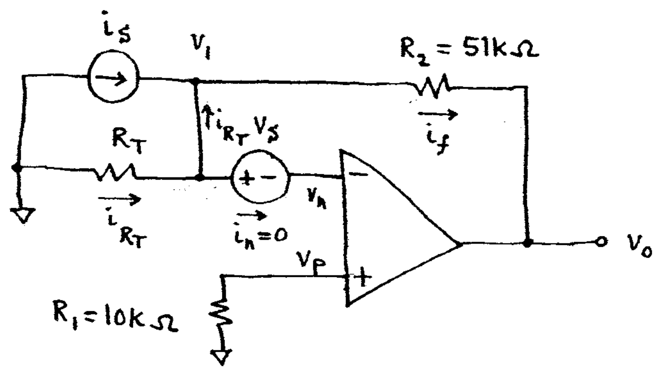
sol'n: 1.a)




• Find $v_p$: $v_p = 0V$ since no current in $R_1$ so no v-drop for $R_1$

$v_n = v_p = 0V$

• Find $i_f$ on left side (total current into $v_1$ node from $i_s$ and $R_T$)

$v_1 = v_n + v_s = v_s$, and no current flows thru $v_s$ since no current flows into op-amp.

$\therefore$ $i_f$ on left side $= i_s + i_{R_T} = i_s + \dfrac{0-v_1}{R_T} = i_s + \dfrac{-v_s}{R_T}$

• Find $i_f$ on right side

$i_f$ on right side $= \dfrac{v_1 - v_o}{R_2} = \dfrac{v_s - v_o}{R_2}$

• Set $i_f$ on left side $= i_f$ on right side

$$i_s - \frac{v_s}{R_T} = \frac{v_s - v_o}{R_2} \quad \text{or} \quad \boxed{v_o = v_s\left(1+\frac{R_2}{R_T}\right) - i_s R_2}$$

verify: Superposition $v_s = 0 \Rightarrow i_{R_T} = 0 \Rightarrow v_o = 0V - i_s R_2$ ✓

$i_s = 0$ $i_{R_T} = \dfrac{-v_s}{R_T} = i_f = \dfrac{v_s - v_o}{R_2}$

Same as having $v_p = v_s$ $v_o = v_s\left(1+\dfrac{R_2}{R_T}\right)$ ✓

HW #10

ECE 1000 Su 05

sol'n: 1. b) $R_T(273°K) = 7250\, e^{100°K\left(\frac{1}{273°K} - \frac{1}{300°K}\right)}\,\Omega \doteq \boxed{7.5\,k\Omega = R_T(273°)}$

$R_T(373°K) = 7250\, e^{100°K\left(\frac{1}{373°K} - \frac{1}{300°K}\right)}\,\Omega \doteq \boxed{6.8\,k\Omega = R_T(373°)}$

c) $1V = v_o(373°K) - v_o(273°K) = v_s\left(\cancel{1} + \frac{R_2}{R_T(373°)}\right) - v_s\left(\cancel{1} + \frac{R_2}{R_T(273°)}\right)$

Note: $i_s R_2$ terms cancel

$$v_s = \frac{1V}{R_2} \frac{R_T(273°) \cdot R_T(373°)}{R_T(273°) - R_T(373°)} = \frac{1V}{51k\Omega} \frac{7.5k\Omega \cdot 6.8k\Omega}{7.5k\Omega - 6.8k\Omega}$$

$$v_s = \frac{1V}{\cancel{51k\Omega}} \frac{\cancel{51k} \cdot \cancel{k\Omega^2}}{0.7\cancel{k\Omega}} = \frac{1V}{0.7} = 1.43\,V \qquad \boxed{v_s = 1.43V}$$

d) $v_o(273°K) = v_s\left(1 + \frac{R_2}{R_T(273°)}\right) - i_s R_2 = 0V$

$$i_s = \frac{1V}{0.7}\left(1 + \frac{51k\Omega}{7.5k\Omega}\right) \cdot \frac{1}{51k\Omega} = \frac{1V}{0.7}\left(\frac{1}{51k\Omega} + \frac{1}{7.5k\Omega}\right)$$

$$\boxed{i_s \doteq 218\,\mu A \approx 220\,\mu A}$$

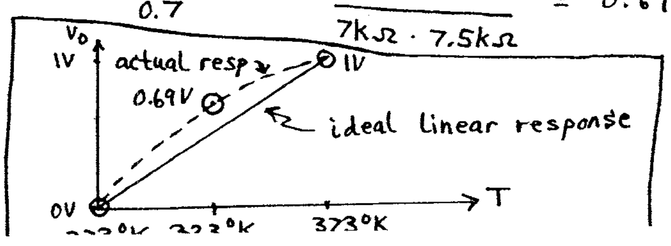
e) $R_T(323°K) = 7250\, e^{100°K\left(\frac{1}{323°K} - \frac{1}{300°K}\right)}\,\Omega \doteq 7.08\,k\Omega \approx 7k\Omega$

$$v_o(323°) = v_s\left(1 + \frac{R_2}{R_T(323°)}\right) - i_s R_2 =$$

$$" = v_s\left(1 + \frac{R_2}{R_T(273°)} - \frac{R_2}{R_T(273°)} + \frac{R_2}{R_T(323°)}\right) - i_s R_2$$

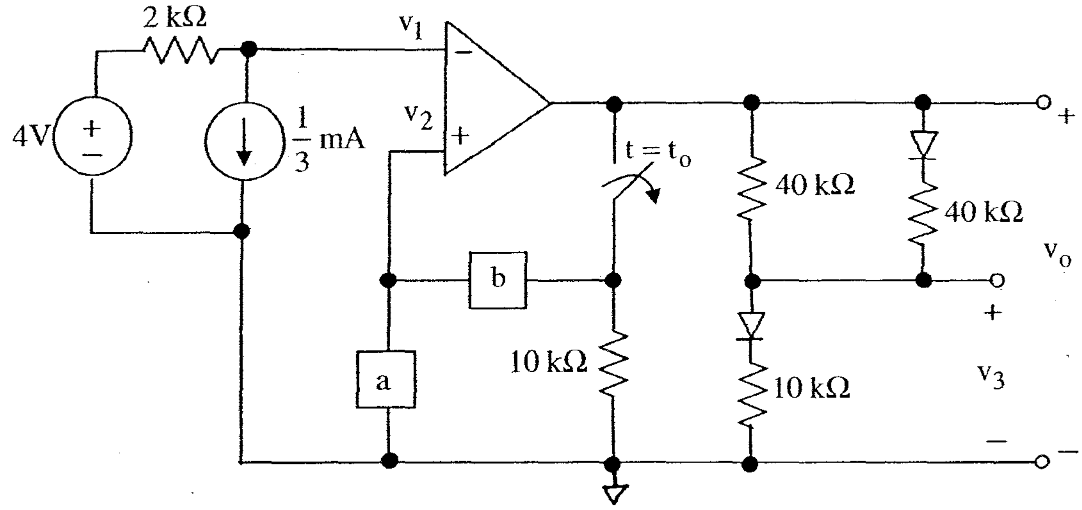
$$" = \underbrace{0V}_{v_o(273°)} + v_s R_2\left(\frac{1}{R_T(323°)} - \frac{1}{R_T(273°)}\right) = \frac{1V}{0.7} 51k\Omega\left(\frac{1}{7k\Omega} - \frac{1}{7.5k\Omega}\right)$$

$$" = \frac{1V}{0.7}\, 51k\Omega\, \frac{7.5k\Omega - 7k\Omega}{7k\Omega \cdot 7.5k\Omega} \doteq 0.69V$$



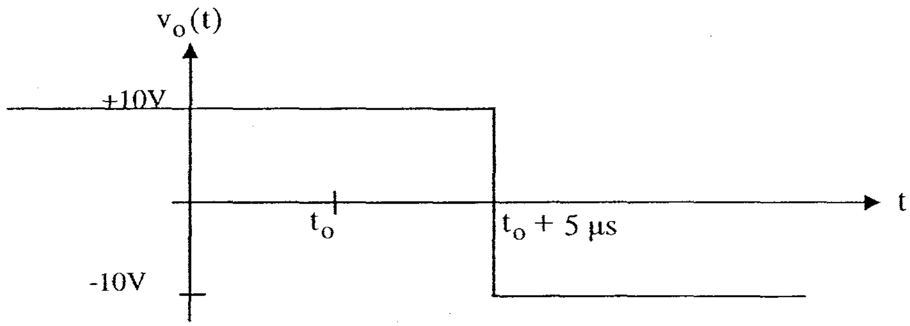
HW #10 cont. Su 2005

2.




Rail voltages = ±10 V

After being closed for a long time, the switch closes at $t = t_o$.




a. Choose either an R or L to go in box a and either an R or L to go in box b to produce the $v_o(t)$ shown above. Specify which element goes in each box and its value.

b. Sketch $v_1(t)$, showing numerical values appropriately.

c. Sketch $v_2(t)$, showing numerical values appropriately.

d. Sketch $v_3(t)$. Show numerical values for $t < t_o$, for $t_o < t < t_o + 5\ \mu s$, and for $t_o + 5\ \mu s < t$. Use the ideal model of the diode: when forward biased, its resistance is zero; when reverse biased, its resistance is infinite.

Explain your work carefully.

HW #10 Cont.

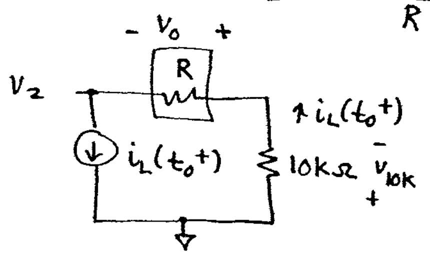
ECE 1000 Su 05

sol'n: 2. a) Consider possibilities.

$a = R$ and $b = R$ Doesn't work. $v_2$ would change at $t_0$ but never again. Delay of 5 $\mu s$ not possible.

$a = L$ and $b = L$ Doesn't work. Before time $t_0$, the L's look like wires and would short $v_0$ to ref. But $v_0 = \pm v_{Rail} = \pm 10V$. Thus, we would have an invalid circuit.

$a = L$ and $b = R$ Before $t_0$, the L looks like a wire, and $v_2 = 0V$. $i_L(t_0^-) = \frac{v_0}{R} = i_L(t_0^+)$.




Circuit at $t_0^+$.

At $t_0^+$, the current in R will be $i_L(t_0^+) = i_L(t_0^-) = \frac{v_0}{R}$ or the same as at $t_0^-$. Thus, the v-drop for R at $t_0^+$ will be $v_0$. Current $i_L(t_0^+)$ flowing in the $10k\Omega$ will cause a voltage drop in series with the drop for R, resulting in a very negative voltage at $v_2$. This would cause $v_0$ to go low at $t = t_0^+$ rather than after a delay of 5 $\mu s$.

$\therefore$ This case doesn't work.

HW #10 Cont.

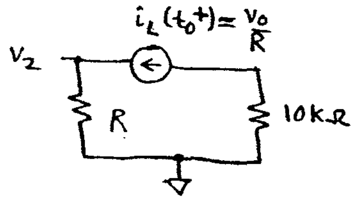
Su 05

ECE 1000

Sol'n: 2.a) cont. $\boxed{a = R \text{ and } b = L}$

$i_L(t_0^-) = \frac{V_0}{R}$ as in prev case.

At $t_0^+$ with $i_L(t_0^+) = i_L(t_0^-) = \frac{V_0}{R}$ :




we have $v_2(t_0^+) = \underbrace{\frac{V_0}{R}}_{i_L(t_0^+)} \cdot R = V_0.$

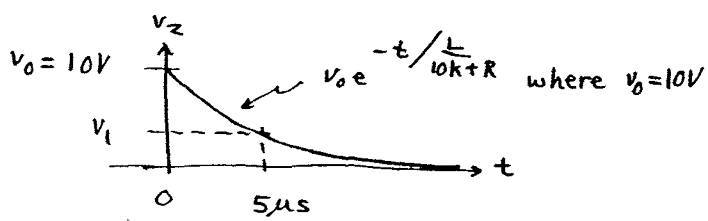
So $v_2$ doesn't change immediately.
This will work!
For $t \to \infty$ we will have $v_2 = 0V$
since there is no power source.

Using the general formula for
$v_2(t)$, we have:

$$v_2(t) = \underbrace{v_2(t \to \infty)}_{= 0V} + [\underbrace{v_2(t_0^+)}_{= V_0} - \underbrace{v_2(t \to \infty)}_{= 0V}] e^{-t/\frac{L}{R_{Th}}}$$

where $R_{Th} = 10k\Omega + R$

$$v_2(t) = V_0 \, e^{-t/\frac{L}{10k + R}}$$




The output, $v_o$, will drop at
$t_0 + 5\mu s$ if $v_2(t_0 + 5\mu s) = V_1$.
[Assume $t_0 = 0$ for convenience.]

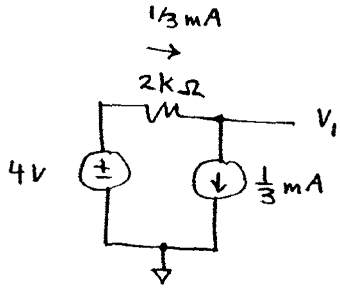
Now find $V_1$.

HW #10 Cont.

ECE 1000

Su 05

sol'n: 2.a) cont.




$$V_1 = 4V - \frac{1}{3}mA \cdot 2k\Omega$$

$$V_1 = 4V - \frac{2}{3}V = \frac{10}{3}V$$

$\therefore$ we want $V_2(5\mu s) = V_1 = \frac{10}{3}V$

or $\quad 10V\, e^{-5\mu s / \frac{L}{10k\Omega + R}} = \frac{10}{3}V$

$$-5\mu s \Big/ \frac{L}{10k\Omega + R} = \ln\frac{1}{3} \doteq -1.1$$

or $\quad 5\mu s = 1.1 \dfrac{L}{10k\Omega + R}$

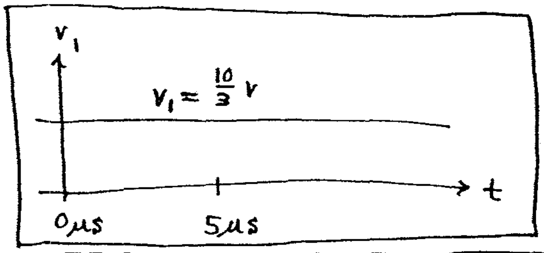
If we use $R = 12k$ we get a convenient value for $L$. Many solutions for $R$ and $L$ will work, however.

$R = 12k\Omega$ gives $\quad L = 5\mu s \cdot \dfrac{10k\Omega + 12k\Omega}{1.1}$

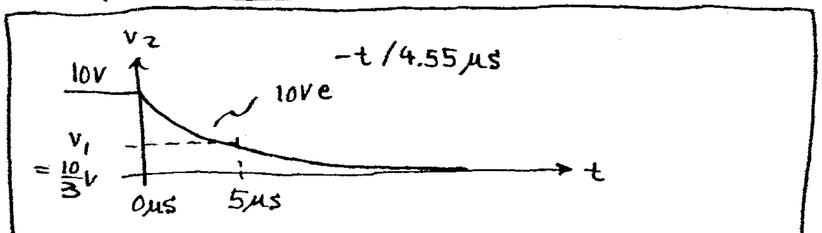
$$L = 5\mu s \cdot 20k\Omega = 100\,mH$$

$\boxed{R = 12k\Omega \quad L = 100\,mH}$ One solution among many.

b)




c)

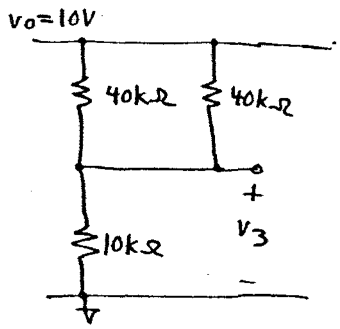



Note: $\dfrac{L}{R_{Th}} = \dfrac{100mH}{22k\Omega} = 4.55\mu s$

HW #10 Cont.

ECE 1000 Su 05

sol'n: 2.d) For $v_o = +10V$, both diodes are forward biased and look like wires.

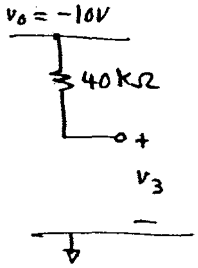



$$v_3 = 10V \cdot \frac{10k\Omega}{10k\Omega + 40k\Omega \| 40k\Omega}$$

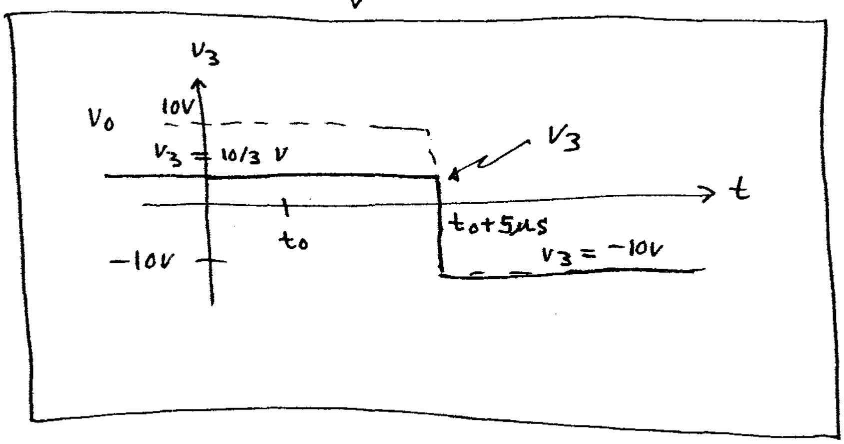
$$" = 10V \cdot \frac{10k\Omega}{10k\Omega + 20k\Omega}$$

$$v_3 = \frac{10}{3} V$$

For $v_o = -10V$, both diodes are reverse biased and look like open circuits.

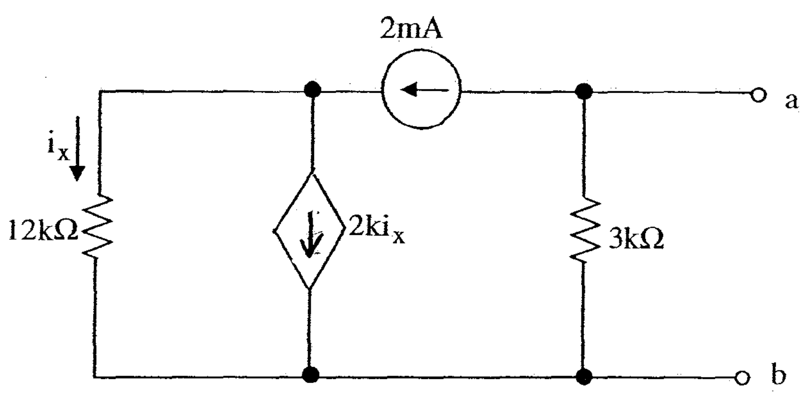



$$v_3 = -10V$$



HW #10 Cont.

3.




a. Find the Thevenin equivalent of the above circuit relative to terminals a and b.

b. If we attach $R_L$ to terminals a and b, find the value of $R_L$ that will absorb maximum power.

c. Calculate the value of that maximum power absorbed by $R_L$.

HW#10 Cont.

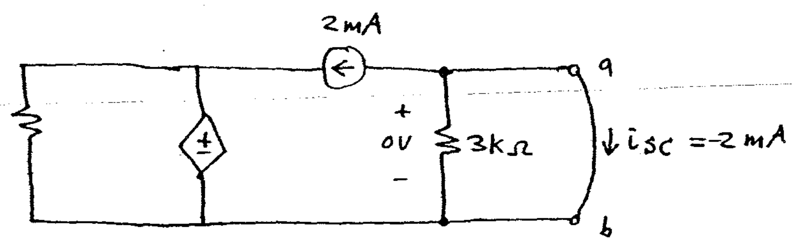
ECE 1000 Su 05

sol'n: 3. a) $V_{Th} = V_{a,b \text{ open circ}} = -2\,mA \cdot 3\,k\Omega = -6\,V$

The current source is between a, b and the $12\,k\Omega$ and dependent source.

The current source thus isolates behavior at a, b from the $12\,k\Omega$ and dependent source.

Use $i_{sc}$ to find $R_{Th}$:




we short a, b so no v-drop across $3\,k\Omega$.

So $i_{3k\Omega} = 0$ and $i_{sc} = -2\,mA$.

$$R_{Th} = \frac{V_{Th}}{i_s} = \frac{-6\,V}{-2\,mA} = 3\,k\Omega$$

$$\boxed{V_{Th} = -6\,V \qquad R_{Th} = 3\,k\Omega}$$

Comments: 1) We could also just turn off the 2 mA source and look into a, b to see $R_{Th} = 3\,k\Omega$.

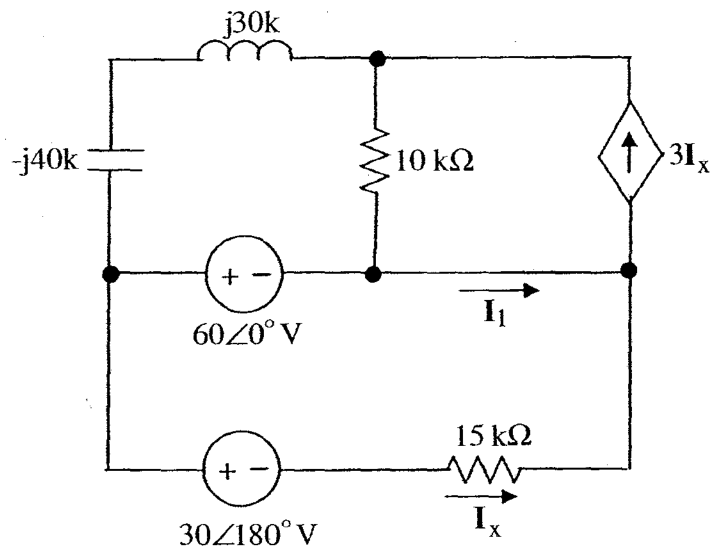
2) We really just started with a Norton equivalent that we converted to Thevenin equivalent.

b) max pwr when $R_L = R_{Th} = \boxed{3\,k\Omega = R_L}$

c) max pwr $P_{max} = \dfrac{V_{Th}^2}{4R_{Th}} = \dfrac{(-6\,V)^2}{4 \cdot 3\,k\Omega} = \boxed{3\,mW = P_{max}}$

*HW #10 Cont.*

4.




a. A frequency-domain circuit is shown above. Write the value of phasor $\mathbf{I}_1$ in polar form.

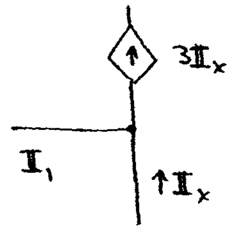
b. Given $\omega = 53.13$ rad/s, write a numerical time-domain expression for $i_1(t)$, the inverse phasor of $\mathbf{I}_1$.

HW #10 Cont.

Su 05

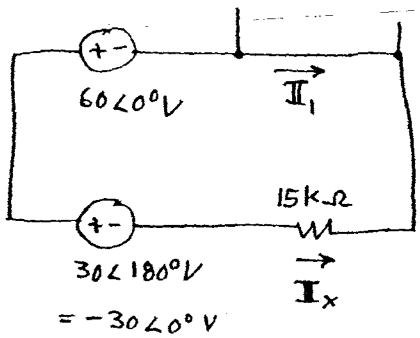
ECE 1000

soln: 4. a) Sum of currents for node on right side:




We see that $\mathbf{I}_1 = 2\mathbf{I}_x$ from sum of currents out of node $= 0$.

From the bottom half of the circuit, we can compute $\mathbf{I}_x$ directly:




From V-loop we have

$$\mathbf{I}_x = \frac{60\angle 0° V - -30\angle 0° V}{15 k\Omega}$$

$$\mathbf{I}_x = \frac{90\angle 0° V}{15 k\Omega}$$

$$\mathbf{I}_x = 6 \text{ mA} \angle 0°$$

So $\mathbf{I}_1 = 2\mathbf{I}_x = 12 \text{ mA} \angle 0°$

$$\boxed{\mathbf{I}_1 = 12\angle 0° \text{ mA}}$$

b) $\boxed{i_1(t) = 12 \cos(53.13t) \text{ mA}}$

or $\pi t$