow I_6 = I_5 + I_4 = 2.25 \Rightarrow V_6 = I_5 \times 4 = 9$$

$$V_7 = V_6 + V_5 = 13.5 \Rightarrow I_7 = \frac{V_7}{3} = 4.5 \Rightarrow I_8 = I_7 + I_6 = 6.75 \Rightarrow V_8 = I_8 \times 4 = 27$$

$$V_9 = V_8 + V_7 = 40.5 \Rightarrow I_9 = \frac{V_9}{3} = 13.5 \Rightarrow I_{10} = I_9 + I_8 = 20.25 \Rightarrow V_{10} = I_{10} \times 2 = 40.5$$

$$V_S = V_9 + V_{10} = 40.5 + 40.5 = 81 \text{ V}$$

Thus, an 81 V input produces a 1 V output ➔ $V_{out} = (1/81) \times V_S = 2$ V.

Solution 5.4 Label the resistances R_1 to R_{10} progressively from right to left just like in the previous problem. Then, assume $I_{out} = 1$ and proceed as follows:

$$I_{out} = 1 \Rightarrow V_1 = I_{out} \times 4 = 4 \Rightarrow I_2 = \frac{V_1}{4} = 1$$

$$I_3 = I_1 + I_2 = 2 \Rightarrow V_3 = I_3 \times 4 = 8 \Rightarrow V_4 = V_3 + V_1 = 12 \Rightarrow I_4 = \frac{V_4}{3} = 4$$

$$I_5 = I_4 + I_3 = 6 \Rightarrow V_5 = I_5 \times 4 = 24 \Rightarrow V_6 = V_5 + V_4 = 36 \Rightarrow I_6 = \frac{V_6}{3} = 12$$

$$I_7 = I_6 + I_5 = 18 \Rightarrow V_7 = I_7 \times 4 = 72 \Rightarrow V_8 = V_7 + V_6 = 108 \Rightarrow I_8 = \frac{V_8}{3} = 36$$

$$I_9 = I_8 + I_7 = 54 \Rightarrow V_9 = I_9 \times 4 = 216 \Rightarrow V_{10} = V_9 + V_8 = 324 \Rightarrow I_{10} = \frac{V_{10}}{3} = 108$$

$I_S = I_{10} + I_9 = 162$

➔ $I_{out}/I_S = 1/162$ ➔ $I_{out} = (1/162)\times 40.5 = 0.25$A.

Solution 5.5 (a) MATLAB code given in problem.

(b) Subsitute to obtain $V_1 = 10$V.

(c) $R_{eq} = V_S/I_S = 11.6667\Omega$.

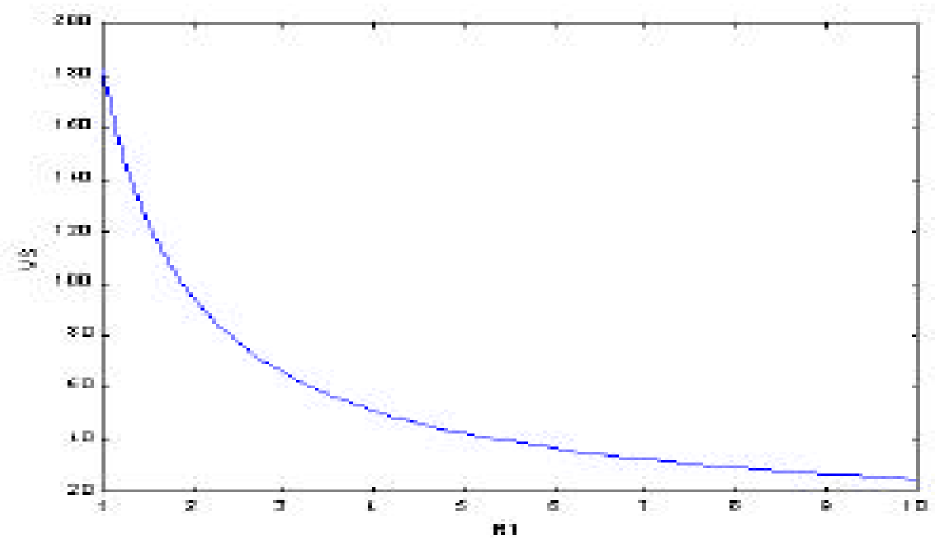
(d) First, define r1 = 1:0.25:10;

then create an outermost loop around the code of part (a) as: for j=1:length(r1)

then, in the statement defining R, do R = [R1(j), R2, R3, R4, R5, R6, R7, R8]';

Finally, replace the last statement with Vs(j) = V(n) + V(n-1); end;

The following is the resulting plot:



Solution 5.6 (a)

The following code can be used:

n = 9;

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v = zeros(n,1);
i = zeros(n,1);
r = [r1 r2 r3 r4 r5 r6 r7 r8 r9]';
i(1) = 1;
v(1) = i(1)*r(1);
i(2) = i(1);
for k=2:2:n-2
    v(k) = r(k)*i(k);
    v(k+1) = v(k)+v(k-1);
    i(k+1) = v(k+1)/r(k+1);
    i(k+2) = i(k+1) + i(k);
end;
v(8) = i(8)*r(8);
v(9) = v(8) + v(7);
i(9) = v(9)/r(9);
Is = i(9) + i(8);
```

It follows that $I_S = 16.9877A$.

(b) By the proportionality property: $\frac{I_1^{new}}{I_1^{old}} = \frac{I_S^{new}}{I_S^{old}} \rightarrow I_1^{new} = \frac{1}{16.9877} \times 200mA = 11.77mA$

(c) R_{eq} = v(9)/Is = 38.15Ω.

Solution 5.7 V_a = 12V, i_B = 60m

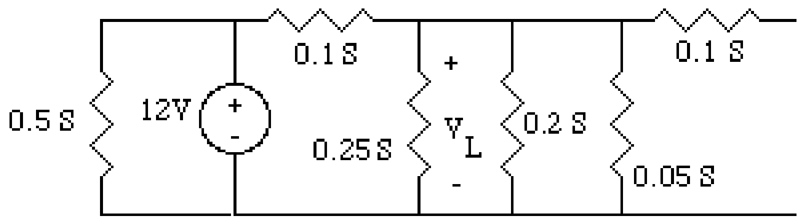
By inspection:

V_{out_a} = 300/900×12 = 4V

V_{out_b} = (300||600)×60m = 12

_ $V_{out} = 4 + 12 = 16V.$

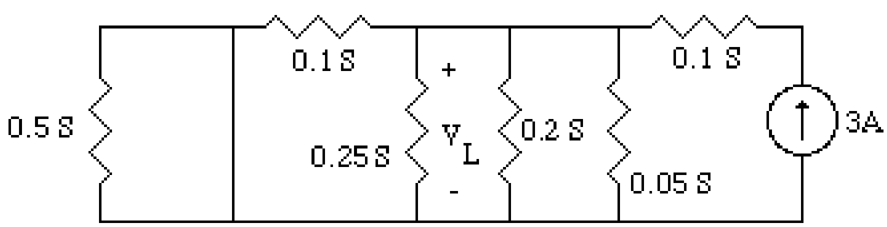
***SOLUTION 5.8. Part 1:** Set the 3 A current source to zero. This generates an open circuit in place of the current source eliminating the effect of the series 0.1 S resistor. The equivalent circuit is:



By voltage division,

$$V_L^{12V} = \frac{\frac{1}{0.25+0.2+0.05}}{\frac{1}{0.25+0.2+0.05}+\frac{1}{0.1}} \times 12 = \frac{2}{2+10} \times 12 = 2\text{ V}$$

Part 2: Set the 12 V source to zero. This generates a short circuit in place of the voltage source which shorts out the effect of the 0.5 S resistor. The equivalent circuit is:



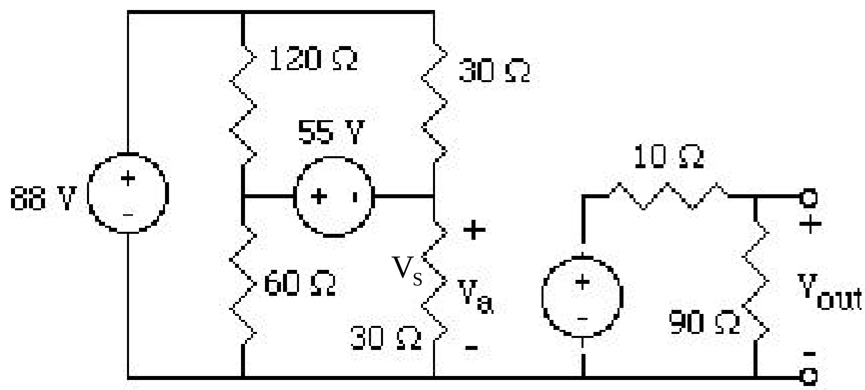
Note that the 0.1 S resistor in series with the 3 A source is redundant to the calculation of VL. Hence, by Ohm's law,

$$V_L^{3A} = \frac{1}{0.25+0.2+0.05+0.1} \times 3 = \frac{3}{0.6} = 5\text{ V}$$

Therefore by superposition,

$$V_L = V_L^{12V} + V_L^{3A} = 2 + 5 = 7 \text{ V}$$

Solution 5.9 Replace the dependent source by an independent voltage source V_S:

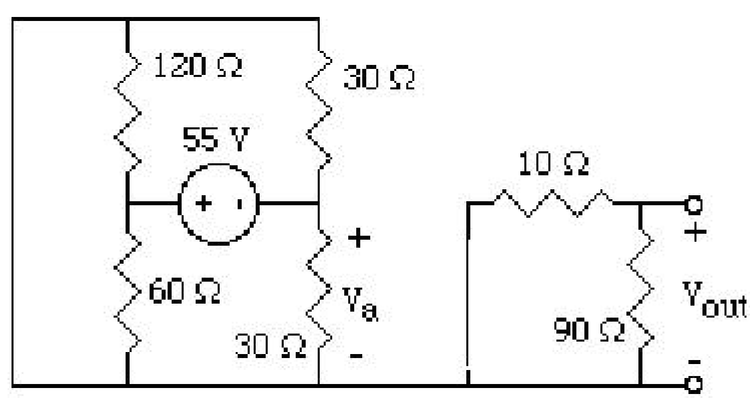


In the following analysis, we have to always compute V_a because It defines the constraint on V_s. So, when only the 88V source Is active, VA Is the result of voltage division between the 60||30 Ω resistor and the 120||30 Ω resistor. So,

$V_{a\_1} = 40V$

And, since deactivated V_S, $V_{out\_1} = 0$.

Now, due to the 55V source, we have



Now, the 120 and 60 Ω resistors are in parallel, and the same can be said about the 30 and 30 Ω resistors.

Thus, another voltage divider gives:

$V_{a\_2} = -15V$ and $V_{out\_2} = 0V$.

Finally, when V_{S1} is active, the left part of the circuit consists only of resistances, so $V_{a\_3} = 0$. V_{out} is given by another divider formula:

$V_{out\_3} = 90/100 \times V_S$

Now add all contributions:

$V_a = 40 - 15 + 0 = 25V$

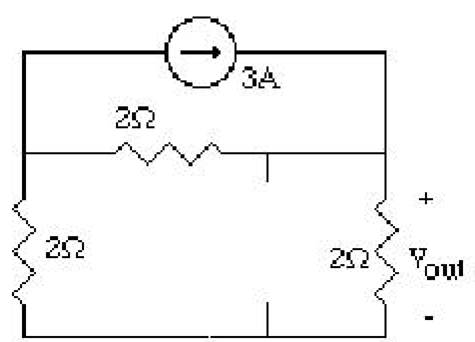
$V_{out} = 0 + 0 + 0.9V_S$, where $V_S = 2V_a$.

$V_{out} = 0.9 \times 2 \times 25 = 45V$.

Finally, $P = V^2/R = 22.5W$.

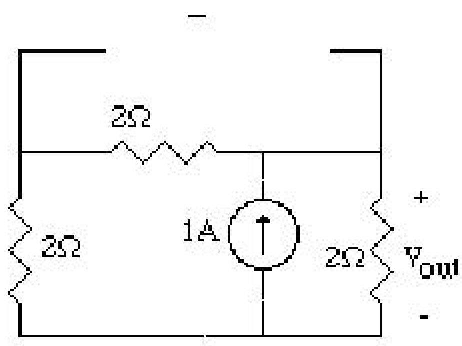
Solution 5.10

Due to 3A source:



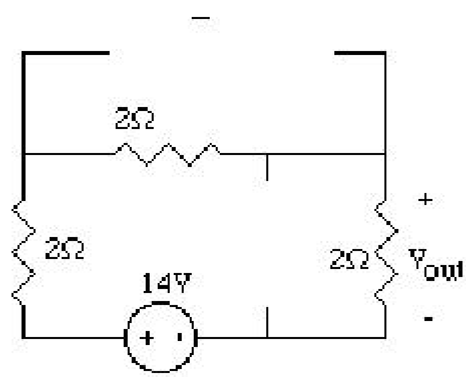
$i_{out} = 1A$ by current division between the two paths. So, $v_{out\_1} = 2$ V.

Due to 1A source:



i_{out} = 2/3A again by current division. So, v_{out_2} = 4/3V.

Due to 1vV source:

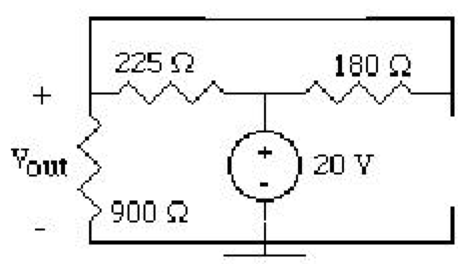


i_{out} = 14/6 = 7/3A (by Ohm's Law). So, v_{out_3} = 14/3V.

Finally, v_{out} = 6/3 + 4/3 + 14/3 = 8V, and the power delivered by the source is 8×1 = 8 W.

Solution 5.11

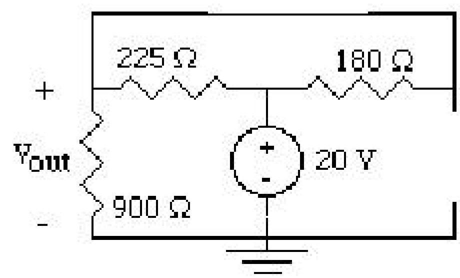
Due to 22 V source:



R_{eq} = 900||225 = 180. Now, by voltage divider:

V_{out_1} = 0.5×22 = 11 V.

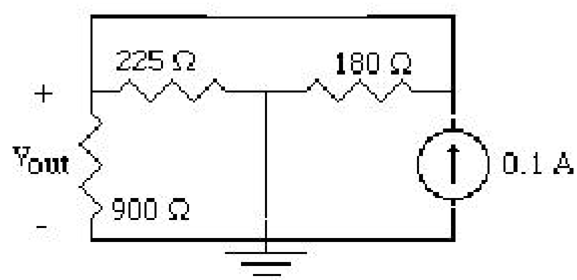
Due to the 20 V source:



R_{eq} = 180||225 = 100 Ω. So, again, by voltage division:

V_{out_2} = 900/(900+100)×20 = 18 V.

Finally, due to current source:

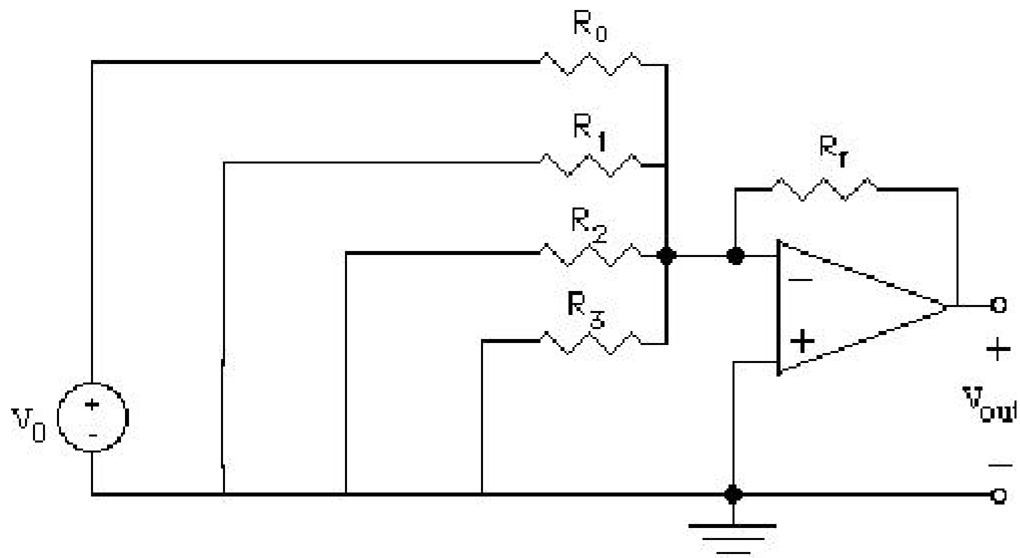


We have three resistances in parallel with a resistance equal to 90 Ω. So, V_{out_3} = 0.1×90 = 9 V.

V_{out} = 11 + 18 + 9 = 38V and P = 38×38/900 = 1.6 W.

Solution 5.12

Find contribution to V_{out} :



First, note that no current flows through R1 - R3 because of the virtual ground property of the op-amp. Thus, this circuit is identical to the inverting amplifier studied in Chapter 4. So,

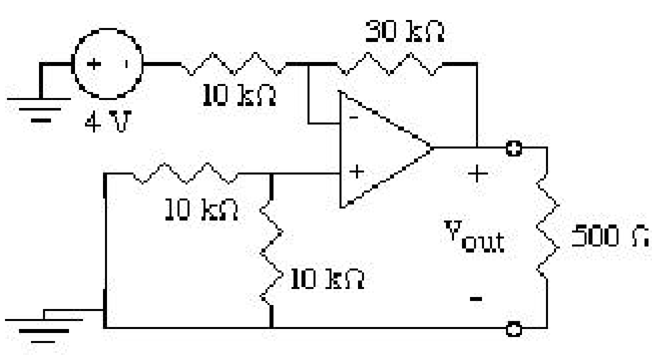
$$V_{out\_0} = -\frac{R_f}{R_0} V_0$$

Similarly, when each of the other sources is activated, the circuit will be an inverting amplifier. So,

$$V_{out\_1} = -\frac{R_f}{R_1} V_1, \quad V_{out\_2} = -\frac{R_f}{R_2} V_2, \quad V_{out\_3} = -\frac{R_f}{R_3} V_3$$

$$V_{out} = -R_f \left(\frac{V_0}{R_0} + \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right)$$

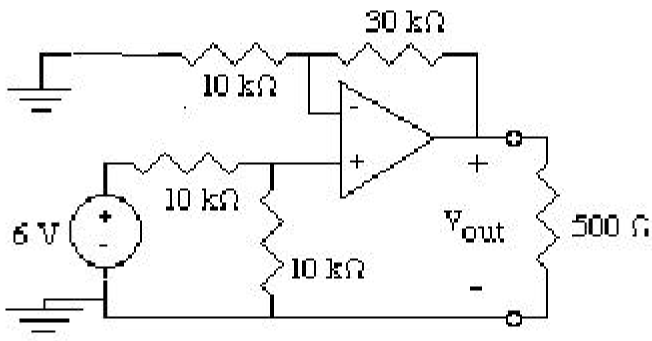
Solution 5.13 Due to the 4 V source, the circuit looks like an inverting amplifier:



So, V_{out_1} = -30/10×(-4) = 12 (from the results of Chapter 4).

Again, note here that no current flows through the two resistances connected to the + terminal of the op amp. Since no current flows through them, then no voltage develops across them. So, the + terminal can be assumed to be connected to ground, and this is why we say that the circuit looks like that of the inverting amplifier.

Now, due to the 6 V source:



The voltage at the + terminal is established by a resistive divider between the two 10K resistors. So, this voltage is 3V. Thus, the voltage at the negative terminal is also 3V. We can now use KVL on the inverting side of the op-amp to get:

$$V_{out\_2} = 3 + 30k \times 0.3m = 12V$$

So, V_{out} = 12 + 12 = 24V, and P = (24)×(24)/500 = 1.15W.

Solution 5.14

(a) When V_{S2} is deactivated. The circuit looks like two inverting amplifiers in cascade.

Thus, by inspection, $V_1 = -2V_{S1}$ and $V_{out\_1} = -3V_1 = 6V_{S1} = 3V$.

(b) Similarly, when V_{S1} is zero, V_1 is zero because the first inverting amplifier has zero input. Thus, the circuit consists just of the second inverting amplifier:

$V_{out\_2} = -\,3/2V_{S2} = -\,4.5$

(c) $V_{out} = 3 - 4.5 = -\,1.5V.$

***SOLUTION 5.15.** For V_{s1} and V_{s2}, the situation reduces to the analysis of two inverting amplifiers in cascade. For V_{s3}, the situation is simply a single stage inverting amplifier. Note that because of the virtual ground at the inverting terminal of the op amp, when V_{s1} and V_{s2} are zero, they have no contribution to the input of the second stage.

(a) With V_{s2} and V_{s3} set to zero,

$$V_{out}^{s1} = \left(\frac{-R}{R}\right)\left(\frac{-2R}{2R}\right)V_{s1} = V_{s1} = 5\ \text{V}$$

(b) With V_{s1} and V_{s3} set to zero,

$$V_{out}^{s2} = \left(\frac{-R}{R}\right)\left(\frac{-2R}{R}\right)V_{s2} = 2V_{s2} = 2\times(-2.5) = -5\ \text{V}$$

(c) With V_{s1} and V_{s2} set to zero,

$$\text{V}_{\text{out}}^{\text{s3}} = \left(\frac{-\text{R}}{\text{R}}\right)\text{V}_{\text{s3}} = -\text{V}_{\text{s3}} = -2\ \text{V}$$

(d) By superposition,

$$\text{V}_{\text{out}} = \text{V}_{\text{out}}^{\text{s1}} + \text{V}_{\text{out}}^{\text{s2}} + \text{V}_{\text{out}}^{\text{s2}} = -2\ \text{V}$$

Solution 5.16

If the op-amp were ideal, we would get:

$V_{out} = -\,4V_{S1} - 2V_{S2} = -\,26$

This is clearly beyond the linear range of operation of the op-amp. In other words, the amplifier responds in a non-linear manner to this level of input. Hence, superposition, which relies on linearity, cannot be used.

Solution 5.17

We know by linearity that

$$V_{out} = aI_{s1} + bV_{s2}$$

Substitute the first measurement to obtain:

$$5 = 0 + b\times 10 \Rightarrow b = 0.5$$

Now, take the second measurement:

$$1 = a\times 10 + 0 \Rightarrow a = 0.1$$

So,

$$V_{out} = 0.1I_{s1} + 0.5V_{s2}$$

At 20A, 20V: $V_{out} = 12V$

Solution 5.18

Again $V_{out} = aI_{s1} + bV_{s2}$

Substitute the two measurements to obtain:

$$5a + 10b = 15$$

$$2a + 5b = 10$$

These two simultaneous equations in a and b can easily be solved to obtain:

$$a = -5 \quad \text{and} \quad b = 4$$

Therefore, at 1A and 5V,

$$V_{out} = -5 + 20 = 15V$$

Solution 5.19 (a)

Again,

$$V_{out} = aI_{s1} + bV_{s2}$$

Substituting the result of the first measurement into this equation yields:

$$a \times 4 \times \cos(2t) + 0 = -2\cos(2t) \Rightarrow a = -0.5$$

Now, substitute the second measurement:

$$0 + 10b = 55 \Rightarrow b = 5.5$$

Therefore, for the given input current and voltage:

$$V_{out} = -\cos(2t) - 55\cos(2t) = -56\cos(2t) \text{ V}$$

(b) $$V_{out} = 2\cos(5t) + 110\cos(5t) = 112\cos(5t) \text{ V}$$

Solution 5.20 (a)

First of all,

$$I_{load} = aV_a + bI_b$$

Now, substitute the two measurements into this equation:

$$7a + 3b = 1$$

$$9a + b = 3$$

Solving these two equations for the unknowns a and b, we get

$$a = 0.4 \quad \text{and} \quad b = -0.6$$

(b) $$I_{load} = 0.4 \times 15 - 0.6 \times 9 = 0.6\text{A}$$

Solution 5.21 (a)

We know that the output is going to be a linear combination of the three inputs:

$$V_{out} = aI_{s1} + bV_{s2} + cV_{s3}$$

Now, substitute the three measurements into this relationship:

$$50\text{m}a - 2b + 5c = -13$$

$$0 + 3b + 5c = 2$$

$0 + 2b + 4c = 0$

These equations can be written in matrix form and solved as follows:

$$\begin{bmatrix} 0.05 & -2 & 5 \\ 0 & 3 & 5 \\ 0 & 2 & 4 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} -13 \\ 2 \\ 0 \end{bmatrix} \qquad \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 100 \\ 4 \\ -2 \end{bmatrix}$$

(b) Substitute the given values of the input sources to obtain:

$V_{out} = 100\times1 - 4\times40 + 2\times10 = -40V$

Solution 5.22

$V_{out} = AI_{s1} + BV_{s2} + CV_{s3}$

Substituting the measurements into this equation results in a system of three equations and three unknowns. This system can be written in matrix form by inspection:

$$\begin{bmatrix} 30\;10^{-3} & 2 & -1 \\ -20\;10^{-3} & 4 & 2 \\ -10\;10^{-3} & -3 & 1 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} 11.5 \\ 27 \\ -14 \end{bmatrix} \qquad \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} 150 \\ 5.5 \\ 4 \end{bmatrix}$$

This can be solved to obtain:

Solution 5.23 (a)

The coefficient matrix is inverted, and both sides of the nodal equation are multiplied by it to obtain:

$$\begin{bmatrix} V_a \\ V_b \end{bmatrix} = \begin{bmatrix} 43.0108 & 0.233 \\ 43.0108 & -1.4337 \end{bmatrix} \begin{bmatrix} 0.02V_{s1} - 0.00125V_{s2} \\ V_{s2} \end{bmatrix}$$

Expanding the first row of the above equation gives:

$$V_a = 0.8602V_{s1} - 0.0538V_{s2} + 0.233V_{s2}$$

This is exactly in the form required, where A = 0.8602 and B = 0.1792

(b) For this part, we expand the second row of the equation:

$$V_b = 0.8602V_{s1} – 0.0538V_{s2} – 1.4337V_{s2}$$

Again, this is in the desired form, where A = 0.8602 and B = – 1.4875

(c) $V_{ab} = V_a – V_b = 0 + 1.667\ V_{s2}$

Thus, A = 0 and B = 1.667

Solution 5.24 (a)

Again, we invert the coefficient matrix to obtain

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 0.0022 & 0.0022 & 0.0022 & 0.6296 & -0.0741 \\ 0.0022 & 0.0022 & 0.0022 & -0.7037 & 0.2593 \\ 0.0022 & 0.0022 & 0.0022 & -0.3704 & -0.0741 \\ -0.2222 & 0.7778 & -0.2222 & 137.037 & -92.5926 \\ -0.3333 & -0.3333 & 0.6667 & -11.1111 & 77.7778 \end{bmatrix} \begin{bmatrix} V_{s1} \\ 0 \\ 0 \\ I_{s2} \\ 0 \end{bmatrix}$$

Expanding the first row of this equation:

$$I_1 = 0.0022V_{s1} + 0.6296I_{s2}$$

So, A = 0.0022, B = 0.6296

(b) Similarly, expanding the third row:

$$I_3 = 0.0022V_{s1} + -0.3704I_{s2}$$

So, A = 0.0022, B = -0.3704

(c) By the same procedure, A = -0.3333 and B = -11.111

Solution 5.25

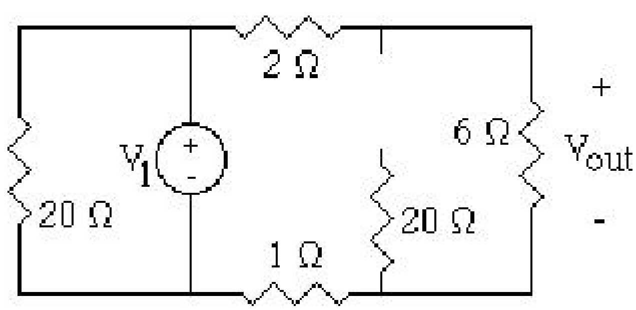
Invert the coefficient matrix and mujltiply both sides of the equation in the problem by this inverse matrix to obtain

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ I_a \\ I_b \\ I_c \\ I_d \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & -3 & 2 & -1 & -4 \\ 0 & 0 & 0 & -3 & 1 & -1 & -4 \\ 0 & 0 & 0 & 12 & -3 & 3 & 16 \\ 0 & 0 & 0 & -4 & 1 & -1 & -5 \\ 0 & -1 & 0 & -16.6 & 9.2 & -5.2 & -21.8 \\ 1 & 1 & 0 & -42.1 & -16.2 & 11.7 & 53.8 \\ 1 & 1 & 1 & 26.1 & -12.2 & 7.7 & 32.8 \end{bmatrix} \begin{bmatrix} I_{s1} \\ 0 \\ 0 \\ 0 \\ V_{s2} \\ 0 \\ 0 \end{bmatrix}$$

The second to last row can be expanded to get $I_c = I_{s1} - 16.2V_{s2}$ ➔ A = 1, B = –16.2

Solution 3.26 (a)

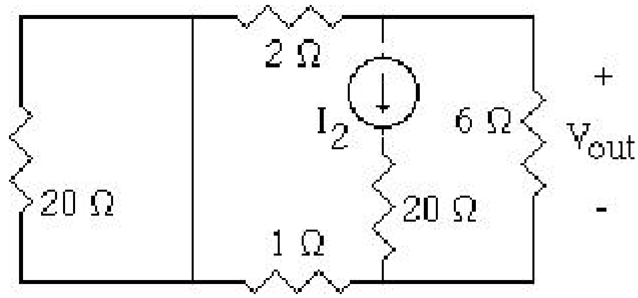
First compute the response due to V_1:



By voltage divider:

$$V_{out\_1} = 6/(2+6+1)\times V_1 = 2/3V_1$$

Then, due to I_2:



I_2 flows through the 20 ohm resistor in series with 6||3. Thus,

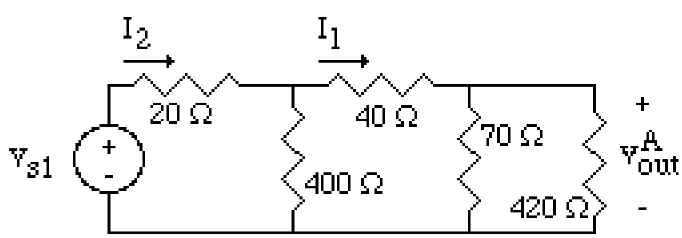
$$V_{out\_2} = -2I_2$$

Therefore, $V_{out} = 2/3V_1 - 2I_2$

(b) $V_{out} = 8\cos(10t) - 4$

***SOLUTION 5.27.** (a) By linearity $V_{out} = A\,V_{s1} + B\,I_{s2}$.

To find A, let $I_{s2} = 0$. The circuit becomes a ladder network as follows.



Let $V_{out}^{A} = 1$ V. Then

»I1 = 1/420 + 1/70

I1 = 1.6667e-02

»V400 = I1*40 + 1

V400 = 1.6667e+00

»I400 = V400/400

I400 = 4.1667e-03

»I2 = I1 + I400

I2 = 2.0833e-02

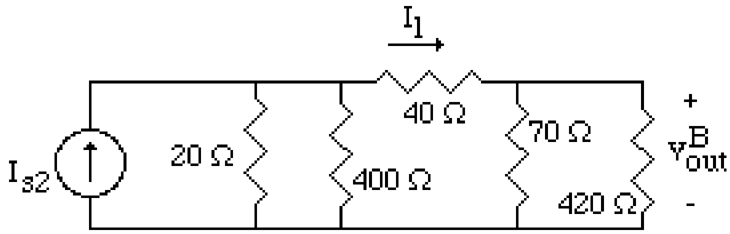
»Vs1 = I2*20 + V400

Vs1 =   2.0833e+00

»A = 1/Vs1

A =   4.8000e-01

To find B, let V_{s1} = 0. The circuit becomes a ladder network as follows.



Again assume that V_{out}^{B} = 1 V. Then

»I1 = 1/420 + 1/70

I1 =   1.6667e-02

»V400 = I1*40 + 1

V400 =   1.6667e+00

»I400 = V400/400

I400 =   4.1667e-03

»I20 = V400/20

I20 =   8.3333e-02

»Is2 = I20 + I400 + I1

Is2 =   1.0417e-01

»B = 1/Is2

B =   9.6000e+00

Hence by linearity $V_{out} = 0.48\ V_{s1} + 9.6\ I_{s2}$.

(b)

»Vout = A*20 + B* 0.5

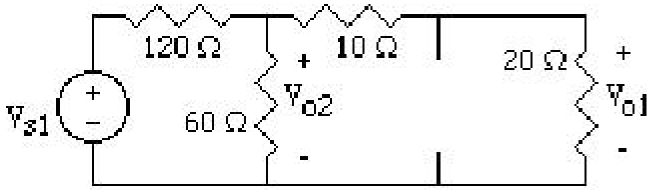
Vout =   1.4400e+01

(c) Doubling resistances does not change voltage ratios hence A is the same. However, the doubling also doubles the voltage to current ratio. Hence, B is doubled. It follows that if all resistances are doubled, then

$$V_{out} = 0.48\ V_{s1} + 19.2\ I_{s2}$$

Solution 5.28 (a) (b)

We solve parts (a) and (b) at the same time. First, we find the responses to V_{s1}:



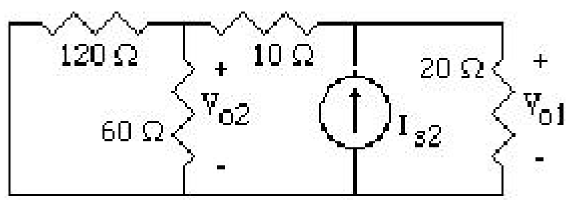
Equivalent resistance across V_{o2}: 60||30 = 20

Now, by voltage divider: $V_{o2\_1} = 20/140V_{s1}$

This voltage now divides between V_{o1} and the 10 ohm resistance:

$$V_{o1\_1} = 20/30V_{o2\_1} = 2/3\times1/7V_{s1} = 2/21V_{s1}$$

Now, compute the responses due to I_{s2}:



Equivalent resistance across V_{o2}: 60||120 = 40Ω

By voltage division: $V_{o2\_2} = 40/50V_{o1\_2}$

Where $V_{o1\_2} = I_{s2}\times(50||20) = 14.286I_{s2}$

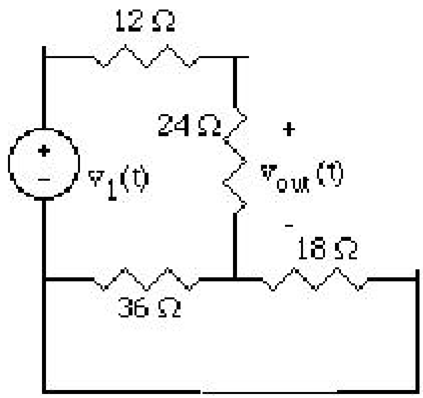
Now, add the contributions:

$$V_{o1} = 0.0952V_{s1} + 14.286I_{s2}$$

$$V_{o2} = 0.1429V_{s1} + 11.4288I_{s2}$$

Solution 5.29 (a)

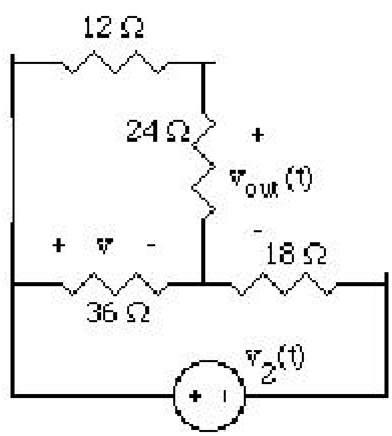
Find contribution due to v_1:



The parallel combination results in a 12 ohm resistance in series with the remaining two. Thus, by voltage division:

$$v_{out1} = 24/48v_1 = 0.5v_1$$

Now, due to v_2



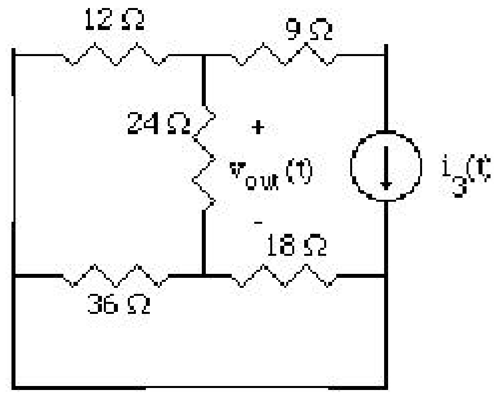
The equivalent resistance across v in this figure is 36||(24+12) = 18, which means that by voltage divider:

$$v = 0.5v_2$$

Similarly, by another voltage division application

$$v_{out2} = 24 / 36 \times v = 0.66 \times 0.5v_2 = 0.333v_2$$

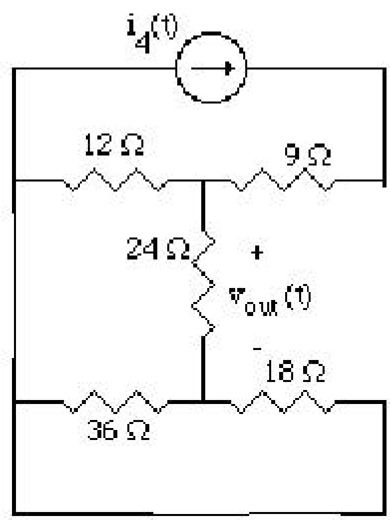
Now, due to i_3



Define Req1 = 24 + 36||18 = 36 Ω. This resistance is in parallel with the 12 ohm resistance to introduce an equivalent of 9 Ω. The total voltage that develops across this 9 ohm resistance is $-9i_{s3}$. This voltage divides between v_{out} and the 36||18 resistance:

$$v_{out3} = 24/36v_1 = -9\times 24/36i_{s3} = -6i_{s3}$$

Finally, due to i4:



A similar analysis of this resistive network can reveal that $v_{out4} = 6i_{s4}$. Thus

$$v_{out} = 0.5v_1 + 0.333v_2 - 6i_{s3} + 6i_{s4}$$

(b) For this part, note that scaling resistance values does not affect voltage ratios. This can be evident from the application of any voltage divider formula. On the other hand, scaling resistances does affect current-to-voltage or voltage-to-current ratios. This is by definition of a resistance! So, in the above equation, doubling the resistances does not affect the first two terms, but doubles the second two terms.

Solution 5.30 (a)

Define two clockwise mesh currents: I_1 in the bottom left loop and I_2 in the top loop. The bottom right loop has a current source, so it will not be considered:

$$V_a – (I_1-I_2)3 – I_2 – (I_1 – i_b) = 0$$

and

$$6I_2 – I_2 + (I_2 – I_1)3 = 0$$

Solving these two equations for the two currents gives:

$$I_1 = 8\text{ A} \qquad \text{and} \qquad I_2 = 3\text{ A}$$

The power delivered by the dependent source is: $P = i_X \times I_{iX}$ where I_{iX} is the current leaving the '+' terminal of the dependent voltage: $P = i_X \times (I_2 - I_1) = I_2 \times (I_2 - I_1) = -15W$

➔ $v_{out} = I_1 + i_b = 8 + 26 = 34V$

(b) Now, we express $v_{out} = Av_a + Bi_b$

Turning off i_b, we still have two loops, in which we can define the same mesh currents as above to obtain:

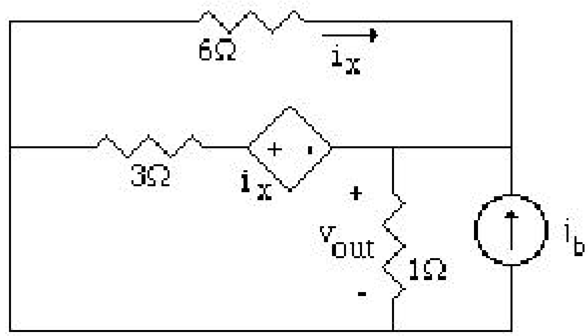
$$v_a – 3(I_1 – I_2) – I_2 – I_1 = 0$$

$$I_2 – 3(I_2 – I_1) – 6I_2 = 0$$

Solving for the two currents, we get I1 = $4/13v_a$ which sets up v_{out} across the 1 ohm resistor:

$$V_{out1} = 4/13v_a$$

Now, turn off the voltage source:



Write a node equation at v_{out}:

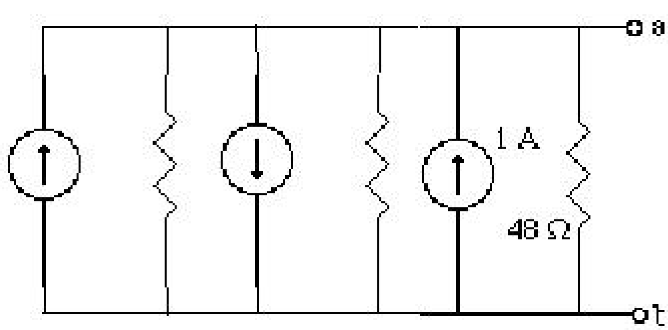
$$\frac{v_{out}}{6} + \frac{v_{out}}{1} + \frac{v_{out} - {}^{v_{out}}\!/\!_{6}}{3} - i_b = 0$$

$$? \quad v_{out2} = \frac{9}{13} i_b$$

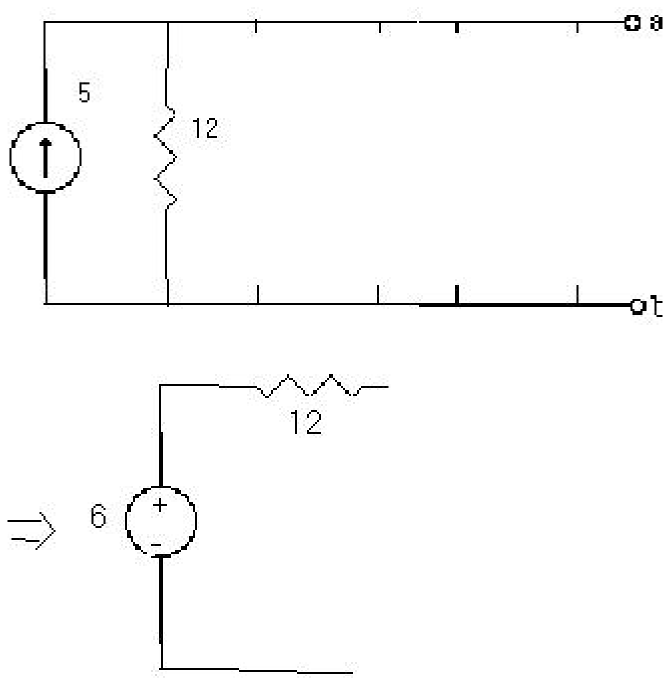
So, $v_{out} = 4/13 v_a + 9/13 i_b$

(c) Substitute into the above equation: $v_{out} = 35V$

Solution 5.31 By inspection:

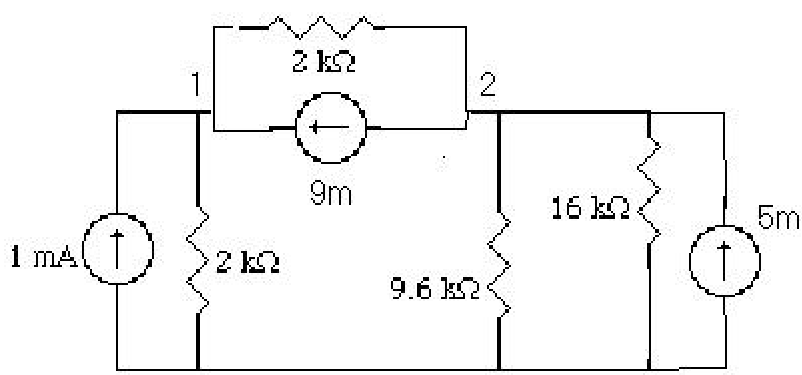


where the leftmost current is 0.25 with a resistance of 32Ω. Similarly, the downward current is 0.75 and its resistance is 32Ω. This reduces to:



Solution 5.32

The circuit can be transformed as follows:



Write two nodal equations at 1 and 2:

$$-1m+\frac{v_1}{2k}-9m+\frac{v_1-v_2}{2k}=0$$

$$\frac{v_2-v_1}{2k}+9m+\frac{v_2}{9.6k}+\frac{v_2}{16k}-5m=0$$

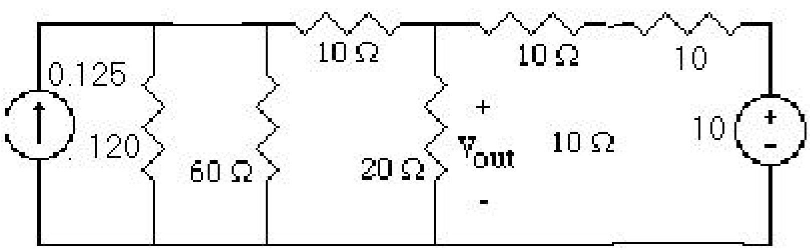
These two equations can be solved using any method to obtain:

$v_1 = 11.2\text{V} \qquad \text{and} \qquad v_2 = 2.4\text{V}$

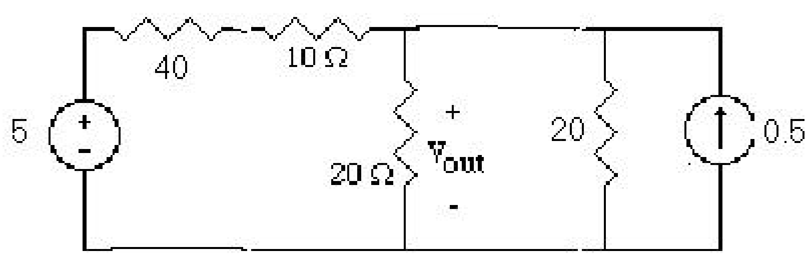
The power absorbed by the 9.6kΩ resistor is:

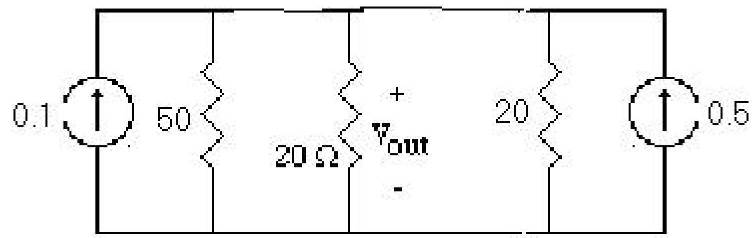
$$P = \frac{V_2^2}{9.6\times 10^3} = 0.6\text{mW}$$

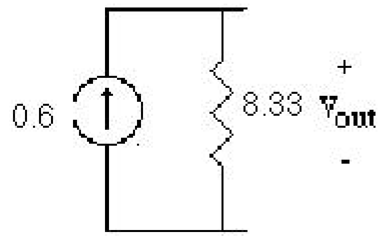
Solution 5.33



Then





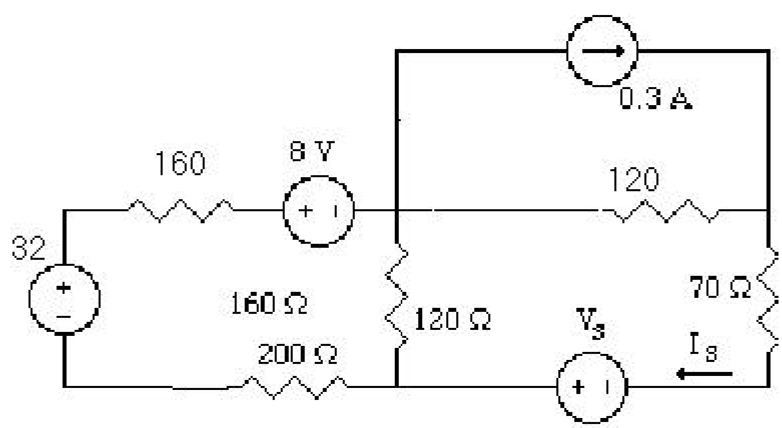


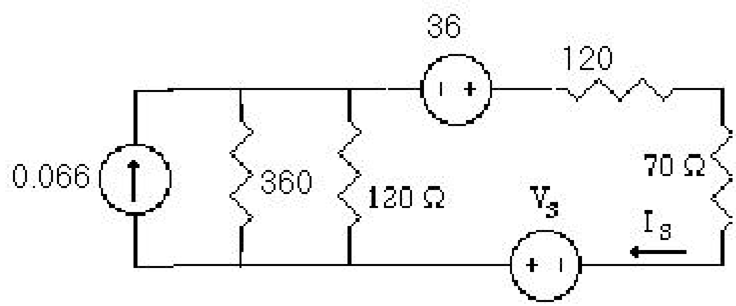
Output voltage is 5V

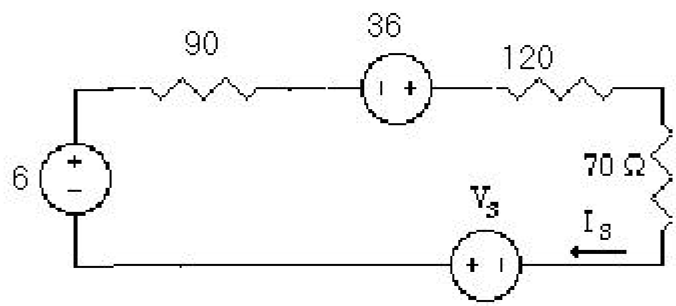
(b) P = 1.25W

(c) For a given resistance, doubling the voltage increases the current by two times. So, the current is doubled. It follows that $V_{out}^{new} = 2 \times V_{out}^{old} = 10V$

Solution 5.34

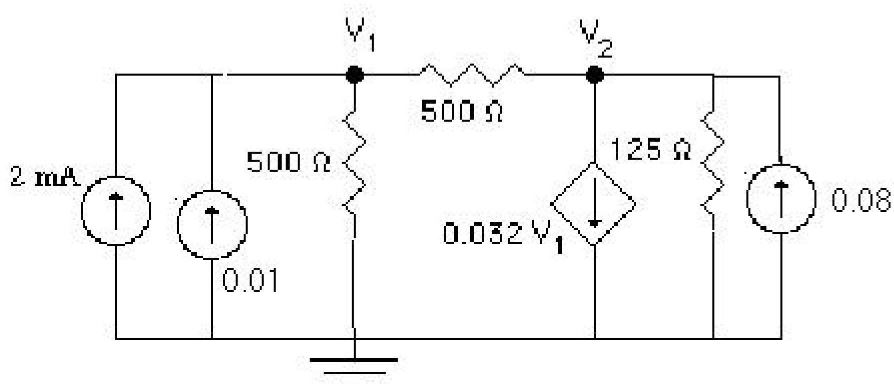






This circuit is easy enough to solve by inspection. V_s = 28V.

Solution 5.35



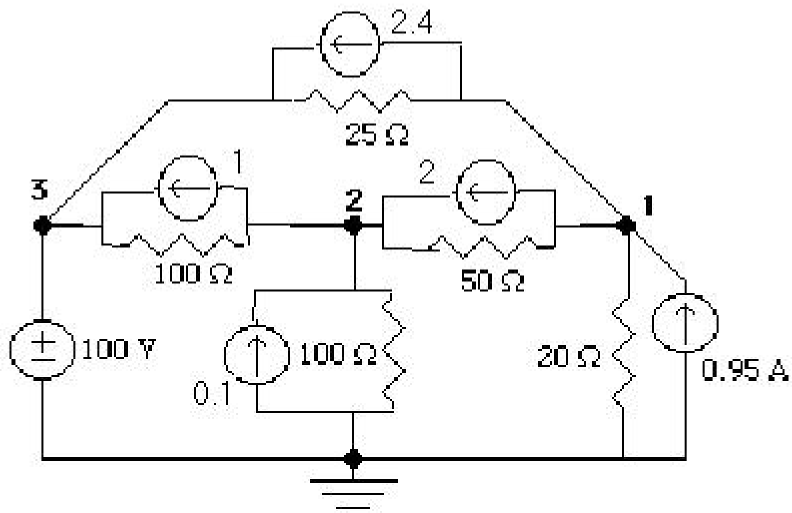
Now, write two node equations:

$$\frac{v_1}{500} - \frac{v_2}{500} + \frac{v_1}{500} = 12m$$

$$\frac{v_2}{500} - \frac{v_1}{500} + 0.032v_1 + \frac{v_2}{125} = 80m$$

These two equations can be solved to get v_1 = 2.8V, v_2 = -0.4V.

Solution 5.36



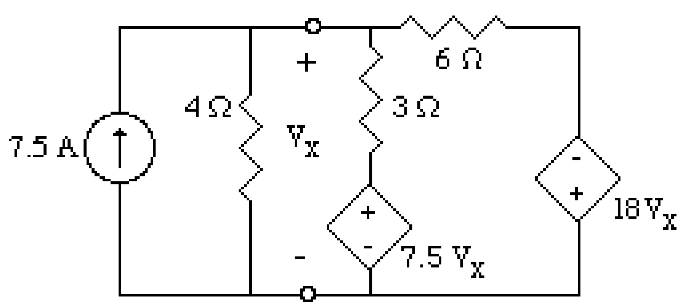
Now, we can write the node equations:

$$\frac{v_1}{50}-\frac{v_2}{50}+\frac{v_1}{25}-\frac{100}{25}+0.2+0.4+\frac{v_1}{20}-0.95=0$$
$$\frac{v_2}{100}-\frac{100}{100}+\frac{v_2}{50}-\frac{v_1}{50}+\frac{v_2}{100}+1-0.1-0.2=0$$

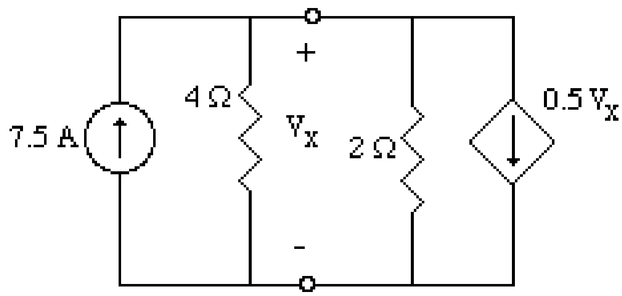
Solving these two equations yields:

v_1 = 25V and v_2 = 20V

***SOLUTION 5.37.** After a source transformation on the 30 V independent source and one on the 9Vx dependent source we obtain the circuit below.



Transforming the two dependent voltage sources and combining yields the following circuit.



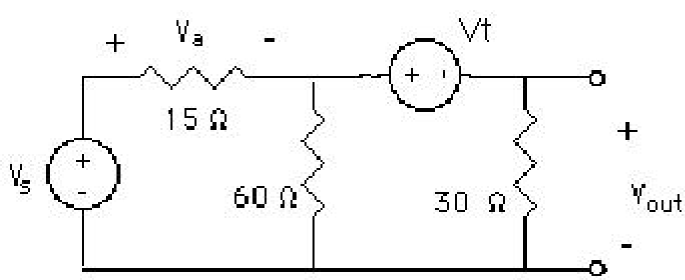
Writing a single node equation for Vx yields

$$7.5 = \frac{V_x}{4} + \frac{V_x}{2} + \frac{V_x}{2} = 1.25V_x$$

Hence, V_x = 6 V.

Solution 5.38

Replace the dependent source with a temporary independent source. When doing the analysis, always compute Va in order to keep track of the constraint on the dependent source.



When Vt is not active, v_{out} is obtained from a voltage divider between the 60||30 combination and the 15 ohm resistor:

$v_{out1} = 4/7V_s$

Similarly $v_{a1} = 3/7V_s$

Now, compute the response due to the temporary source.

Straightforward voltage division also applies here to get:

v_{a2} = -2/7Vt

and v_{out2} = -5/7Vt

So, v_{out} = 4/7V_s – 5/7Vt

va = 3/7V_s – 2/7Vt, where Vt = μv_a ➔ v_a = 3/7V_s – 2μ/7v_a

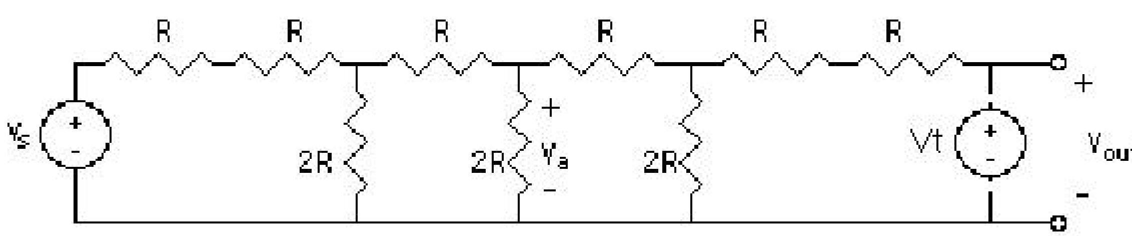
Rearranging,

$$v_a = \frac{3}{7+2\mu}V_s$$

Then,

$$v_{out} = \frac{4}{7}V_s - \frac{5\mu}{7}v_a$$
$$v_{out} = \frac{4-\mu}{7+2\mu}V_s$$

Solution 5.39 Replace the dependent source by a temporary independent source:



When Vt is shorted, the result is a ladder network. The input resistance looking each of the vertical branches is R. Label these vertical branches V_1, V_a, V_2 from left to right. It follows that

V_1 = R/3RV_s

– V_{a_1} = R/2R × R/3RV_s = 1/6V_s

Also, V_{out_1} = 0

Now, short V_S and turn on Vt.

Again, the result is a ladder network (note the symmetry in the above figure). Thus, we can write by inspection:

$V_{a\_2} = 1/6Vt$

$V_{out\_2} = Vt$

Adding the contributions:

$V_{out} = 0 + Vt = Vt = \mu V_a$ where we have substituted the constraint on Vt

and $V_a = 1/6V_s + 1/6Vt = 1/6V_s + 1/6\ \mu V_a$

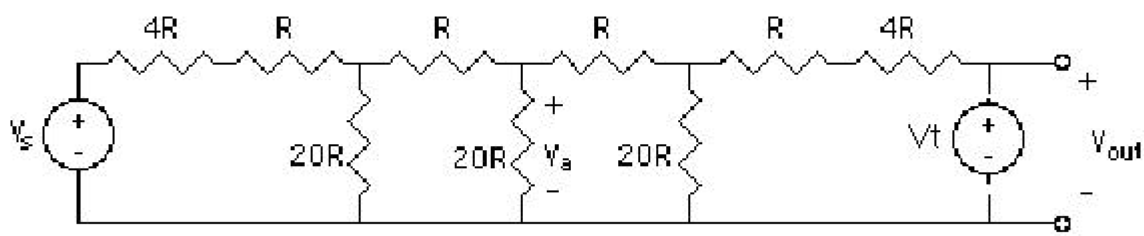
➔ $Va = [1/(6 - \mu)]V_s$

Substitute this Va into the expression for Vout:

$$V_{out} = \frac{\mu}{6-\mu} V_s$$

Solution 5.40

The first step is to replace the dependent source with a temporary independent source. Then, superposition can proceed as usual.



Now, let's short the temporary source, Vt. Again, this network is a ladder network, like the one in the previous problem. However, now, the equivalent resistance looking into each of the vertical branches (from left to right) is different. Now, it is

$R_{eq} = 20R||(R+4R) = 20R\times5R/25R = 4R$

Now, again, define the voltages across these three vertical branches (from left to right) as V_1, V_a, V_2. It follows by voltage division that

$$V_1 = 4/9V_s$$

➔ $$V_{a\_1} = 4/5 \times 4/9 \times V_s$$

➔ $$V_{a\_1} = 16/45\ V_s$$

It should be noted that $V_{out} = 0$.

Now, short the input source and find the response due to Vt. Again, in this case, the circuit is identical to the case when V_s was active (note the symmetry in the above figure). Therefore,

$$V_{a\_2} = 16/45\ Vt$$

$$V_{out\_2} = Vt$$

Adding the two contributions:

$$V_a = \frac{16}{45}V_s + \frac{16}{45}\mu V_a$$

$$? \quad V_a = \frac{1}{\left(\frac{45}{16} - \mu\right)}V_s$$

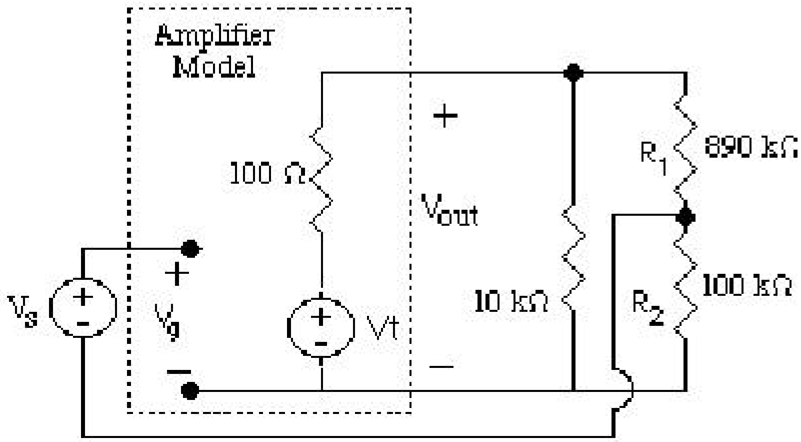
and

$$V_{out} = V_t = \mu V_a$$

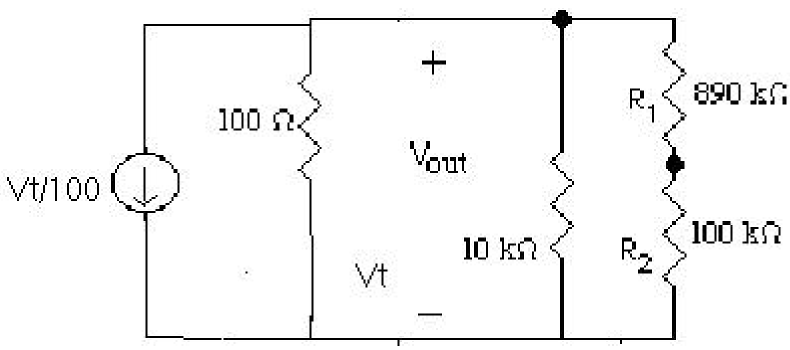
$$V_{out} = \frac{16\mu}{45 - 16\mu}V_s$$

Solution 5.41

First, replace the controlled source by a temporary independent source:



Now, do a source transformation on the Vt source:



The equivalent resistance seen by the current source is 99Ω. Therefore:

$$V_{out} = -99/100Vt = -0.99Vt$$

Now, $Vt = \mu V_g$ and $I_L = -0.99Vt/990k$ where I_L is the current through R_2

➔ $V_{R2} = I_L R_2 = (100k/990k)\times(-0.99Vt) = -0.1Vt$

By KVL

$$V_g = V_{R2} + V_s = -0.1Vt + V_s = -0.1\mu V_g + V_s$$

Rearranging

$$V_g = \frac{1}{0.1\mu + 1} V_s$$

Finally, and substituting:

$$\frac{V_{out}}{V_s} = -0.99\mu \frac{1}{1 + 0.1\mu}$$
$$\frac{V_{out}}{V_s} = -8.91$$

Solution 5.42

$$\frac{V_{out}}{V_{in}} = \frac{b_0 + b_1 x}{a_0 + a_1 x} = \frac{b_0 + b_1 R}{1 + a_1 R}$$

At R = 0

$$\frac{V_{out}}{V_{in}} = \frac{b_0}{1} = 20$$
$$? \quad b_0 = 20$$

At infinite R

$$\frac{V_{out}}{V_{in}} = \frac{b_1}{a_1} = 8$$
$$? \quad b_1 = 8a_1$$

Finally, at R = 10

$$\frac{20 + 80a_1}{1 + 10a_1} = 10$$
$$? \quad a_1 = 0.5$$
$$? \quad b_1 = 4$$

Substituting these values for R = 2 yields

$$\frac{V_{out}}{V_{in}} = \frac{20 + 4 \leftrightarrow 2}{1 + 0.5 \leftrightarrow 2} = 14$$

SOLUTION 5.43. From the chapter

$$\frac{V_{out}}{V_{in}} = \frac{b_0 + b_1\mu}{a_0 + a_1\mu} = \frac{b_0 + b_1\mu}{1 + a_1\mu}$$

Equivalently,

$$-\mu \frac{V_{out}}{V_{in}} a_1 + b_0 + \mu b_1 = \frac{V_{out}}{V_{in}}$$

Plugging in the data yields three equations in three unknowns which in matrix form are:

$$\begin{bmatrix} 0 & 1 & 0 \\ -154 & 1 & 1 \\ -168 & 1 & 2 \end{bmatrix} \begin{bmatrix} a_1 \\ b_0 \\ b_1 \end{bmatrix} = \begin{bmatrix} 264 \\ 154 \\ 84 \end{bmatrix}$$

```
»A=[0  1  0;-154  1   1;-168  1  2]
A =
     0     1     0
  -154     1     1
  -168     1     2

»y = [264  154  84]'
y =
   264
   154
    84
»Coefs = A\y
Coefs =
   2.8571e-01
   2.6400e+02
  -6.6000e+01
```

Therefore, a_1 = 0.28571, b_0 = 264, and b_1 = –66. Making a_1 = 1, will yield a different set of answers. When m = ∞, $V_{out}/V_{in} = b_1/a_1$ = –231.