ECE 35 Homework #4 (Spring 2023, Taur)

<u>All homework problems come from the textbook, "Introduction to Electric Circuits", by Svoboda & Dorf, 9th Edition.</u>

P 5.2-1 The circuit shown in Figure P 5.2-1*a* has been divided into two parts. The circuit shown in Figure P 5.2-1*b* was obtained by simplifying the part to the right of the terminals using source transformations. The part of the circuit to the left of the terminals was not changed.

(a) Determine the values of R_t and v_t in Figure P 5.2-1*b*.

(b) Determine the values of the current i and the voltage v in Figure P 5.2-1*b*. The circuit in Figure P 5.2-1*b* is equivalent to the circuit in Figure P 5.2-1*a*. Consequently, the current i and the voltage v in Figure P 5.2-1*a* have the same values as do the current i and the voltage v in Figure P 5.2-1*b*.

(c) Determine the value of the current i_a in Figure P 5.2-1*a*.

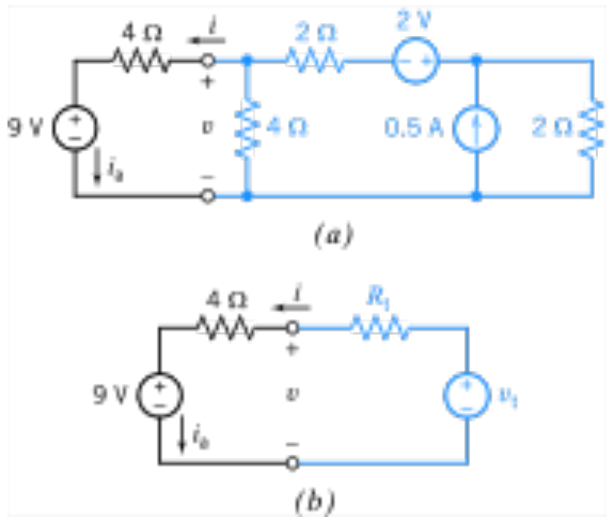
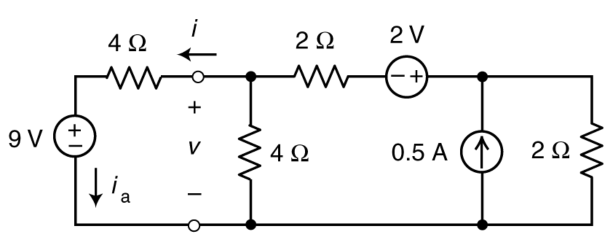
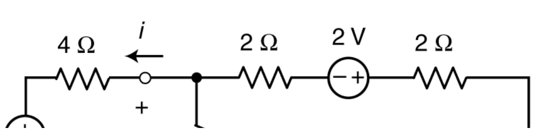


Figure P 5.2-1

Solution:

(a)





P 5.2-3 Find v_o using source transformations if i = 5/2 A in the circuit shown in Figure P 5.2-3.

Hint: Reduce the circuit to a single mesh that contains the voltage source labeled v_o.

Answer: v_o = 28 V

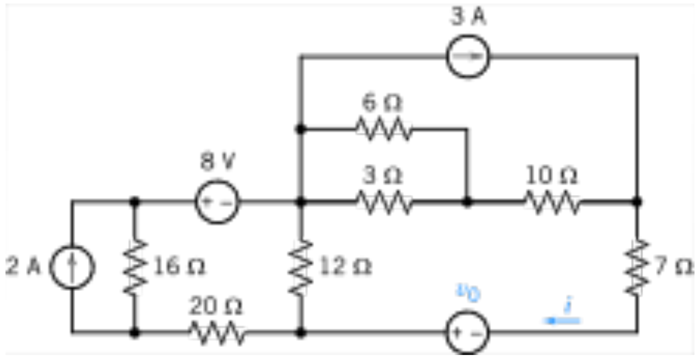
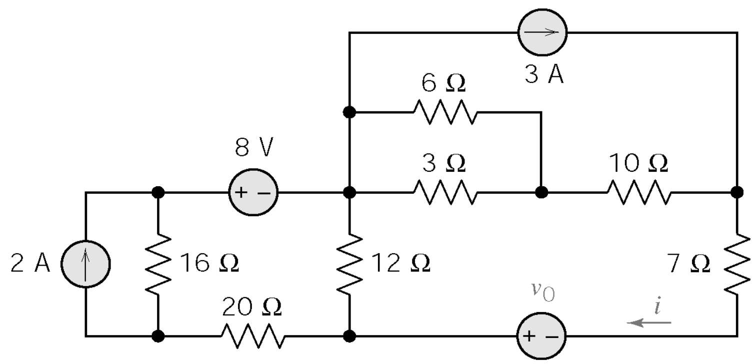
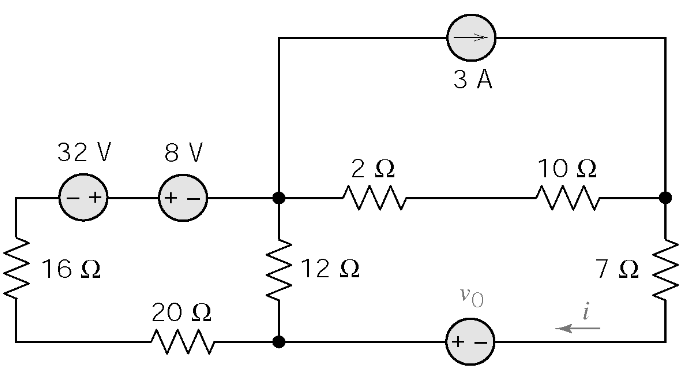


Figure P 5.2-3

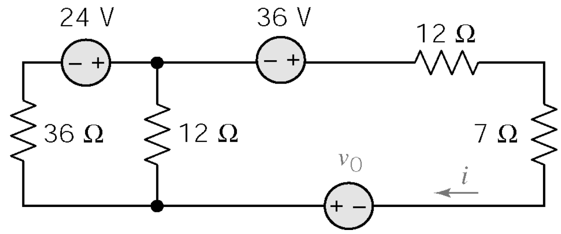
Solution:



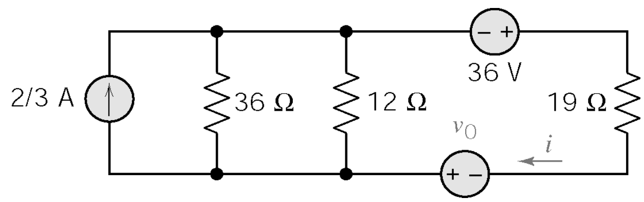
Source transformation at left; equivalent resistor for parallel 6 and 3 Ω resistors:



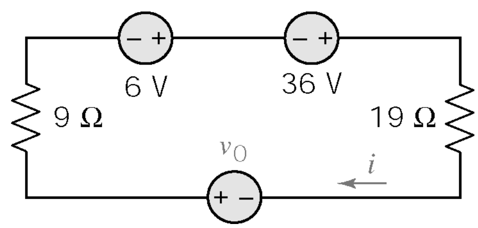
Equivalents for series resistors, series voltage source at left; series resistors, then source transformation at top:



Source transformation at left; series resistors at right:



Parallel resistors, then source transformation at left:



Finally, apply KVL to loop

$$-6 + i\ (9+19) - 36 - v_o = 0$$
$$i = 5/2\ \Rightarrow v_o = -42 + 28\ (5/2) = 28\text{ V}$$

P 5.2-6 Use source transformations to find the value of the voltage v_a in Figure P 5.2-6.

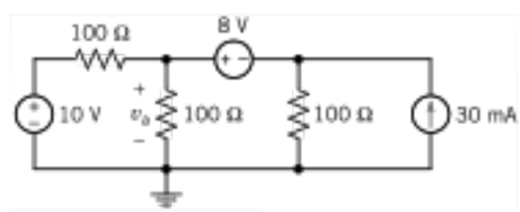
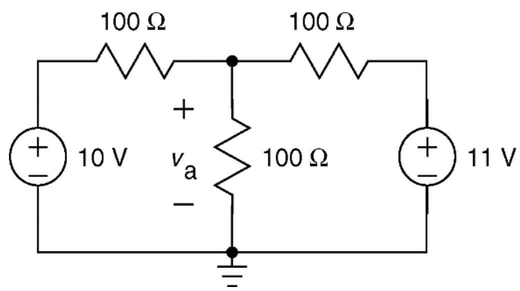
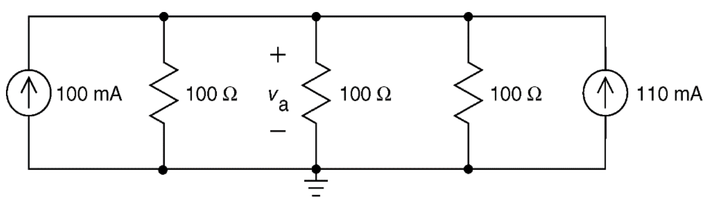


Figure P 5.2-6

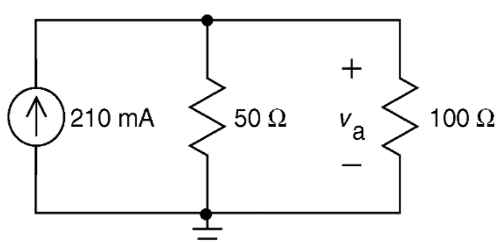
Solution:
A source transformation on the right side of the circuit, followed by replacing series resistors with an equivalent resistor:



Source transformations on both the right side and the left side of the circuit:



Replacing parallel resistors with an equivalent resistor and also replacing parallel current sources with an equivalent current source:



Finally,

$$v_a = \frac{50(100)}{50+100}(0.21) = \frac{100}{3}(0.21) = 7 \text{ V}$$

P 5.3-6 Use superposition to find the value of the current i in Figure P 5.3-6.

Answer: $i = 3.5$ mA

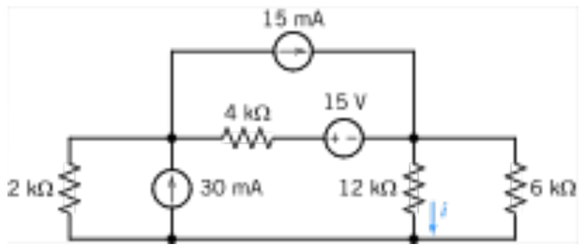
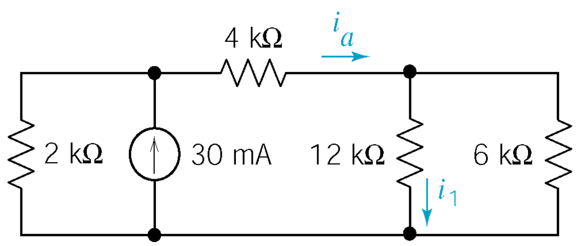
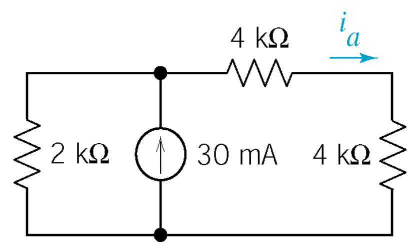


Figure P5.3-6

Solution:

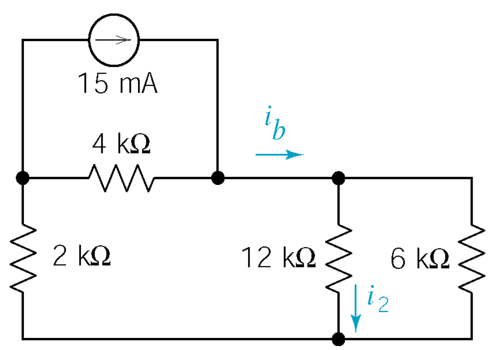
Consider 30 mA source only (open 15 mA and short 15 V sources). Let i_1 be the part of i due to the 30 mA current source.

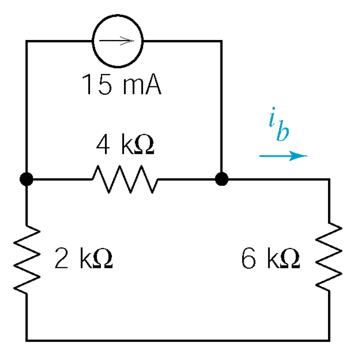




$$i_a = 30\left(\frac{2}{2+8}\right) = 6 \text{ mA} \Rightarrow i_1 = i_a\left(\frac{6}{6+12}\right) = \underline{2 \text{ mA}}$$

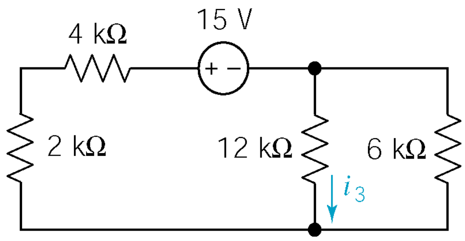
Consider 15 mA source only (open 30 mA source and short 15 V source) Let i_2 be the part of i due to the 15 mA current source.

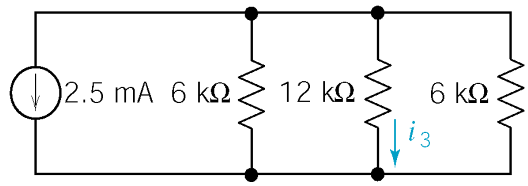




$$i_b = 15\left(\frac{4}{4+6}\right) = 6 \text{ mA} \Rightarrow i_2 = i_b\left(\frac{6}{6+12}\right) = \underline{2 \text{ mA}}$$

Consider 15 V source only (open both current sources). Let i_3 be the part of i due to the 15 V source.





$$i_3 = -2.5\left(\frac{6\,\|\,6}{(6\,\|\,6)+12}\right) = -10\left(\frac{3}{3+12}\right) = \underline{-0.5 \text{ mA}}$$

Finally, $\underline{i = i_1 + i_2 + i_3 = 2 + 2 - 0.5 = 3.5 \text{ mA}}$

P 5.3-9 The input to the circuit shown in Figure P 5.3-9 is the voltage source voltage, v_s. The output is the voltage v_o. The current source current, i_a, is used to adjust the relationship between the input and output. Design the circuit so that input and output are related by the equation, $v_o = 2v_s + 9$.

Hint: Determine the required values of A and i_a.

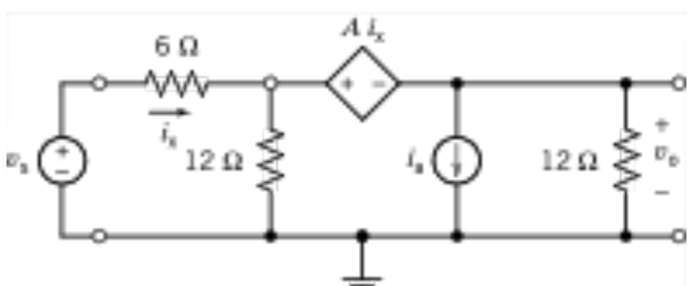
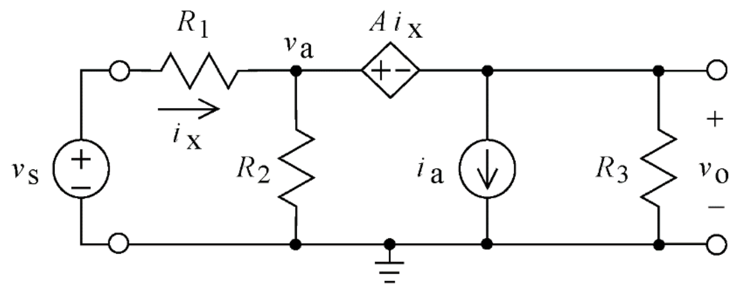


Figure P 5.3-9

Soluton:



$$i_x = \frac{v_s - v_a}{R_1}$$

$$v_a - v_o = A\,i_x = A\,\frac{v_s - v_a}{R_1}$$

$$v_a = \frac{R_1\,v_o + A\,v_s}{R_1 + A}$$

Apply KCL to the supernode corresponding to the CCVS to get

$$\frac{v_a - v_s}{R_1} + \frac{v_a}{R_2} + i_a + \frac{v_o}{R_3} = 0$$

$$\frac{R_1 + R_2}{R_1\,R_2}\,v_a - \frac{v_s}{R_1} + i_a + \frac{v_o}{R_3} = 0$$

$$\frac{R_1 + R_2}{R_1\,R_2}\left(\frac{R_1\,v_o + A\,v_s}{R_1 + A}\right) - \frac{v_s}{R_1} + i_a + \frac{v_o}{R_3} = 0$$

$$\left(\frac{R_1 + R_2}{R_2\left(R_1 + A\right)} + \frac{1}{R_3}\right)v_o + \left(\frac{\left(R_1 + R_2\right)A}{R_1\,R_2\left(R_1 + A\right)} - \frac{1}{R_1}\right)v_s + i_a = 0$$

$$\frac{R_3\left(R_1 + R_2\right) + R_2\left(R_1 + A\right)}{R_2\,R_3\left(R_1 + A\right)}\,v_o + \frac{A - R_2}{R_2\left(R_1 + A\right)}\,v_s + i_a = 0$$

$$v_o = \frac{R_3\left(R_2 - A\right)}{R_3\left(R_1 + R_2\right) + R_2\left(R_1 + A\right)}\,v_s - \frac{R_2\,R_3\left(R_1 + A\right)}{R_3\left(R_1 + R_2\right) + R_2\left(R_1 + A\right)}\,i_a$$

When $R_1 = 6\ \Omega$, $R_2 = 12\ \Omega$ and $R_3 = 12\ \Omega$

$$v_o = \frac{12 - A}{24 + A}\,v_s - \frac{12\,(6 + A)}{24 + A}\,i_a$$

Comparing this equation to $v_o = 2\,v_s + 9$, we requires

$$\frac{12-A}{24+A}=2 \quad \Leftrightarrow \quad A=-12\ \frac{\text{V}}{\text{A}}$$

Then $2v_s+9=v_o=2v_s+6i_a$ so we require

$$9=6i_a \quad \Rightarrow \quad i_a=1.5\text{ A}$$

P 5.3-13 The input to the circuit shown in P 5.3-13 is the current $\boldsymbol{i_1}$, the output is is the voltage $\boldsymbol{v_o}$. The current $\boldsymbol{i_2}$ is used to adjust the relationship between the input and output. Determine values of the current $\boldsymbol{i_2}$ and the resistance, $\boldsymbol{R}$, that cause the output to be related to the input by the equation: $v_o=-0.5\,i_1+4$

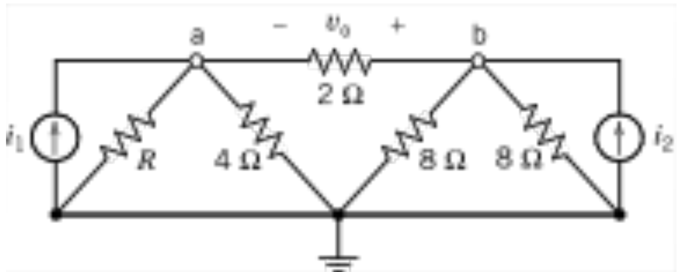


Figure P 5.3-13

Solution:

Using superposition

$$v_o=-2\left(\frac{R\,||\,4}{6+(R\,||\,4)}\right)i_1+2\left(\frac{4}{2+(R\,||\,4)+4}\right)i_2$$

Comparing to $v_o=-0.5\,i_1+4$, we require

$$-2\left(\frac{R\,||\,4}{6+(R\,||\,4)}\right)=-0.5 \quad \Rightarrow \quad 4(R\,||\,4)=6+(R\,||\,4) \quad \Rightarrow \quad R\,||\,4=2 \quad \Rightarrow \quad R=4\ \Omega$$

and

$$2\left(\frac{4}{2+(R\,||\,4)+4}\right)i_2=4 \quad \Rightarrow \quad 2\left(\frac{4}{2+(4\,||\,4)+4}\right)i_2=4 \quad \Rightarrow \quad i_2=4\text{ A}$$