Homework 2

Due date: Mar. 24th, 2020, Tuesday

Submit online before 23:59

Rules:

- Work on your own. Discussion is permissible, but extremely similar submissions will judged as plagiarism.
- Please show all intermediate steps: a correct solution without an explanation will get zero credit.
- Please submit on time.
- Please prepare your submission in English only. No Chinese submission will be accepted.

1. a) Use source transformations to find v_o in the circuit in Fig. 1.(10 points)
   b) Find the power delivered from the 520 V source.
   c) Find the power delivered from the 1 A current source.
   d) Verify that the total power delivered equals the total power dissipated.

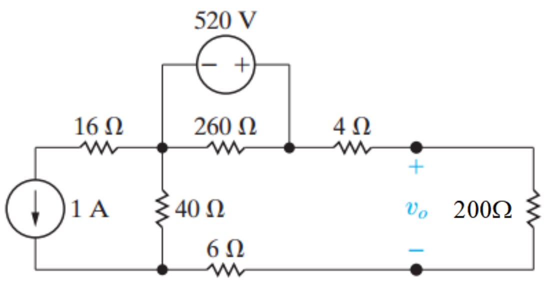

Figure 1.

(a)

When the current source is connected in series with a resistor, the resistor does not affect the circuit and it could be replaced with a short circuit. When the voltage source is connected in 1 parallel with a resistor, the resist out does not affect the circuit and it could be replaced with an open circuit. Apply those two notes on the given Figure and redraw the circuit. the resultant circuit is shown in Figure la.

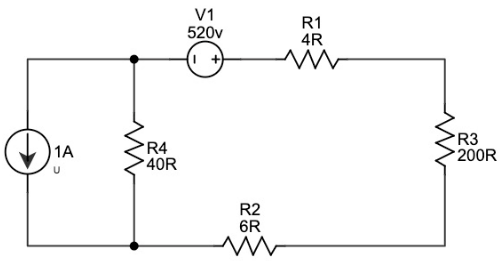

Figure 1a.

From Figure 1a, Apply source transformation to the 1 A current source and to the 40 Ω resistor, thus.

$$V = IR = 1 \times 40 = 40\text{V}$$ 1 point

The resultant circuit is shown in Figure 1b.

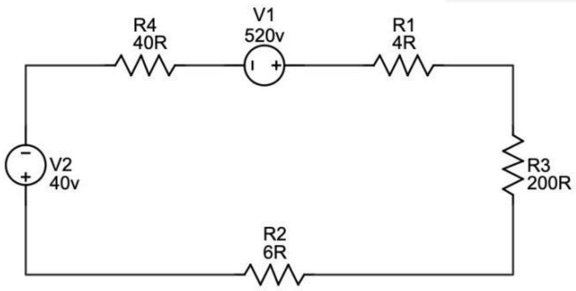

Figure 1b.

From Figure 1b, The $4\,\Omega, 40\,\Omega, 6\,\Omega$ resistors are connected in series, thus

$$R = 40 + 4 + 6 = 50\Omega$$ 1 point

The result voltage source is given by,

$$V = 520 - 40 = 480\text{V}$$ 1 point

The result circuit is shown in Figure 1c.

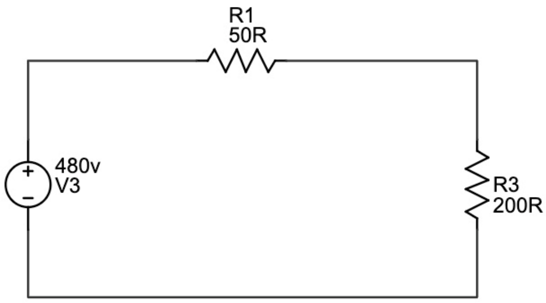

Figure 1c.

From Figure 1c, The v_o could be calculated by voltage divider

$$v_o = 480 \times \frac{200}{50 + 200} = 384\text{V}$$

$$I_o = \frac{384}{200} = 1.92\text{A}$$

2 points

(b)

From Figure 1a, and from the results obtained in part(a), the power developed by the 520V voltage source is,

$$I_{260\Omega} = \frac{520}{260} = 2\text{A}$$
$$I_{520\text{V}} = I_{260\Omega} + I_o = 3.92\text{A}$$
$$P_{520\text{V}} = -I_{520\text{V}} \times 520 = -2038.4\text{W}$$

1 point

The voltage source developed power is,

$$P_{520\text{V}\ developed} = 2038.4\text{W}$$

1 point

(c)

From Figure 1a, the power developed by current source is equivalent to the power developed by the 40V voltage source,

$$I_{40\Omega} = 1 + I_o = 2.92\text{A}$$
$$V_{40\Omega} = 2.92 \times 40 = 116.8\text{V}$$
$$V_{1\text{A}} = 16 + V_{40\Omega} = 132.8\text{V}$$
$$P_{1\text{A}} = -132.8 \times 1 = -132.8\text{W}$$

1 point

The current source developed power is,

$$P_{1\text{A}\ developed} = 132.8\text{W}$$

(d)

$$P_{16\Omega} = (1A)^2 \bullet 16 = 16\text{W}$$
$$P_{40\Omega} = (2.92)^2 \bullet 40 = 341.056\text{W}$$
$$P_{260\Omega} = (2)^2 \bullet 260 = 1040\text{W}$$
$$R_o = 200 + 6 + 4 = 210\Omega$$
$$P_{R0} = (1.92)^2 \times 210 = 774.144\text{W}$$
$$\sum P_R = 2171.2\text{W}$$
$$P_{deliver} = P_{520V} + P_{1\text{A}} = -2171.2\text{W}$$
$$P_R + P_{deliver} = 0\text{W}$$

3 points

2. Find the Norton equivalent with respect to the terminals *a*,*b* for the circuit seen in Fig. 2.(10 points)

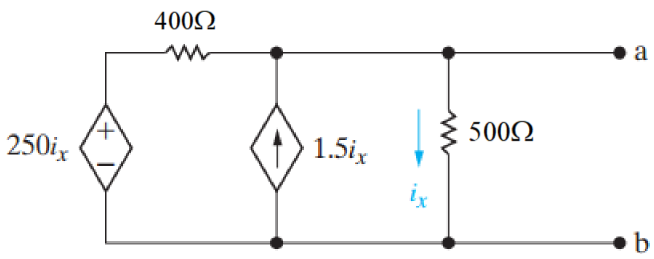

Figure 2.

Because there are no independent sources in the circuit

$$i_N = 0$$

To calculate R_N we write no de-voltage equation, and place an independent 1A current source between nodes a and b with the current going from node b to node a.

$$\frac{v - 250ix}{400} - 1.5ix + \frac{v}{500} - 1 = 0$$ 2 points

$$ix = \frac{v}{500}$$ 2 points

Now we can calculate

$$V = 4000\text{V}$$
$$ix = 8\text{A}$$ 3 points

Now we can calculate R_N

$$R_N = \frac{4000}{1} = 4000\Omega$$ 3 points

3. Use the principle of superposition to find v_o in the circuit in Fig. 3.(10 points)

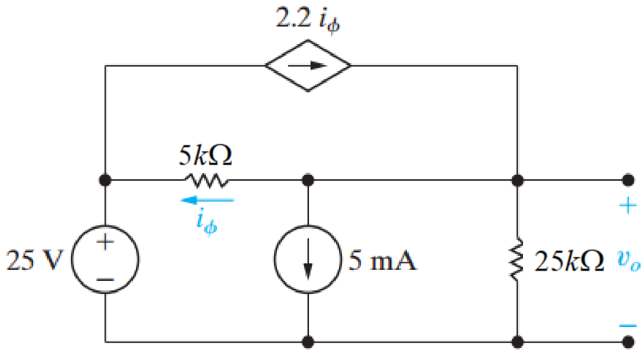

Figure 3.

Deactivate the 25V voltage source by placing a short circuit. Let v_o' be the node between the $5k\Omega$ and $25k\Omega$ resistors.

Solve for v_o' using no de-voltage method,

$$\frac{v_o'}{5000} + 0.005 + \frac{v_o'}{25000} - 2.2i_\phi = 0$$ 2 points

$$i_\phi = \frac{v_o'}{5000}$$ 1 point

$$v_o' = 25\text{V}...(1)$$ 1 point

Deactivate the 5mA current source by placing an open circuit. Let v_o" be the node between the $5k\Omega$ and $25k\Omega$ resistors.

Solve for v_o" using no de-voltage method,

$$\frac{v_o'' - 25}{5000} + \frac{v_o''}{25000} - 2.2i_\phi = 0$$ 2 points

$$i_\phi = \frac{v_o'' - 25}{5000}$$ 1 point

$$v_o'' = 30\text{V}...(2)$$ 1 point

Calculate the value of v_o by equation (1) and (2),

$$v_o = v_o' + v_o'' = 55\text{V}$$ 2 points

4. (a) For the circuit in Fig. 4 , obtain the Thevenin equivalent at terminals *a-b* (excluding RL).(10 points)
   (b) Calculate the current in $R_L = 8\,\Omega$.
   (c) Find R_L for maximum power deliverable to R_L
   (d) Determine that maximum power.

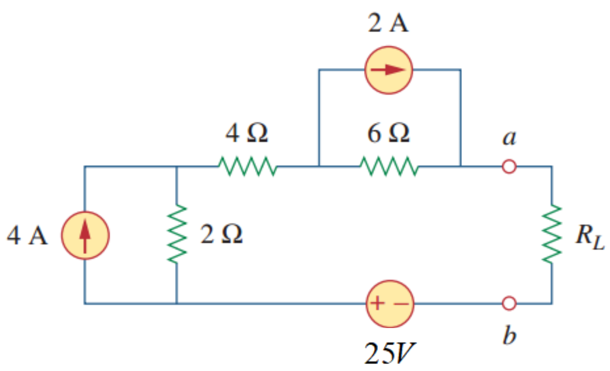

Figure 4.

(*a*)

$R_{TH} = 2+4+6 = 12\Omega$ 2 points

$V_{TH} = 12+8+25 = 45\text{V}$ 2 points

(*b*)

$i = \dfrac{V_{TH}}{R_{TH}+R_L} = 2.25\text{A}$ 2 points

(*c*)

$R_L = R_{TH} = 12\Omega$ 2 points

(*d*)

$P_{\max} = \dfrac{V^2_{TH}}{4R_{TH}} = 42.19\text{W}$ 2 points

5. For the op amp circuit of Fig. 5, the op amp has an open-loop gain of 100,000, an input resistance of $15\,k\Omega$, and an output resistance of $100\,\Omega$. Find the voltage gain v_o/v_i using the nonideal model of the op amp.(10 points)

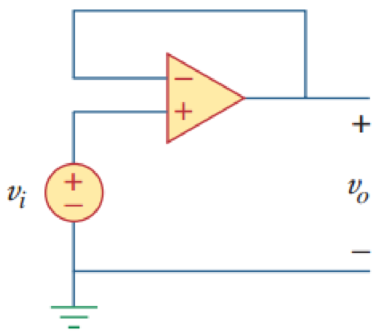

Figure 5.

$$\frac{v^{+}-v^{-}}{R_i}=\frac{v_0-A(v^{+}-v^{-})}{R_0}$$ 2 points

$v^{+}=v_i \quad v^{-}=v_0$ 2 points

$R_0(v_i-v_0)=R_iv_0-AR_i(v_i-v_o)$ 6 points

$$\frac{v_0}{v_i}=\frac{R_0+AR_i}{R_i+R_0+AR_i}\approx 1$$ 3 points

6. Obtain v_o for each of the op amp circuits in Fig. 6(10 points)

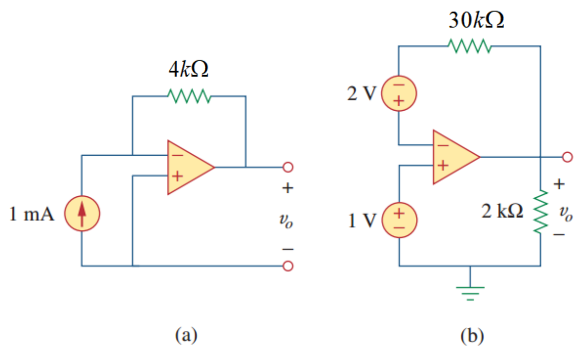

Figure 6.

(a)

$$V^- = V^+ = 0$$ 2 points

At node V⁻, applying KCL gives

$$1\text{ mA} = \frac{0 - v_0}{4000} \Rightarrow v_0 = -4\text{V}$$ 3 points

(b)

$$V^- = V^+ = 1\text{V}$$ 2 points

Applying KVL around the loop that contains the 2kΩ resistor.

$$\text{V}^- - 2 + 30K \times I + v_0 = 0 \Rightarrow v_0 = -1\text{V}$$ 3 points

7. Calculate the gain v_o/v_i when the switch in Fig. 7 is in:
   (a) position 1 (b) position 2 (c) position 3.(10 points)

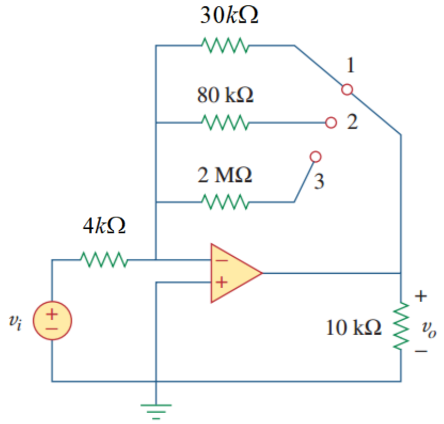

Figure 7.

Gain of the inverting amplifier using Op-Amp is

$$G=\frac{v_o}{v_i}=-\frac{Rf}{R1}$$ 2 points

$$R1=4k\Omega$$ 2 points

In the foil owing switch positions, gain is:

$$(a)Rf=30k\Omega, G=\text{-}30/4=\text{-}7.5$$ 2 points

$$(b)Rf=80k\Omega, G=\text{-}80/4=\text{-}20$$ 2 points

$$(c)Rf=2000k\Omega, G=\text{-}2000/4=\text{-}500$$ 2 points

8. In the circuit shown in Fig. 8, find i_x and the power absorbed by the 20 $k\Omega$ resistor.(10 points)

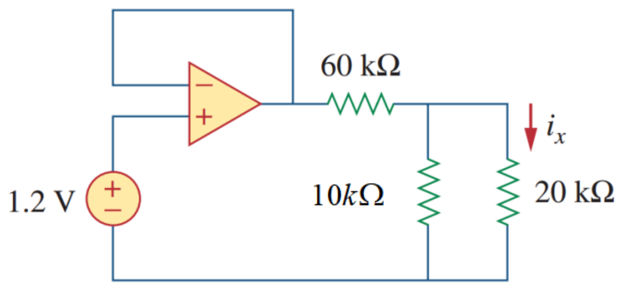

Figure 8.

$v^- = v^+ = 1.2\text{V}$ 2 points

$\dfrac{v_0 - 1.2}{60k} + \dfrac{v_0}{10k} + \dfrac{v_0}{20k} = 0$ 2 points

$\Rightarrow v_0 = 0.12\text{V}$ 2 points

$i_x = \dfrac{v_0}{20k} = 6\mu\text{A}$ 2 points

$P_{20k} = i^2{}_x \times 20k = 0.72\mu\text{W}$ 2 points

9. For the op amp circuit in Fig. 9, determine the value of v_2 in order to make v_o = -16.5 V.(10 points)

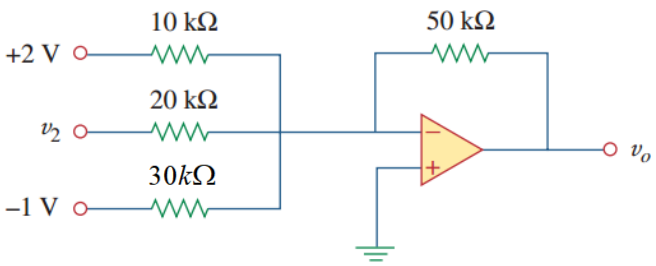

Figure 9.

$$v_o = -\left(\frac{50k}{10k}\times 2 + \frac{50k}{20k}\times v_2 + \frac{50k}{30k}\times(-1)\right) \Rightarrow v_2 = 3.27\text{V}$$

10. The circuit in Fig. 10 is for a difference amplifier. Find v_o given that $v_1 = 1$ V and $v_2 = 2$ V.(10 points)

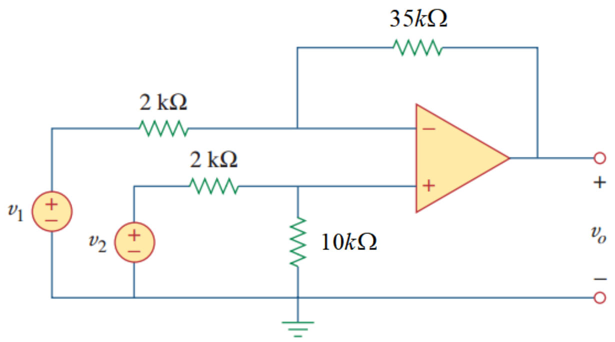

Figure 10.

$$\frac{v_1 - (\frac{v_2}{2+10} \times 10)}{2} = \frac{(\frac{v_2}{2+10} \times 10) - v_0}{35}$$

$$\Rightarrow v_0 = 13.33\text{V}$$