1)

2.3 For the circuit shown in Fig. P2.1, select node b as the reference node. (a) Use nodal analysis to find the node voltages. (b) Use the node voltages to determine i_1, i_2, i_3, and i_4.

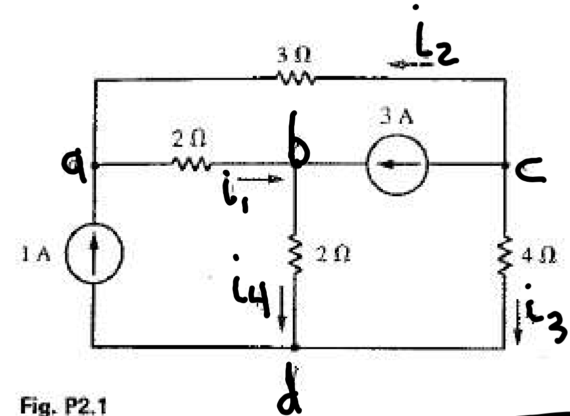


Fig. P2.1

a) KCL at:

(a) $1 + \dot{i}_2 = \dot{i}_1$

(c) $\dot{i}_2 + 3 + \dot{i}_3 = 0$

(d) $\dot{i}_4 + \dot{i}_3 = 1$

Using Ohm's law:

$$\dot{i}_1 = \frac{v_a - v_b}{2} \qquad \dot{i}_3 = \frac{v_c - v_d}{4}$$

$$\dot{i}_2 = \frac{v_c - v_a}{3} \qquad \dot{i}_4 = \frac{v_b - v_d}{2}$$

Remember $v_b = 0\,V$.

(a) $1 + \dfrac{v_c - v_a}{3} = \dfrac{v_a}{2}$

$$6 + 2v_c = 5v_a$$

(c) $\dfrac{v_c - v_a}{3} + 3 + \dfrac{v_c - v_d}{4} = 0$

$$4v_c - 4v_a + 36 + 3v_c - 3v_d = 0$$

$$7v_c - 4v_a - 3v_d = -36$$

(d) $-\dfrac{v_d}{2} + \dfrac{v_c - v_d}{4} = 1$

$$-2v_d + v_c - v_d = 4$$

$$v_c - 3v_d = 4$$

$$\begin{bmatrix} 5 & -2 & 0 \\ 4 & -7 & 3 \\ 0 & 1 & -3 \end{bmatrix} \begin{bmatrix} v_a \\ v_c \\ v_d \end{bmatrix} = \begin{bmatrix} 6 \\ 36 \\ 4 \end{bmatrix}$$

$$\begin{bmatrix} v_a \\ v_c \\ v_d \end{bmatrix} = \begin{bmatrix} 5 & -2 & 0 \\ 4 & -7 & 3 \\ 0 & 1 & -3 \end{bmatrix}^{-1} \begin{bmatrix} 6 \\ 36 \\ 4 \end{bmatrix} = \begin{bmatrix} -2 \\ -8 \\ -4 \end{bmatrix}$$

$v_a = -2\,V$, $v_c = -8\,V$, $v_d = -4\,V$

b) Using the equations above:

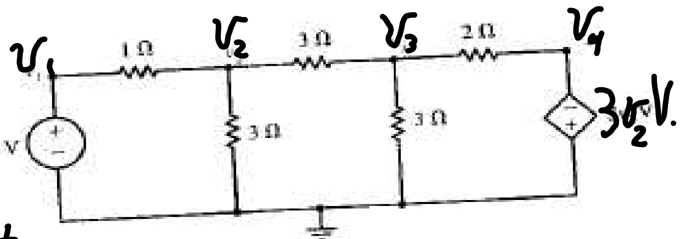
$$i_1 = \frac{v_a - v_b}{2} = \frac{-2-0}{2} = -1A$$

$$i_2 = \frac{v_c - v_a}{3} = \frac{-8 - -2}{3} = \frac{-6}{3} = -2A$$

$$i_3 = \frac{v_c - v_d}{4} = \frac{-8 - -4}{4} = \frac{-4}{4} = -1A$$

$$i_4 = \frac{v_b - v_d}{2} = \frac{0 - -4}{2} = \frac{4}{2} = 2A$$

2) **2.7** Find the node voltages for the circuit shown in Fig. P2.7. (See p. 100.)



Using nodal analysis, but skipping the current labels we can write 4 eqns with 4 unknowns.

$v_1 = 6V$ (due to source) (1)

KVL@ v_2: $\frac{v_2 - v_1}{1\Omega} + \frac{v_2}{3} + \frac{v_2 - v_3}{3\Omega} = 0 \Rightarrow -18 + 5v_2 - v_3 = 0$

$\Rightarrow 18 = 5v_2 - v_3$ (2)

KVL@ v_3: $\frac{v_3 - v_2}{3} + \frac{v_3}{3} + \frac{v_3 - v_4}{2} = 0 \Rightarrow 7v_3 - 2v_2 - 3v_4 = 0$ (3)

Eqn using dep. source: $v_4 = -3v_2$ (4)

(4) → (3) yields

$7v_3 + 7v_2 = 0$

$v_3 + v_2 = 0$ (5)

$v_2 = -v_3$ into (2) $5v_2 + v_2 = 18 \Rightarrow 6v_2 = 18$

$v_2 = 3V$

$v_3 = -3V$

$v_4 = -3v_2 = -9V$

$v_1 = 6V$

3)

3. (20 points) In FoEE, Fig. P1.39: Assume R1=4Ω and R2=4Ω.

a) Calculate the current i, using mesh analysis.

b) Find the Thevenin equivalent circuit as seen from the two terminals that are connected by the 4 Ω "bridge" resistor (the one that "i" is traveling through). Label the left node as "a" and the right node as "b." Be sure to actually draw your Thevenin equivalent circuit.

c) Find the Norton equivalent circuit from the same two terminals as in part (b). Again, be sure to draw your Norton equivalent circuit.

d) Using your result from (b) or (c), calculate the current i through a 4 Ω load resistor.

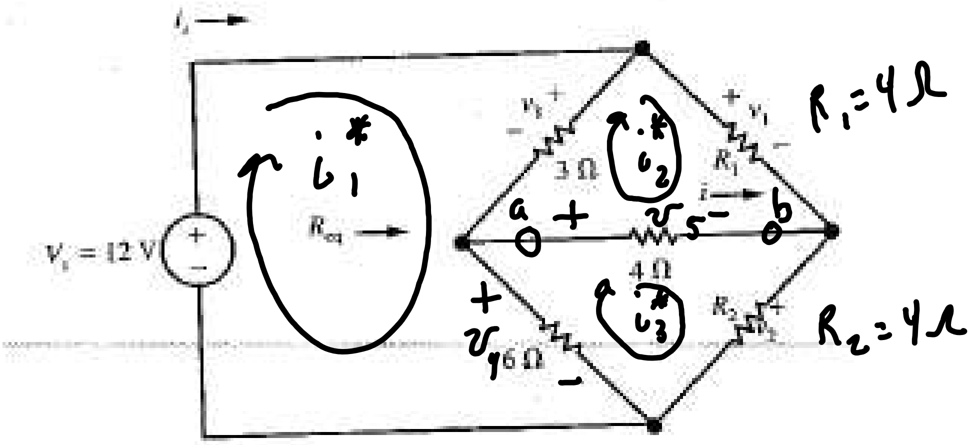


Fig. P1.39

a) Mesh analysis:

$$\left.\begin{aligned} 12 &= v_3 + v_4 \\ v_3 + v_5 &= v_1 \\ v_4 &= v_5 + v_2 \end{aligned}\right\} \text{our 3 KVL eqns.}$$

$$\left.\begin{aligned} v_1 &= i_2^* 4 \\ v_2 &= i_3^* 4 \\ v_3 &= (i_1^* - i_2^*)\,3\,\Omega \\ v_4 &= (i_1^* - i_3^*)\,6 \\ v_5 &= (i_3^* - i_2^*)\,4 \end{aligned}\right\} \text{our 5 Ohm's Law Eqns.}$$

Combining the above eqns we get:

$$12 = (i_1^* - i_2^*)3 + (i_1^* - i_3^*)6 \Rightarrow 12 = 9i_1^* - 3i_2^* - 6i_3^*$$

$$\boxed{\begin{aligned} &\Rightarrow 4 = 3i_1^* - i_2^* - 2i_3^* \\ (i_1^* - i_2^*)3 + (i_3^* - i_2^*)4 = i_2^* 4 &\Rightarrow 3i_1^* - 11i_2^* + 4i_3^* = 0 \\ (i_1^* - i_3^*)6 = (i_3^* - i_2^*)4 + i_3^* 4 &\Rightarrow 6i_1^* + 4i_2^* - 14i_3^* = 0 \end{aligned}}$$

Solving this system of equations gives us:

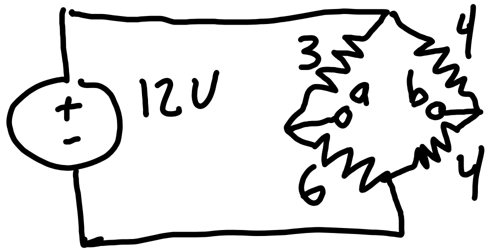
$i_1^* = 2.875$

$i_2^* = 1.375$

$i_3^* = 1.625$

$$i = i_3^* - i_2^* = .25\text{ A}$$

b)



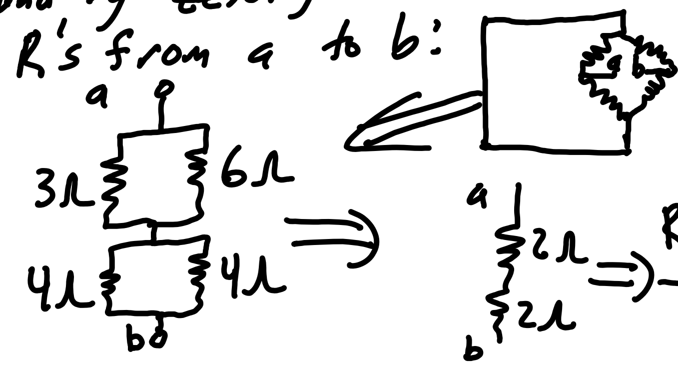
$v_{oc} = v_a - v_b$

v_a by voltage division is $\frac{6}{9} \cdot 12 = 8V$

v_b by voltage div is $6V$.

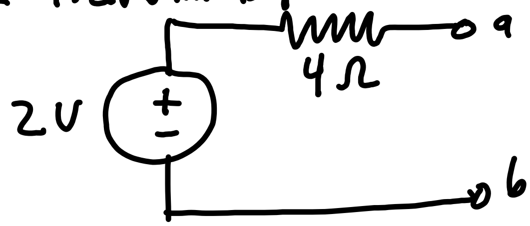
$\therefore \; v_{oc} = 2V$

Req can be found by zeroing our indep. source and combining R's from a to b:



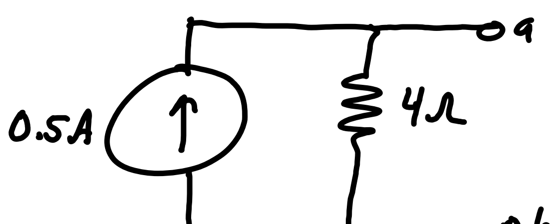
$\underline{R_{eq} = 4\Omega}$

So, the Thevenin Equivalent will be

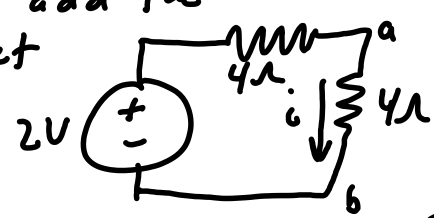


c) We can find $i_{sc} = \frac{v_{oc}}{R_{eq}} = \frac{2}{4} = 0.5A$

So, the Norton Equivalent is



d) Using the Thevenin Eq. from part (b) we can add the load resistance of 4Ω to get



$i = \frac{2V}{8\Omega} = 0.25A$

Same answer as in (a).

4) 2.41 For the circuit given in Fig. P2.41, determine the value of R_L, which absorbs the maximum amount of power, and find this power when $v_1 = 20$ V.

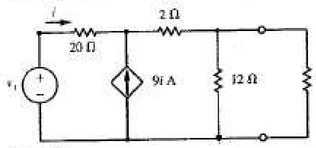
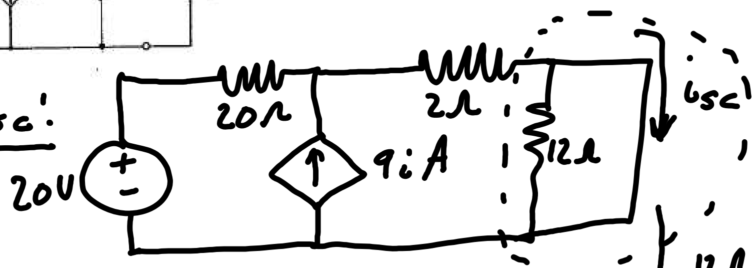


Fig. P2.41

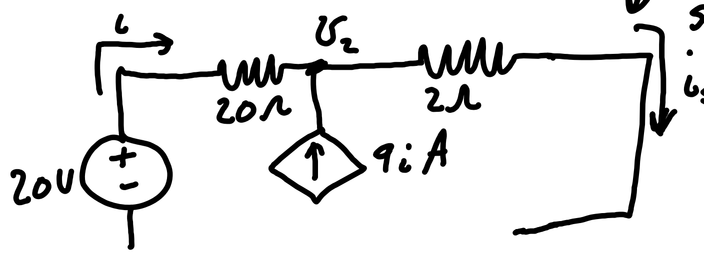
Find R_{eq} to determine R_L for max power.

We can find V_{oc} & i_{sc}:

For i_{sc}:



12Ω gets shorted out



Ohm's Law:

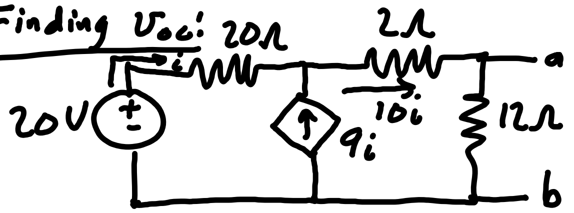
$$\frac{20 - v_2}{20} = i \quad \& \quad 10i = \frac{v_2}{2} \text{ by KCL}$$

Combine & solve: $10\left(\frac{20 - v_2}{20}\right) = \frac{v_2}{2}$

$$\frac{20 - v_2}{2} = \frac{v_2}{2} \Rightarrow v_2 = 10V$$

$$i_{sc} = \frac{10V}{2\Omega} = 5A$$

Finding V_{oc}:



KVL around outer loop:

$$20 = 20i + (10i)2 + (10i)12$$

$$i = \frac{1}{8}A$$

So $V_{ab} = V_{oc} = (10i)12 = 10\left(\frac{1}{8}\right)(12) = 15V$

$$\therefore R_{eq} = \frac{15V}{5A} = 3\Omega$$

$$\text{Max Power} = \frac{V_{oc}^2}{4R_L} = \frac{225}{(4)(3)} = 18.75 \text{ W.}$$

5)

2.61 Consider the circuit shown in Fig. P2.61. (a) Find the portion of i and the portion of v that are due to the 2-A current source. (b) Find the portion of i and the portion of v that are due to the 6-V voltage source. (c) Find the portion of i and the portion of v that are due to the 4-V voltage source. (d) Find i and v.

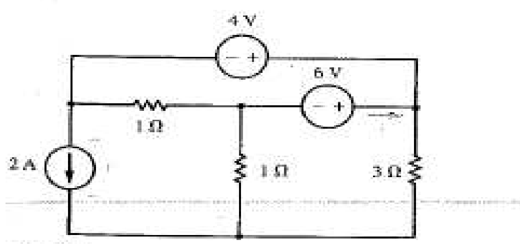
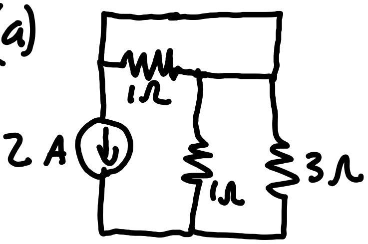


Fig. P2.61

Using Superposition/Linearity:

(a)



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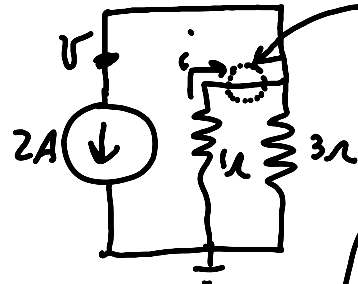


where source was

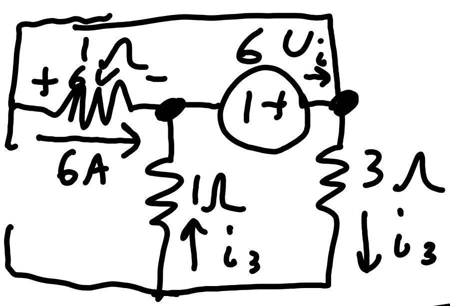
$\therefore i = \frac{3}{4} \cdot 2$

$i = 1.5A$

$v = (-1.5)\,1$

$v = -1.5\,V$

(b)

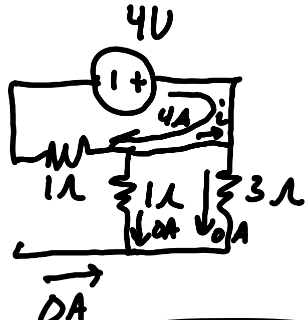


$\downarrow i_3 = \frac{6}{1+3} = 1.5\,A$

$i = 6 + i_3$
$= 7.5A$

$v = 3\,i_3 = 4.5V$

(c)



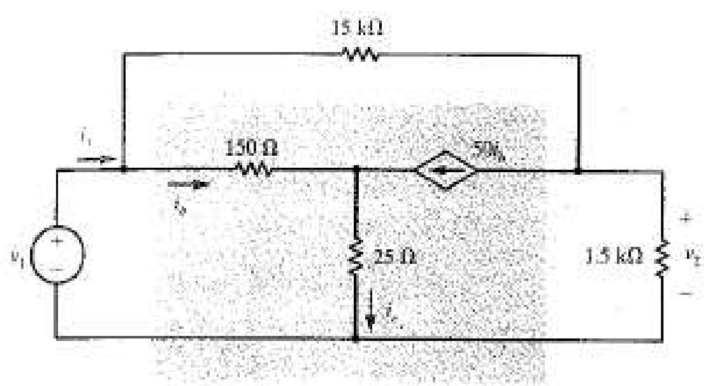
$\therefore i = -4A$

$v = -4V$

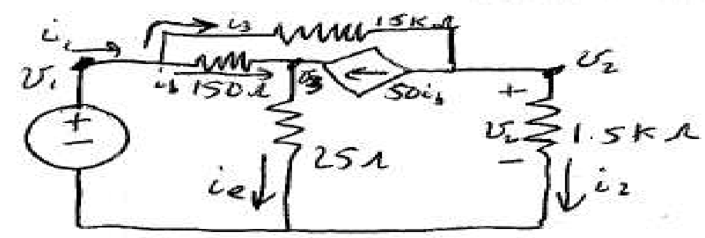
(d) Σ i from a, b, c = 5A
$v = -1V$

Optional Problems

6) **2.14** The circuit shown in Fig. P2.14 is a single BJT amplifier with "feedback." The portion of the circuit in the shaded box is an approximate T-model of a transistor in the common-emitter configuration. (a) Use nodal analysis to find the voltage gain v_2/v_1 of the amplifier. (b) Use the results of part (a) to determine the input resistance v_1/i_1 of the amplifier.



(3) For E 2.14



KCL @ v_1 node: $i_1 = i_b + i_3$ (1)

" @ v_3 node: $i_b + 50 i_b = i_e$ (2)

@ v_2 node: $i_3 = 50 i_b + i_2$ (3)

Make replacements where possible using Ohm's law:

(1) $$i_1 = \frac{v_1 - v_3}{150} + \frac{v_1 - v_2}{15{,}000}$$

(2) $$\frac{v_1 - v_3}{150} + 50\left(\frac{v_1 - v_3}{150}\right) = \frac{v_3}{25}$$

(3) $$\frac{v_1 - v_2}{15{,}000} = 50\left(\frac{v_1 - v_3}{150}\right) + \frac{v_2}{1500}$$

From (2): $$51\left(\frac{v_1 - v_3}{150}\right) = \frac{v_3}{25} \implies 51 v_1 - 51 v_3 = 6 v_3$$
$$\implies v_3 = \frac{51}{57} v_1$$

For (3): $$v_1 - v_2 = 5000(v_1 - v_3) + 10 v_2$$
$$v_1 - v_2 = 5000\left(\frac{6}{57} v_1\right) + 10 v_2$$
$$v_1 - \frac{30{,}000}{57} v_1 = 11 v_2$$
$$\boxed{\frac{v_2}{v_1} = \frac{-29943}{11 \times 57} = -47.76}$$

(b) From (1) above: $$i_1 = \frac{\left(v_1 - \frac{51}{57} v_1\right)}{150} + \frac{v_1 - -47.76 v_1}{15{,}000}$$

$$\frac{i_1}{v_1} = \frac{6/57}{150} + \frac{48.76}{15000} = .00395$$

$$\boxed{\text{So } \frac{v_1}{i_1} = 253.3\ \Omega}$$

7) **2.23** Assume clockwise mesh currents for the circuit shown in Fig. P2.10. Use mesh analysis to find these mesh currents.

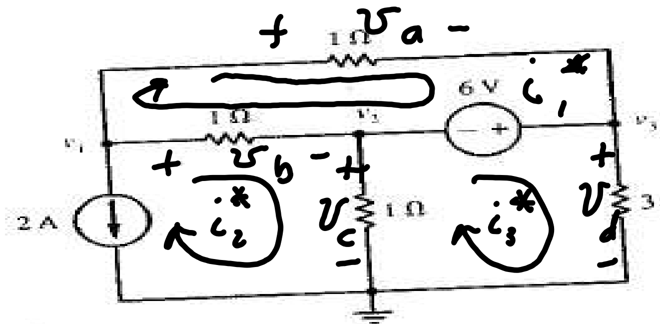


Fig. P2.10

Around i_1^*: $v_b - v_a - 6 = 0$

Around i_2^*: Not needed $i_2^* = -2A$

Around i_3^*: $v_c + 6 = v_d$

Using mesh currents: $v_a = i_1^*$

$v_b = i_2^*$

$v_c = (i_2^* - i_3^*)$

$v_d = i_3^* \cdot 3$

So, $i_2^* - i_1^* = 6$ & since

$-2 - i_1^* = 6$

$-i_1^* = 8$

$i_2^* = -2A$

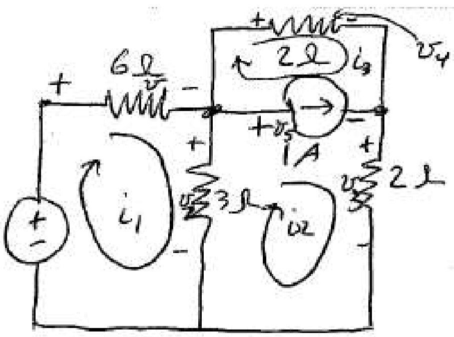
$i_1^* = -8A$

$i_3^* = 1A$

$(i_2^* - i_3^*) + 6 = 3 i_3^*$

$-2 - i_3^* + 6 = 3 i_3^* \Longrightarrow 4 i_3^* = 4$

8) FoEE 2.25



Loop 1: $30 = v_1 + v_2$ ①

" 2: $v_2 = v_5 + v_3$ ②

" 3: $v_5 = v_4$ ③

Ohm's law is used to get these equations in terms of i_1, i_2, i_3.

① becomes $30 = 6i_1 + 3(i_1 - i_2)$

② becomes $3(i_1 - i_2) = 2i_3 + 2i_2$

because $v_5 = v_4$ from ③

4^{th} equation we have is

$i_2 - i_3 = 1A \Longrightarrow i_3 = i_2 - 1$

So, ① is $30 = 9i_1 - 3i_2 \Longrightarrow 10 = 3i_1 - i_2$

② is $3i_1 - 3i_2 = 2(i_2 - 1) + 2i_2 \Longrightarrow -2 = 3i_1 - 7i_2$

So, $i_2 = 2A$
$i_1 = 4A$
$i_3 = 1A$