EIT Review

The following pages are the examples used in the DC Circuits review lecture presented at CSU Sacramento on behalf of the students and Tau Beta Pi honor society.

Questions and corrections should be addressed to
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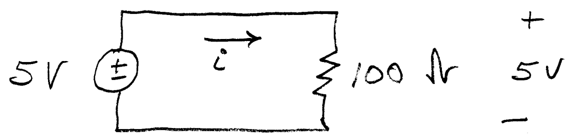
Example

Power delivered to a resistor



$$P_{100\Omega} = (+)\,v\,i = i^2 R = \frac{v^2}{R}$$

$$= \frac{(5V)^2}{100\Omega} = \frac{1}{4} \text{ watt Absorbed}$$

$$P_{5V\ source} = (-)\,v\,i$$

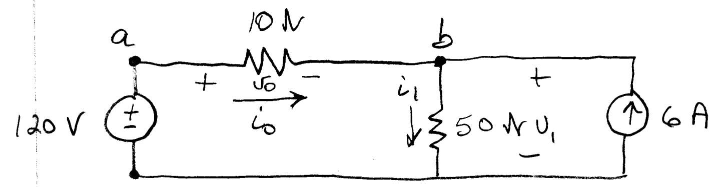
$$i = \frac{v}{R} = \frac{5V}{100\Omega} = \frac{1}{20}A = 0.05\ A$$

$$= 50\ mA$$

$$= (-)(5V)(50\ mA)$$

$$= -\,0.25 \text{ Watt delivered}$$

KCL/KVL Example   find i_o



at node b: KCL

in = − } just be
out = + } consistent!

$-i_o + i_1 - 6A = 0$

$i_1 = i_o + 6A$

Now use KVL around left loop

$-120V + v_o + v_1 = 0$ where $v_o = i_o(10\Omega)$

$v_1 = (i_o + 6A)(50\Omega)$

so

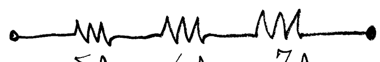
$v_o + v_1 = 120V$

$i_o(10\Omega) + (i_o + 6A)(50\Omega) = 120V$

$i_o(60\Omega) = 120V - 300V = -180V$

$i_o = -3A$ the (−) sign means current is in the opposite direction from that initially drawn.

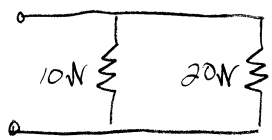
Series Resistance



$R_{eq} = 5 + 6 + 7$

$= \underline{18\,\Omega}$

Parallel Resistance



$$\frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{20} = \frac{2}{20} + \frac{1}{20}$$

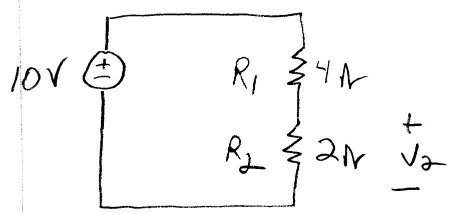
$$= \frac{3}{20}$$

$$R_{eq} = \frac{20}{3} = \underline{6.67\,\Omega}$$

or

$$R_{eq} = \frac{10 \cdot 20}{10 + 20} = \frac{200}{30} = \underline{6.67\,\Omega}$$

Voltage Divider



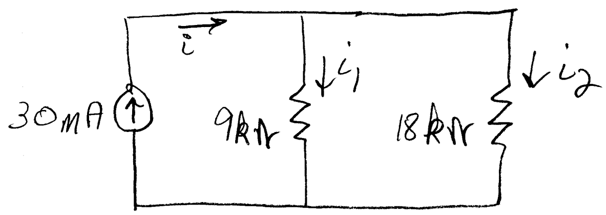
find v_2

$$v_2 = \frac{R_2}{R_1+R_2} v$$

$$= \frac{2\,\Omega}{4\,\Omega + 2\,\Omega} (10\,V)$$

$$= \frac{2}{6} (10\,V) = \underline{\underline{3.33\,V}}$$

Current Divider find i_2



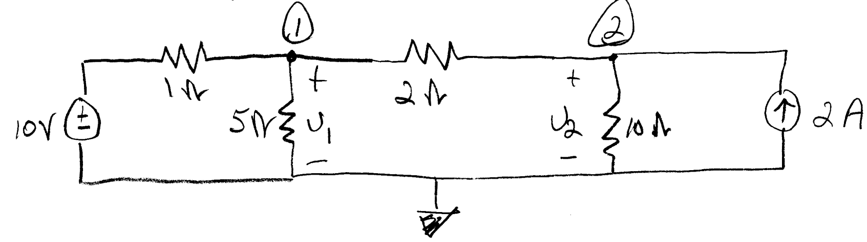
$$i_2 = \frac{R_1}{R_1 + R_2}\, i$$

$$= \frac{9\,k\Omega}{9\,k\Omega + 18\,k\Omega}\,(30\,mA)$$

$$= \frac{9}{27}\,(30\,mA) = \frac{1}{3}\,(30\,mA)$$

$$= \underline{10\,mA}$$

Node Analysis



① Pick reference node – I picked the bottom

② Define the non-reference nodes

③ write the equations $\quad \Sigma i = 0$

node ① $\quad \dfrac{v_1 - 10V}{1\,\Omega} + \dfrac{v_1}{5\,\Omega} + \dfrac{v_1 - v_2}{2\,\Omega} = 0$

node ② $\quad \dfrac{v_2 - v_1}{2\,\Omega} + \dfrac{v_2}{10\,\Omega} + (-)\,2A = 0$

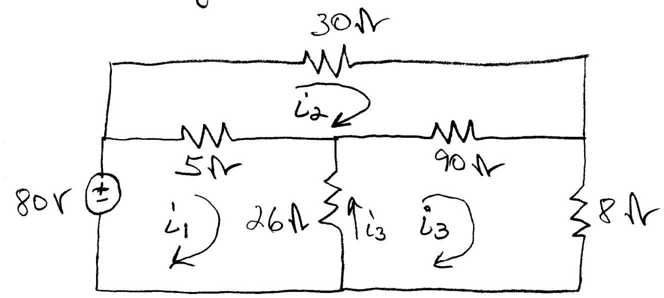
put in "standard form" for your calculator

node ① $\quad 10v_1 - 100V + 2v_1 + 5v_1 - 5v_2 = 0$

$$v_1(17) + v_2(-5) = 100\,V$$

node ② $\quad v_1(-5) + v_2(6) = 20\,A$

Mesh Analysis



① Assign mesh currents

② write KVL around the loop

mesh i_1

$$-80V + (i_1 - i_2)5\Omega + (i_1 - i_3)26\Omega = 0$$

$$i_1(31\Omega) + i_2(-5\Omega) + i_3(-26\Omega) = 80V$$

mesh i_2

$$i_2(30\Omega) + (i_2 - i_3)90\Omega + (i_2 - i_1)5\Omega = 0$$

$$i_1(-5\Omega) + i_2(125\Omega) + i_3(-90\Omega) = 0$$

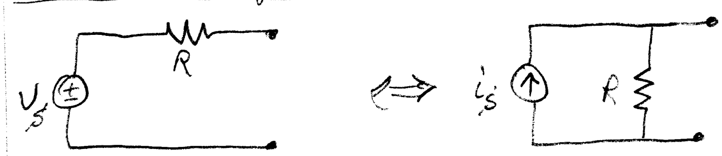
mesh i_3

$$(i_3 - i_2)90\Omega + i_3(8\Omega) + (i_3 - i_1)26\Omega = 0$$

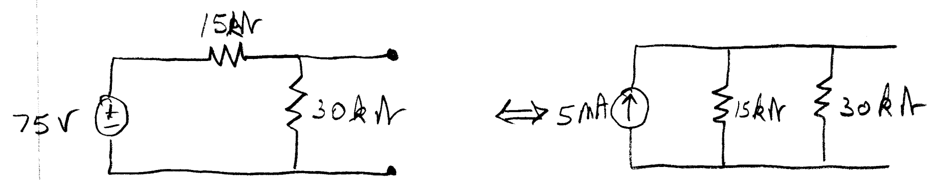
$$i_1(-26\Omega) + i_2(-90\Omega) + i_3(124\Omega) = 0$$

Plug into calculator $i_1 = 5A$

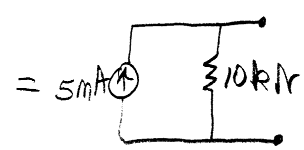
Source Transformations

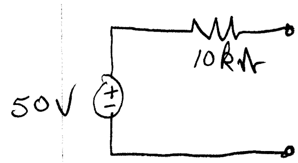


$$v_s = i_s R \quad \Leftrightarrow \quad i_s = \frac{v_s}{R}$$



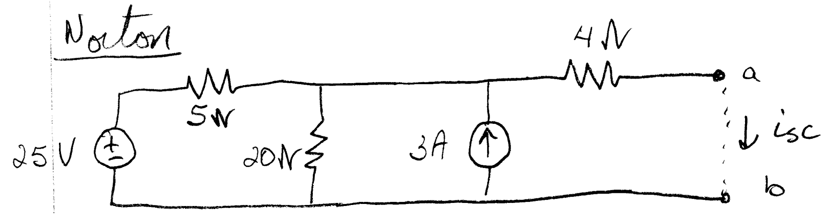
$$i_s = \frac{75\ V}{15 k\Omega} = 5\ mA$$



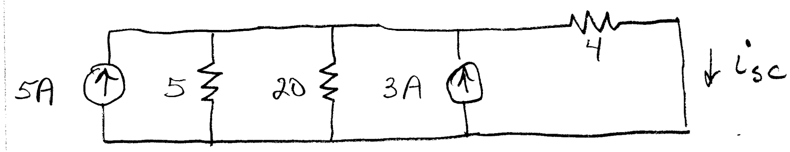


$$\Leftrightarrow \quad v_s = i_s R = (5 mA)(10 k\Omega) = 50 V$$

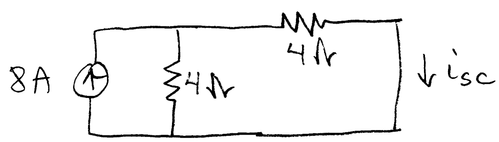
Norton



for I_n find i_{sc}



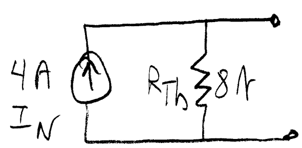
$5 // 20 = 4\,\Omega$



By logic $i_{sc} = 4\,A$ or by current divider

$$i_{sc} = \frac{4}{4+4}(8A) = \frac{1}{2}(8A) = 4A$$

we already found $R_{Th} = 8\,\Omega$

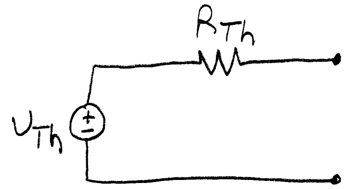


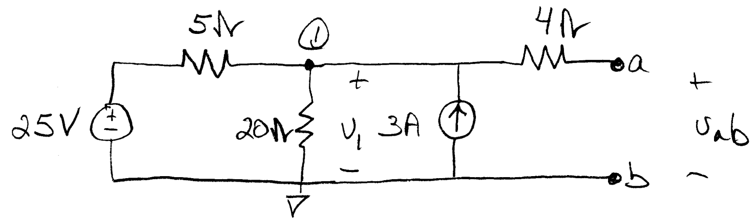
By confirmation

$$I_N = \frac{V_{Th}}{R_{Th}} = \frac{32\,V}{8\,\Omega}$$

$$= \underline{4\,A}$$

Thevenin - Focus on terminal behavior





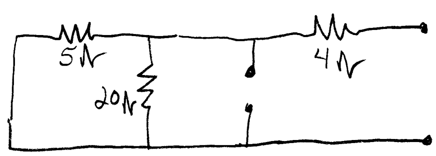
use node to find v_1 $\qquad v_1 = v_{Th}$!

$$\frac{v_1 - 25V}{5\Omega} + \frac{v_1}{20\Omega} - 3A = 0$$

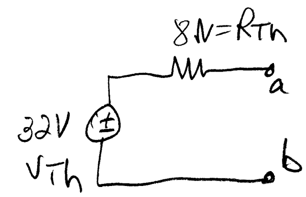
$$4v_1 - 100V + v_1 - 60V = 0$$

$$5v_1 = 160V \Rightarrow v_1 = \underline{\underline{32V}} = V_{Th} \text{ for } V_{ab} = \text{open circuit}$$

find R_{Th} → "kill the independent sources"

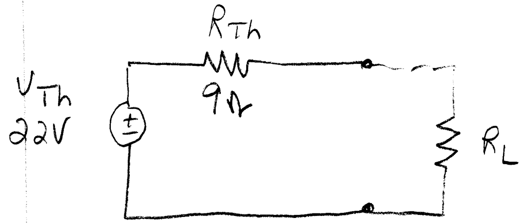


so



$$5 \| 20 + 4 = 4 + 4 = 8\Omega$$

Max Power

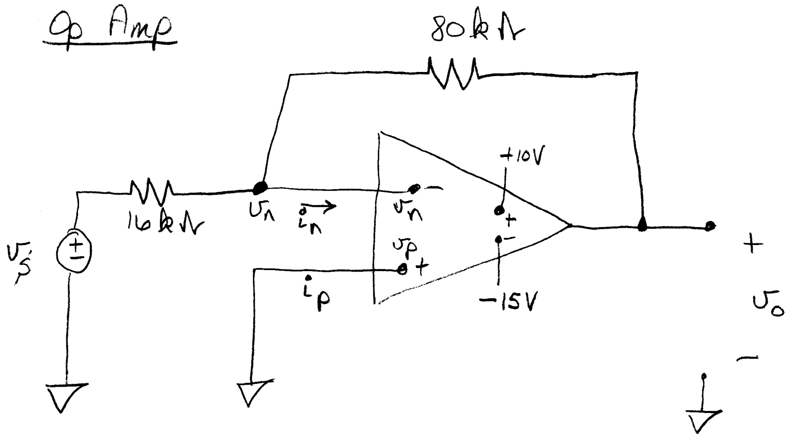


max power delivered when $R_L = R_{Th} = 9\,\Omega$

$$P_{max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{(22V)^2}{4(9\Omega)} = \frac{484}{36}\,W$$

$= 13.44$ Watts

Op Amp



By Ideal Op Amp $\quad i_n = i_p = 0$

$v_n = v_p \quad$ in this case $v_p = 0$

node eqn

$$\frac{v_n - v_s}{16k\Omega} + i_n + \frac{v_n - v_o}{80k\Omega} = 0 \qquad i_n = 0, \quad v_n = 0$$

$$\frac{-v_s}{16k\Omega} - \frac{v_o}{80k\Omega} = 0$$

$$v_o = (-)\frac{80k\Omega}{16k\Omega} v_s = \underline{\underline{(-5)\, v_s}}$$

Op Amp (2)

What is the range of v_s in the linear region?

$-V_{cc} \leq A(v_p - v_n) \leq +V_{cc}$ where $(-5)\,v_s = A(v_p - v_n)$

$-15V \leq (-5)\,v_s \leq 10V$ mult by $\frac{1}{-5}$

$+3V \geq v_s \geq +2V$

or

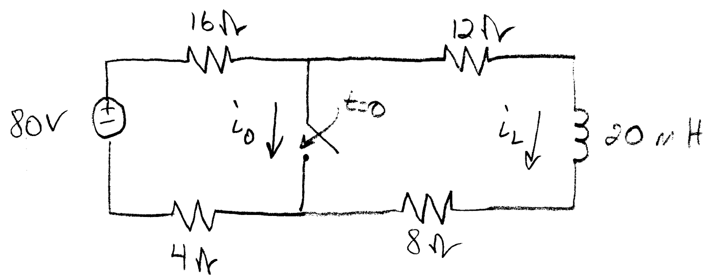
$-2V \leq v_s \leq 3V$

Saturation

if $v_s < -2$ the $v_o = +10V$

if $v_s > 3V$ then $v_o = -15V$

Inductor



at $t<0$ $\quad v_L = 0$ since $\frac{di}{dt} = 0$

$$i_L(0^-) = \frac{80V}{(16+12+4+8)\Omega} = \frac{80V}{40\Omega} = \underline{2A}$$

at $t \to \infty$ "short out" the voltage source

thus $i_L = 0$

at $t=0$

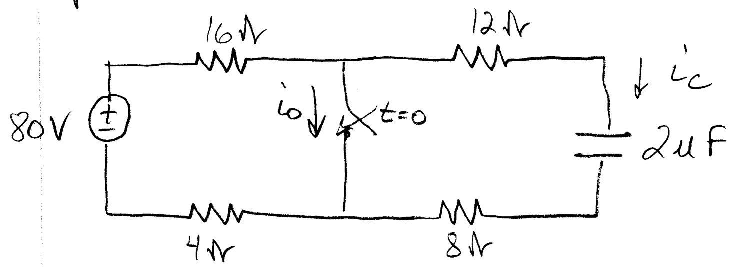
→ inductor cannot change abruptly

$$i_o(0^+) = \frac{80V}{16\Omega + 4\Omega} - 2A = \frac{80V}{20\Omega} - 2A = 4A - 2A = \underline{2A}$$

at $t \to \infty$

$$i_o(\infty) = \underline{4A}$$

Capacitor



at $t < 0$ $\quad v_c = 80V$

$i_c = 0A$

at $t \to \infty$ $\quad v_c = 0V$

$i_c = 0A$

at $t = 0$ $\quad$ left loop + right loop

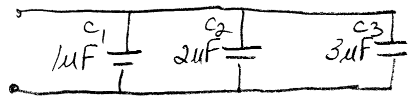
left $i_{left} = \dfrac{80V}{20\Omega} = 4A$

Right $i_{rt} = \dfrac{80V}{20\Omega} = 4A$

total $i_o(t=0^+) = 4A + 4A = \underline{8A}$

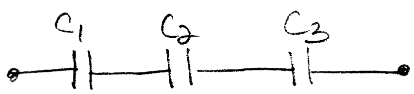
Capacitors

C.A.P.



$$C_{eq} = C_1 + C_2 + C_3$$

$$= 1 + 2 + 3 = \underline{6\mu F}$$



$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{1\mu F} + \frac{1}{2\mu F} + \frac{1}{3\mu F}$$

$$= \frac{6+3+2}{6\mu F} = \frac{11}{6\mu F}$$

$$C_{eq} = \frac{6}{11}\mu F = \underline{0.55\mu F}$$