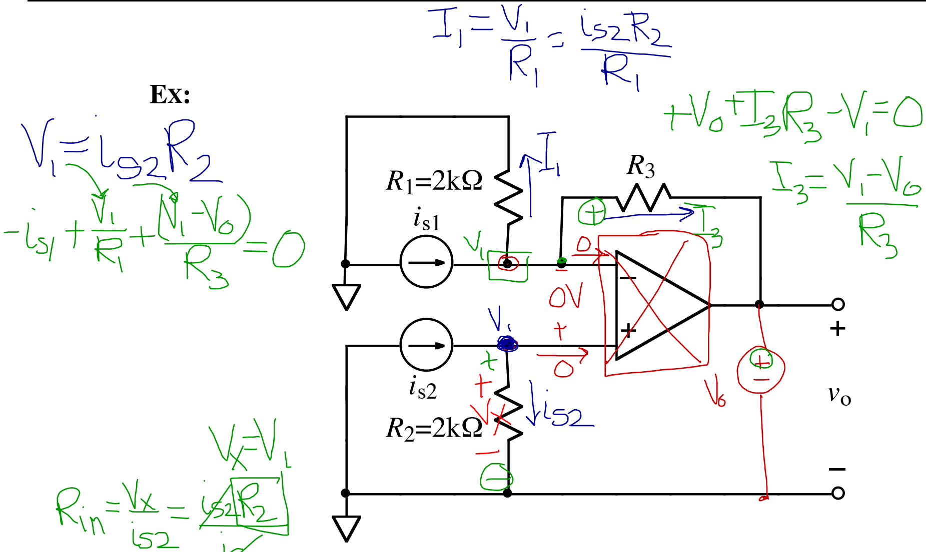
HOMEWORK #17 solution

Ex:



Rail voltages = ±10 V

a) The above circuit operates in linear mode. Derive a symbolic expression for v_o. The expression must contain not more than the parameters i_{s1}, i_{s2}, R_1, R_2, and R_3.

b) If $i_{s1} = 0$ μA, find the value of R_3 that will yield an output voltage of $v_o = 1$ V when $i_{s2} = 10$ μA.

c) Derive a symbolic expression for v_o in terms of common mode and differential input currents:

$$i_\Sigma \equiv \frac{i_{s1} + i_{s2}}{2} \quad \text{and} \quad i_\Delta \equiv \frac{i_{s1} - i_{s2}}{2}$$

The expression must contain not more than the parameters i_Σ, i_Δ, R_1, R_2, and R_3. Write the expression as i_Σ times a term plus i_Δ times a term. Hint: start by writing i_{s1} and i_{s2} in terms of i_Σ and i_Δ:

$$i_{s1} \equiv i_\Sigma + i_\Delta \quad \text{and} \quad i_{s2} \equiv i_\Sigma - i_\Delta$$

$R_{in} = \frac{V_x}{i_{s2}}$

d) If $i_\Delta = 0$ and $R_1 = R_2$, write a formula for the current flowing from left to right in R_3 as a function of not more (and possibly less) than the following terms: i_Σ, R_1, R_2, and R_3.

sol'n: a) First, we find v_p (voltage at + input):

$$v_p = i_{s2} R_2$$

Second, we find the current flowing toward the − input from the left, using v_n (voltage at − input) $= v_p$:

$$i_\ell = i_{s1} - \frac{v_n}{R_1} = i_{s1} - \frac{i_{s2} R_2}{R_1}$$

Third, we find the current flowing in the feedback resistor, R_3, from left to right:

$$i_r = \frac{v_n - v_o}{R_3} = \frac{i_{s2} R_2 - v_o}{R_3}$$

Fourth, we set $i_r = i_\ell$ and solve for v_o:

$$i_{s1} - \frac{i_{s2} R_2}{R_1} = \frac{i_{s2} R_2 - v_o}{R_3}$$

or $$\boxed{v_o = -i_{s1} R_3 + i_{s2} R_2 \left(1 + \frac{R_3}{R_1}\right)}$$

b) $$1\text{V} = 10\mu\text{A} \cdot 2\text{k}\Omega \left(1 + \frac{R_3}{2\text{k}\Omega}\right) = 20\text{mV} \left(1 + \frac{R_3}{2\text{k}\Omega}\right)$$

$$\therefore \; 1 + \frac{R_3}{2\text{k}\Omega} = 50 \quad \text{or} \quad \frac{R_3}{2\text{k}\Omega} = 49$$

or $$\boxed{R_3 = 98\ \text{k}\Omega}$$

c) $$v_o = -(i_\Sigma + i_\Delta) R_3 + (i_\Sigma - i_\Delta) R_2 \left(1 + \frac{R_3}{R_1}\right)$$

or

$$v_o = i_\Sigma \left(R_2 + \frac{R_2 R_3}{R_1} - R_3\right)$$

$$- i_\Delta \left(R_2 + \frac{R_2 R_3}{R_1} + R_3\right)$$

d) For $i_\Delta = 0$ and $R_1 = R_2$, we have

$$v_o = i_\Sigma \left(R_2 + \cancel{R_3} - \cancel{R_3}\right)$$

or $v_o = i_\Sigma R_2$

Then $$i_{R3} = \frac{v_n - v_o}{R_3} = \frac{v_n - i_\Sigma R_2}{R_3}$$

But $$v_n = v_p = i_{s2} R_2 = \frac{i_{s1} + i_{s2}}{2} R_2$$

(since $i_{s1} = i_{s2}$) $$= i_\Sigma R_2$$

Then $$i_{R3} = \frac{i_\Sigma R_2 - i_\Sigma R_2}{R_3} = 0\ A$$

Note: When $i_{s1} = i_{s2}$, the current in R_1 and R_2 is the same (since $v_n = v_p$), so there is no current left over to flow in R_3.

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HOMEWORK #17 solution

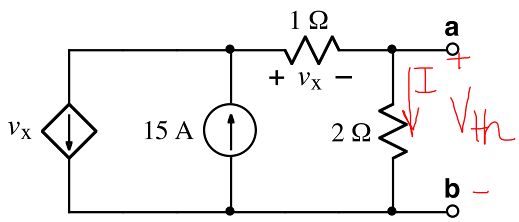
Ex:

$I = 15 - V_x = 15 - I(1)$

$2I = 15$

$I = 15/2$

$V_{th} = 15V$



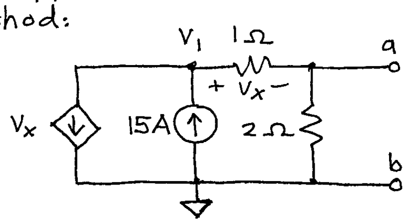
a) Find the Thevenin equivalent of the above circuit relative to terminals **a** and **b**.

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.

sol'n: a) $v_{Th} = v_{a,b}$ with nothing connected across a,b

One approach is to use the node-voltage method:



Using the voltage-divider formula, we relate v_x to v_1:

$$v_x = v_1 \cdot \frac{1\Omega}{1\Omega + 2\Omega} = \frac{v_1}{3}$$

Node v_1 eq'n:

$$\frac{v_1}{3} - 15A + \frac{v_1}{1\Omega + 2\Omega} = 0A$$

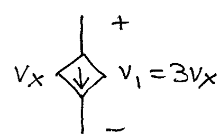
or $\frac{2\,v_1}{3\Omega} = 15A$

or $v_1 = \frac{3}{2}\Omega \cdot 15A = 22.5\ V$

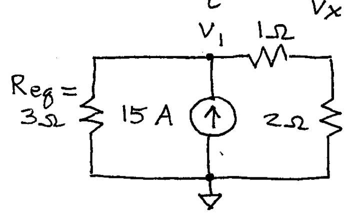
To find v_{Th}, we again use a voltage-divider formula:

$$v_{Th} = v_1 \cdot \frac{2\Omega}{1\Omega + 2\Omega} = 22.5\,V \cdot \frac{2}{3} = 15\ V$$

Note: Another approach is to replace the dependent source with a resistor. To do so, we write the voltage across the dependent source in terms of dependent variable v_x. From an eq'n above, we have $v_1 = 3v_x$.



$$R_{eq} = \frac{v}{i} = \frac{3v_x}{v_x} = 3\Omega$$



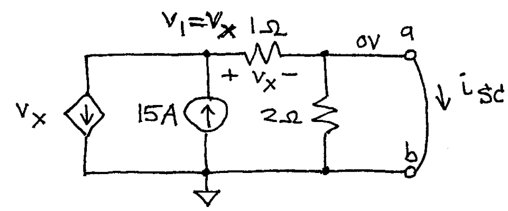
$$v_1 = 15A \cdot 3\Omega \| 3\Omega = 22.5V$$

Note: R_{eq} changes with R across a, b.

One way to find R_{Th} is to use

$$R_{Th} = \frac{v_{Th}}{i_{sc}}$$

where $i_{sc} \equiv$ short circuit from **a** to **b**



We may ignore the 2Ω resistor that is shorted out.

Node v_1 eq'n: (Note that $v_x = v_1$.)

$$v_1 - 15A + \frac{v_1}{1\Omega} = 0A$$

or

$$\frac{2v_1}{1\Omega} = 15A$$

or

$$v_1 = 15A \cdot \frac{1\Omega}{2} = 7.5\,V$$

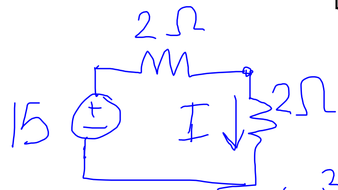
Our current is $i_{sc} = \frac{v_1}{1\Omega} = \frac{7.5V}{1\Omega} = 7.5A.$

$$R_{Th} = \frac{v_{Th}}{i_{sc}} = \frac{15V}{7.5A} = 2\Omega$$

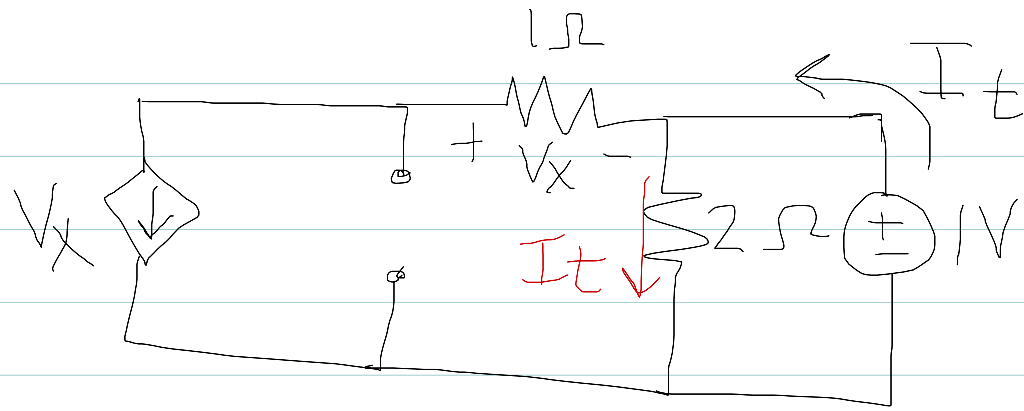
Note: we could replace the dependent source with $R_{eq} = \frac{v}{i} = \frac{v_x}{v_x} = 1\Omega$ for i_{sc}.

b) $R_L = R_{Th} = \boxed{2\Omega}$ for max pwr xfer

c) $P_{max} = \dfrac{V_{Th}^2}{4R_{Th}} = \dfrac{15^2}{4 \cdot 2\Omega} = \boxed{28.125\,W}$



$P = I^2 R = \left(\dfrac{15}{4}\right)^2 \cdot 2$



$$V_x = -V_x(1)$$

$$I_t = \frac{1}{2}$$

$$2V_x = 0$$

$$V_x = 0$$

$$\boxed{R_{th} = 2}$$

HOMEWORK #18 solution

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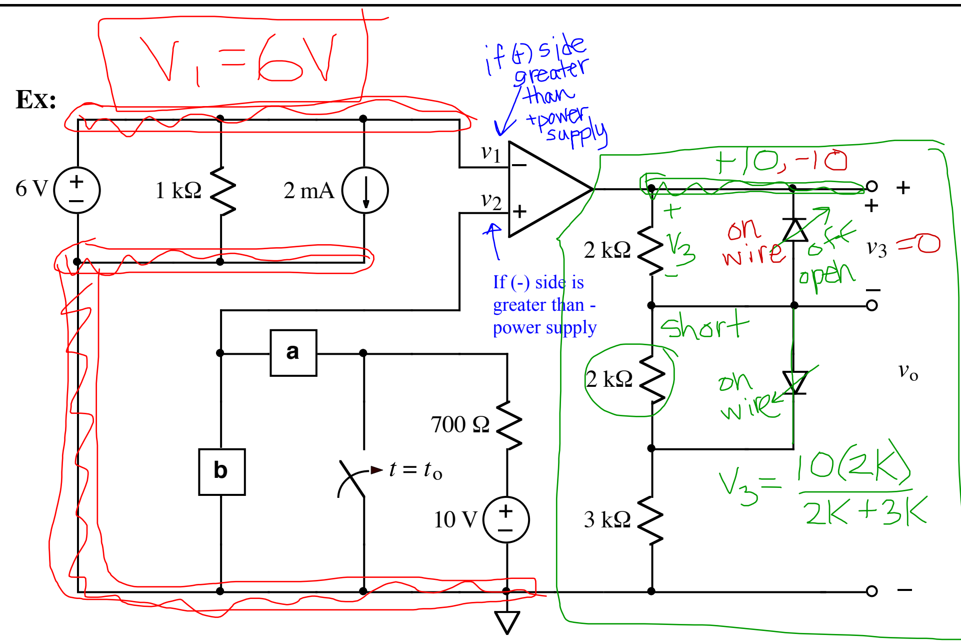
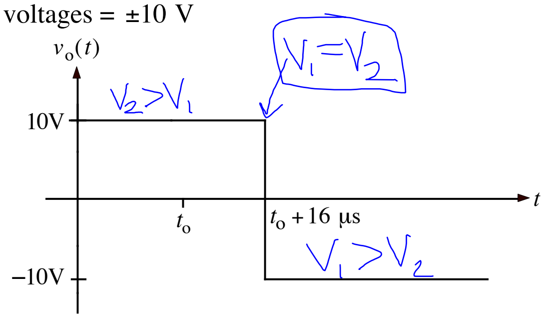
Ex:



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

Rail voltages = ±10 V



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. (You will need one R and one L. Use an R value of 1.3 kΩ. Also, note that v_o stays low forever after t_o + 16 µs.) 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 $t_o < t < t_o + 16$ µs, and for $t > t_o + 16$ µs. Use the ideal model of the diode: when forward biased, its resistance is zero; when reverse biased, its resistance is infinite.

sol'n: a) We first find v_1, which is constant. The $1k\Omega$ resistor and $2mA$ source are across the $6V$ source. Because they are across the $6V$ source, they may be ignored. $v_1 = 6V$ regardless of what is across the $6V$ source.

$$v_1 = 6\,V$$

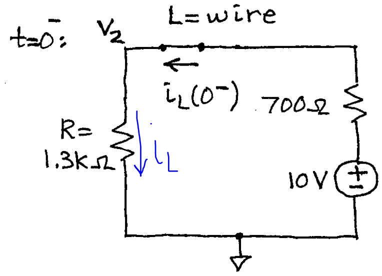
For boxes **a** and **b**, we observe that, if we had an L in **b**, that L will act like a wire at $t=0^-$. This would make $v_2(0^-) = 0V$. The op-amp acts like a comparator, with the output equal to $\pm 10V$ according to the sign of $v_2 - v_1$. For $v_2 = 0V$ and $v_1 = 6V$ we would have $v_2 - v_1 = 0 - 6V = -6V$ and $v_o = -10V$ at $t=0^-$. This differs from the plot of $v_o(t)$ given in the problem statement. Thus, **b** must contain an R rather than an L.

Because the output voltage, $v_o(t)$, changes $16\,\mu s$ after the switch moves, box **a** must contain an L to give the circuit a time-varying behavior.

$$a = L$$
$$b = R \approx 1.3k \text{ (from prob statement)}$$

At $t=0^-$, we have the following equivalent circuit:

$a = L$
$b = R$



$i_L(0^-) = \frac{10V}{1.3k\Omega + 700\Omega}$

$i_L(0^-) = 5mA$

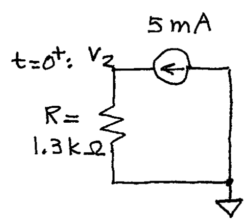
This is a voltage divider.

$$v_2(0^-) = 10V \cdot \frac{1.3k\Omega}{1.3k\Omega + 700\Omega} = \underline{6.5V}$$

We note that $v_2(0^-) = 6.5 > v_1(0^-) = 6V$ and $v_2 - v_1 = 6.5 - 6V = 0.5V > 0V$ so $v_0(0^-) = +10V$, as desired.

Initial Value

$\boxed{\text{At } t=0^+}$, we have the following equivalent circuit:



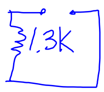
$v_2(0^+) = 5mA \cdot 1.3k\Omega$

$v_2(0^+) = 6.5V$ $\quad V_2 > V_1$ ✓

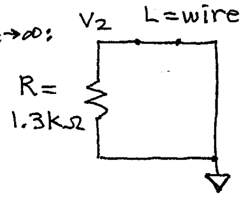
At $t=0^+$, $v_2 - v_1 = 6.5V - 6V = 0.5V > 0V$ so $v_0(0^+) = +10V$, as desired.

As $t \to \infty$, we have the following equivalent circuit:

$V_2 = 0 + (6.5 - 0)e^{-t/\tau}$



$t \to \infty$:



Since there is no power source, $v_2(t \to \infty) = 0\,V$ $\quad V_1 > V_2$ ✓

The time constant of the circuit is

$$\tau = \frac{L}{R_{Th}} = \frac{L}{1.3k\Omega}$$

Using the general form of solution for RL circuits, we write an expression for $v_2(t>0)$:

$$v_2(t>0) = v_2(t\to\infty) + [v_2(0^+) - v_2(t\to\infty)]\,e^{-t/\tau}$$

or $$v_2(t>0) = 0V + [6.5V - 0V]\,e^{-t/\tau}$$

or $$v_2(t>0) = 6.5V\,e^{-t/\tau}$$

The op-amp output switches from high to low when $v_2(t) = v_1 = 6V$, which must occur at $t = t_0 + 16\mu s$.

Setting $t_0 = 0$, we solve for L in $v_1 = v_2$ at $t = 16\mu s$.

$$6V = 6.5\,V\,e^{-16\mu s/\tau}$$

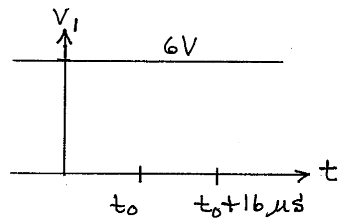
or $$\ln(6/6.5) = -16\mu s/\tau$$

or $\tau = \dfrac{-16\,\mu s}{\ln(6/6.5)} \doteq 200\,\mu s$

$L = \tau \cdot R_{Th} = 200\,\mu s \cdot 1.3\,k\Omega = 260\,mH$

$$\boxed{\begin{aligned} R &= 1.3\ k\Omega \\ L &= 260\ mH \end{aligned}}$$

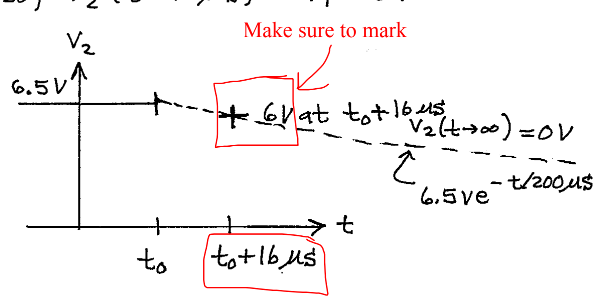
b) From above, $v_1(t) = 6V$ at all times



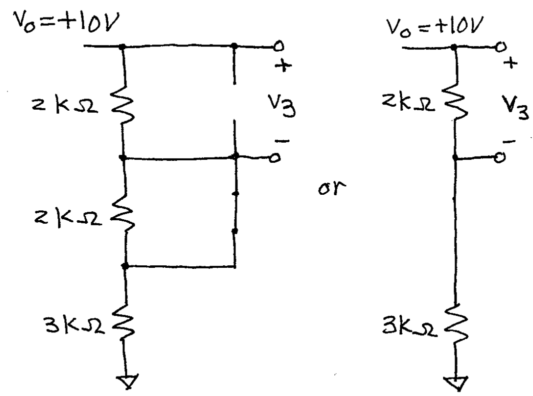
c) From above, $V_2(0^-) = 6.5V$ and

$v_2(t>0) = 6.5\, e^{-t/200\mu s}$ V

Also, $v_2(t = 16\mu s) = v_1 = 6V$



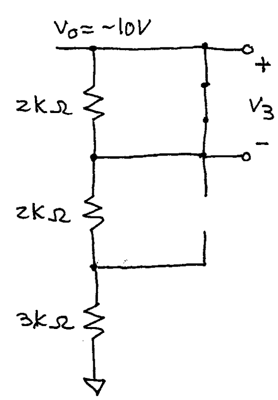
d) When $v_o = +10V$, the equivalent circuit on the right side is as follows:



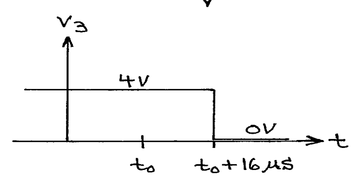
We have a voltage divider: $v_3 = \frac{10V \cdot 2k\Omega}{2k\Omega + 3k\Omega}$

$v_3 = 4V$

When $v_o = -10V$, the equivalent circuit on the right side is as follows:

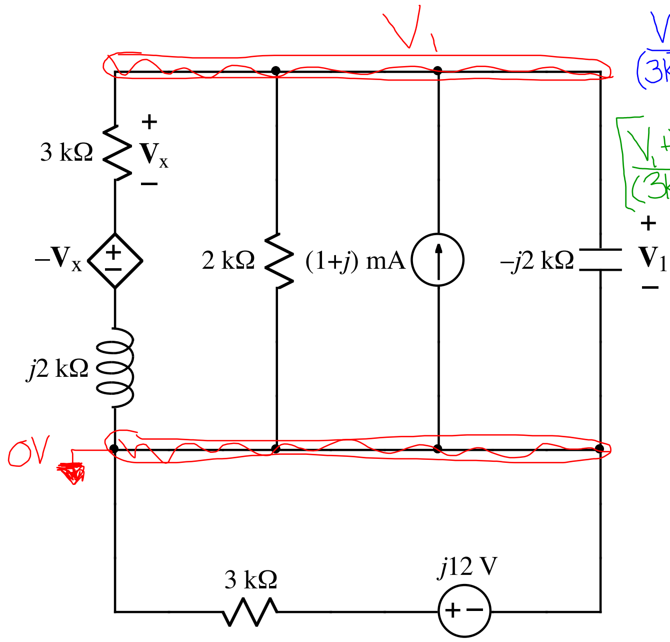


Since we have a short across v_3, $v_3 = 0V$.



HOMEWORK #18 solution

Ex:



$$\frac{V_1-(-V_x)}{(3K+2Kj)}+\frac{V_1}{2K}-(1+j)m+\frac{V_1}{-2Kj}=0$$

$$\left[\frac{V_1+V_x}{(3K+2Kj)}\right]3K=V_x$$

$$3KV_1+\cancel{3KV_x}=\cancel{V_x3K}+2KjV_x$$

$$V_x=\frac{V_1 3K}{2Kj}$$

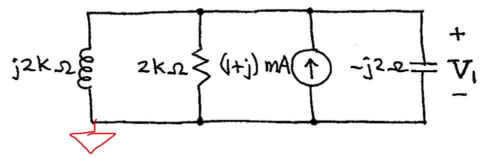
a) A frequency-domain circuit is shown above. Write the value of phasor voltage $\mathbf{V}_1$ in rectangular form.

b) Given ω = 500 rad/s, write a numerical time-domain expression for $v_1(t)$, the inverse phasor of $\mathbf{V}_1$.

sol'n: a) The dependent-source voltage cancels out the voltage across the 3kΩ resistor, yielding the equivalent of a wire, (i.e. 0V).

We may also ignore the bottom part of the circuit, which is shorted out by the middle wire.

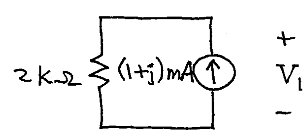
Thus far, we have the following circuit:



Now we observe that the j2kΩ and −j 2kΩ in parallel are equivalent to an open circuit:

$$j2k\Omega \| -j2k\Omega = j2k\Omega \cdot 1 \| -1 = j2k\Omega \cdot \frac{-1}{0} = \infty\,\Omega$$

Thus, the L and C disappear:



Now we use Ohm's law:

$$V_1 = (1+j)\text{ mA} \cdot 2k\Omega = \boxed{2+j2 \text{ V}}$$

b) In polar form, $V_1 = \underbrace{2\sqrt{2}}_{\sqrt{2^2+2^2}} \angle \underbrace{45^\circ}_{\tan^{-1}\left(\frac{2}{2}\right)}$ V

In the time domain, we have

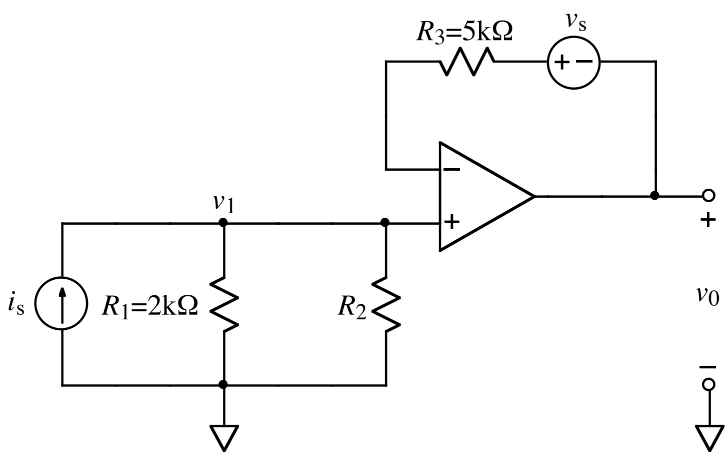
$$v_1(t) = 2\sqrt{2}\cos(500t + 45^\circ) \text{ V}$$

Note: We could also directly take the inverse phasor of $2+j2$ **V**:

$$v_1(t) = 2\cos(500t) - 2\sin(500t) \text{ V}$$

HOMEWORK #17 solution

Ex:



Rail voltage = ±9 V

a) The above circuit operates in linear mode. Derive a symbolic expression for v_o. The expression must contain not more than the parameters i_s, v_s, R_1, R_2, and R_3.

b) If $v_s = 0$ V, find the value of R_2 that will yield an output voltage of $v_o = 1$ V when $i_s = 1$ mA.

c) Using the value of R_2 from part (a), find the value of v_s that will yield $v_o = 1$ V when $i_s = 0$ A.

d) Using the value of R_2 from part (a), calculate the input resistance, $R_{in} = v_1/i_s$, seen by the i_s source.

sol'n: a) First, we find the voltage, v_1, at the + input of the op-amp.

$$v_1 = i_s \cdot R_1 \| R_2$$

Second, we assume the voltage, v_n, at the − input of the op-amp = v_1

$$v_n = i_s \cdot R_1 \| R_2$$

Third, we find the value of v_o that yields the above value of v_n.

Since no current flows into the op-amp inputs, no current flows in R_3, and R_3 has no voltage drop.

$$\therefore \quad v_o = v_n - v_s$$

or $$v_o = i_s \cdot R_1 \| R_2 - v_s$$

b) Given $v_s = 0V$ and $i_s = 1\,mA$ we are to find the value of R_2 that yields $v_o = 1V$.

Using the expression in (a) for v_o we have

$$1V = 1\,mA \cdot 2k\Omega \| R_2 - 0V$$

or $$2k\Omega \| R_2 = 1k\Omega$$

or $$R_2 = 2k\Omega$$

c) We have $1V = \overbrace{0A \cdot \cancel{2k\Omega} \| 2k\Omega}^{0V} - v_s$

or $$v_s = -1V$$

d) From part (a), we have the following:

$$v_1 = i_s \cdot R_1 \| R_2$$

$$R_{in} \cong \frac{v_1}{i_s} = R_1 \| R_2 = 1k\Omega$$

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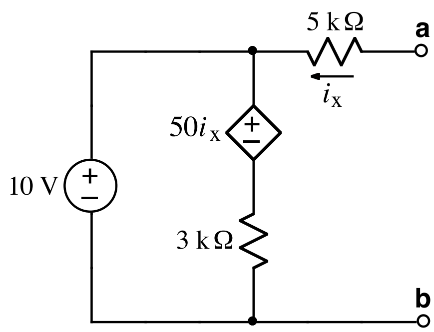
HOMEWORK #17 solution

Ex:



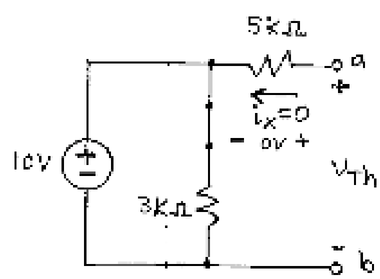
a) Find the Thevenin equivalent of the above circuit relative to terminals **a** and **b**.

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.

sol'n: a) $V_{Th} = V_{a,b}$ no load

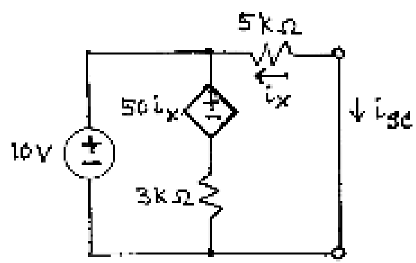
With nothing connected from **a** to **b**,
$i_x = 0$ and $50 i_x = 0V$ acts like a wire



Since $i_x = 0$, there is no v-drop across the 5 kΩ resistor. An outer voltage loop reveals that $V_{Th} = 10V$.

Because we have a dependent source, we can find R_{Th} using the formula

$$R_{Th} = \frac{v_{Th}}{i_{sc}}$$



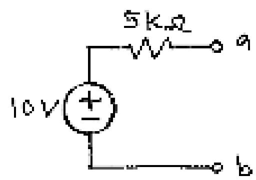
Although we have a dependent source, the 10V source between the top and bottom rails makes the $50 i_x$ and 3kΩ components irrelevant.

From an outer v-loop, we have

$$i_{sc} = \frac{10\,V}{5\,k\Omega} = 2\,mA$$

$$\therefore R_{Th} = \frac{v_{Th}}{i_{sc}} = \frac{10V}{2\,mA} = 5\,k\Omega$$

Note: The 10V source across the rails allows to ignore the $50 i_x$ and 3kΩ. We may remove them. Then we observe that we are left with the Thevenin equivalent circuit: $V_{Th} = 10V$, $R_{Th} = 5k\Omega$.



b) $R_L = R_{Th} = 5k\Omega$ for max pwr transfer

c) $P_{max} = \dfrac{V_{Th}^2}{4R_{Th}} = \dfrac{(10V)^2}{4 \cdot 5k\Omega} = \dfrac{100}{20}$ mW

$P_{max} = 5$ mW

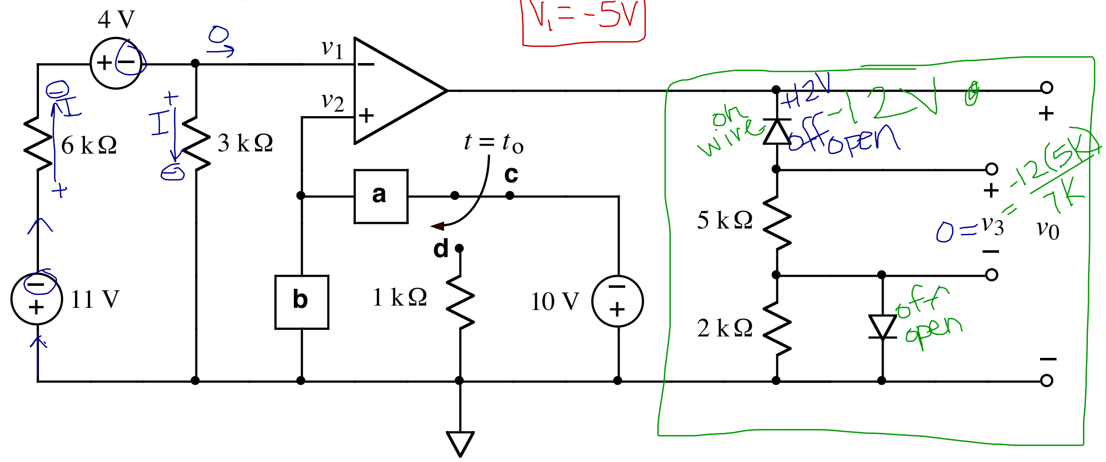
HOMEWORK #18 solution

$$\frac{V_1+4+11}{6K}+\frac{V_1}{3K}=0 \rightarrow V_1\left(\frac{1}{6K}+\frac{2}{6K}\right)=\frac{-15}{6K}$$

$$\boxed{V_1=-5V}$$

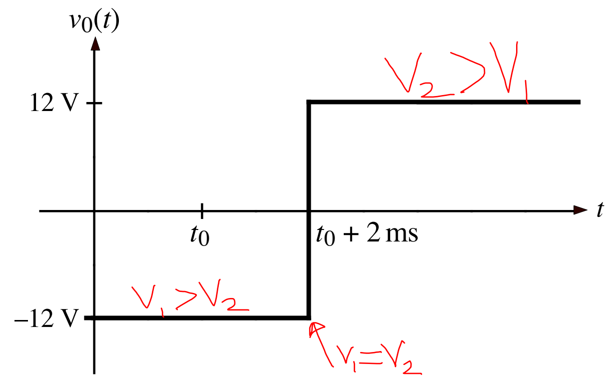
Ex:

$V_1 = I(3K)$
$-15 - I(9K) = 0$
$I = \frac{-15}{9K}$
$V_1 = -5V$



After being in position **c** for a long time, the switch moves from **c** to **d** at $t = t_o$.

Rail voltages = ±12 V



a) Choose either an R or C to go in box **a** and either an R or C to go in box **b** to produce the v_o(t) shown above. (Note that v_o stays high forever after $t_o + 2$ ms.) 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 $t_o < t < t_o + 2$ ms, and for $t_o + 2$ ms $< t$. Use the ideal model of the diode: when forward biased, its resistance is zero; when reverse biased, its resistance is infinite.

sol'n: a) For v_o to be low, (i.e., $-12V$), we must have $v_2 < v_1$.

To find v_1, we slide the 4V source through the $6k\Omega$ resistor and find that we have the equivalent of a $-15V$ source and a voltage divider formed by the $3k\Omega$ and $6k\Omega$ resistors.

$$v_1 = -15V \cdot \frac{3k\Omega}{3k\Omega + 6k\Omega} = -5V$$

At $t = 0^-$, we must have $v_2 < -5V$.

a=R
b=C

This is possible only if box **a** contains a resistor and box **b** contains a capacitor. If **a** is an R and **b** is a C, then the C will charge until $v_2 = -10V < v_1$.

When the switch moves from **c** to **d**, the capacitor voltage start charging toward 0V, but it will still be $-10V$ initially. This gives the desired waveform for $v_o(t)$: v_o will go high when $v_2 = v_1 = -5V$.

Note: The reasons why other components in boxes **a** and **b** fail to yield the desired $v_o(t)$ are as follows:

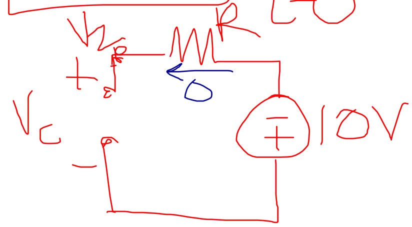
a = R and **b** = R cannot give a waveform that changes after a delay. v_o would have to change instantly at $t = t_o$.

a = C and **b** = R would result in C charging until no current flows in R. This means $v_2 = 0V$, or $v_2 > v_1$, causing v_o to be high before $t = t_o$.

a = C and **b** = C would result in an arbitrary voltage at v_2. The total voltage drop across the two C's would be 10V. When the switch changes from **c** to **d**, the capacitors would charge until the total voltage drop across them was 0V. The same current would flow in both C's, causing a voltage change that would be inversely proportional to the C values. The waveform shown for $v_o(t)$ could be produced, but there is a lack of control over the initial value of v_2. This would make the timing of the $v_o(t)$ waveform uncertain. Thus, we reject this solution.

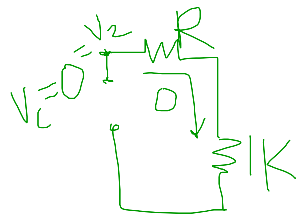
$$\boxed{\begin{matrix} a = R \\ b = C \end{matrix}}$$

$t = 0^-$



$V_c = V_2 = -10V$

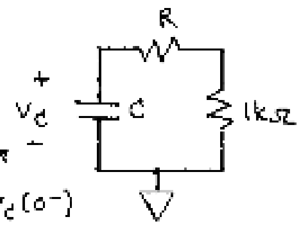
$V_1 = -5 > V_2 = -10V$ ✓



$V_2 > V_1$ ✓

τ found at final

Now we find possible values for R and C. We have the following circuit model for $t > t_0$:



$v_c(0^-) = -10V$

$$v_c(t > t_0) = \underset{0V}{v_c(t \to \infty)} + \left[\underset{-10V}{v_c(t_0^+)} - \underset{0V}{v_c(t \to \infty)} \right] e^{-t/\tau}$$

$$v_c(t > t_0) = -10\, e^{-t/\tau}\ V \quad (\text{where we take } t_0 = 0)$$

where $\tau = (R + 1k\Omega)\, C$

We want $v_c(t = 2ms) = \underline{v_1 = -5V}$

$$\text{or} \qquad -10\, e^{-2ms/\tau}\ V = -5\,V$$

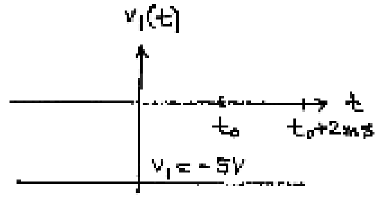
$$e^{-2ms/\tau} = \frac{1}{2}$$

$$-2\,ms = \tau \ln \frac{1}{2}$$

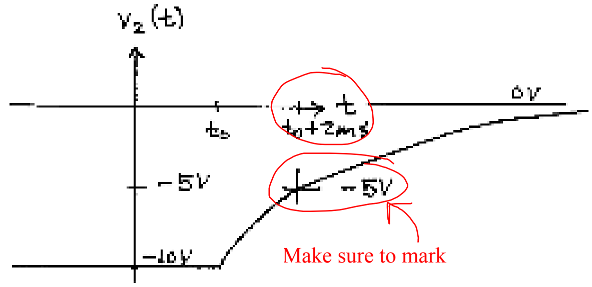
$$\tau = \frac{2\,ms}{\ln 2} \doteq 2.9\,ms$$

One soln is $R = 1.9\,k\Omega$ and $C = 1\,\mu F$.
Note: $R = 0\,\Omega$ is min R, $C = 2.9\,\mu F$ is max C.

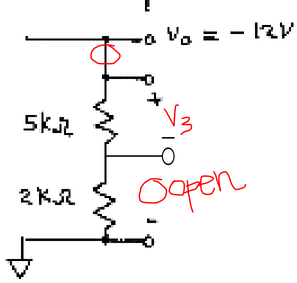
b) $v_1(t) = -5V$ as shown earlier.



c) $v_2 = v_c(t>0) = -10V\, e^{-t/2.9ms}$ from (a)



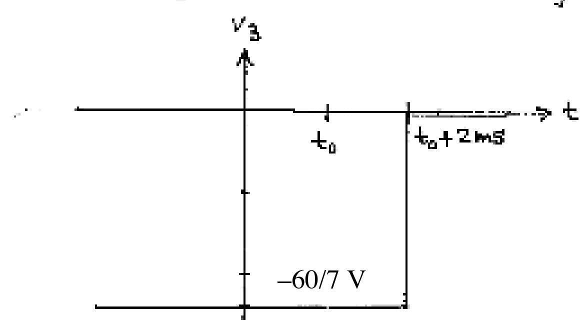
d) When v_o is low, the top diode will act like a wire and the bottom diode will act like an open circuit.



We have a voltage divider: $v_3 = -12\text{ V}\cdot\dfrac{5\text{ k}\Omega}{2\text{ k}\Omega + 5\text{ k}\Omega} = -\dfrac{60}{7}\text{ V}.$

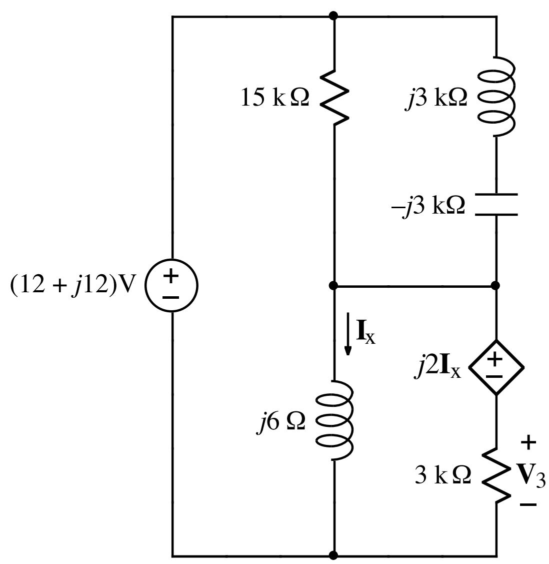
When v_0 is high, the top diode will act like an open circuit, leaving the bottom part of the circuit disconnected from v_0, (or any other power source).

Thus $v_3 = 0V$ when v_0 is high.



HOMEWORK #18 solution

Ex:



a) A frequency-domain circuit is shown above. Write the value of phasor $\mathbf{V}_3$ in polar form.

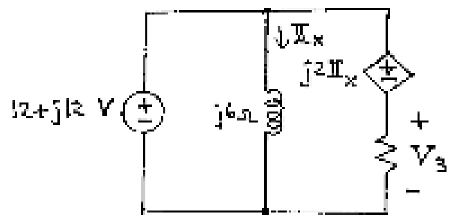
b) Given ω = 37 rad/s, write a numerical time-domain expression for $v_3(t)$, the inverse phasor of $\mathbf{V}_3$.

sol'n: a) The j3kΩ and −j3kΩ sum to 0Ω = wire.

Thus, the 15 kΩ is bypassed by a short and may be ignored.

It also follows that the 12+j12 V is directly across the j6Ω and directly across the j2I_x source in series with the 3kΩ resistor.

Our circuit model is as follows:



By Ohm's law, $\mathbb{I}_x = \dfrac{12+j12\text{ V}}{j6\,\Omega} = \dfrac{2(1+j)}{j}$ A

or $\mathbb{I}_x = -j2(1+j)$ A

or $\mathbb{I}_x = 2-j2$ A

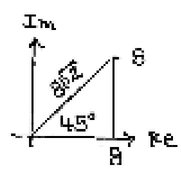
It follows that $j2\mathbb{I}_x = j2(2-j2)\text{ V} = 4+j4$ V.

From a v-loop around the outside of the circuit, we have the following:

$$V_3 = (12+j12)\text{V} - (4+j4)\text{V}$$

or $V_3 = 8+j8$ V

or $V_3 = 8\sqrt{2}\angle 45°$ V



b) $v_3(t) = P^{-1}\left[8\sqrt{2}\angle 45°\text{ V}\right]$, $\omega = 37$ rad/s

$$v_3(t) = 8\sqrt{2}\cos(37t + 45°)\text{ V}$$