Sample Exam 2

ECE 2004
Problem 1

- **Positive Saturation**
- **Neutral Region**
- **Negative Saturation**
- Slope $= A_v$, closed loop gain
- $V_i$ - input voltage
- $V_o$ - output voltage
- $V^+$ - positive voltage
- $V^-$ - negative voltage
- Linear region
Problem 2

Voltage Source

Current of $I_x$ determines value of voltage

a) Current controlled voltage source (CCVS)

b) There are no independent voltage or current sources in the circuit. Therefore, $I_x = 0$ A. Dependent sources can not be the only power source in a circuit.
Problem 3

Dependent sources remain on during superposition.
Problem 3 (con’t)

Turn independent current source off causes R4 to drop out of the circuit.

Since no particular technique other than superposition was mentioned, you can use whatever technique you would like to set up the equations.
Problem 3 (con’t)

I prefer nodal analysis. So, I will use it to solve for \( V_x \) and \( V_y \).

Since the voltages \( V_x \) and \( V_y \) are also equal to node voltages if I place ground at the bottom of the circuit, either analytical technique yields the values for \( V_x \) and \( V_y \) immediately. So choose whichever one you like.
\[ V_x = -V_B \quad V_C = V_y \quad V_A = SV \]

**Node A:** \[ I_1 = I_2 \]

**Node B:** \[ I_2 = I_3 + I_4 \]

**Node C:** \[ I_4 + 4 \left( \frac{A}{V} \right) V_x = I_5 \]

\[
I_2 = \frac{SV + V_x}{8k\Omega} \quad I_3 = -\frac{V_x}{3k\Omega} \quad I_5 = \frac{V_y}{2k\Omega}
\]

Remember that the coefficient on a VCCS is not unitless as the unit V on Vx must become an A for the current source magnitude.
Node A: \[ I_1 = \frac{5V + V_x}{8\text{kn}} \]

Node B: \[ \frac{5V + V_x}{8\text{kn}} = -\frac{V_x}{3\text{kn}} + I_4 \]

Node C: \[ I_4 + 4(A)\frac{V_x}{V} = \frac{V_y}{2\text{kn}} \]

3 equations but 4 unknowns.

The last relationship is that the \( 2V_y \) is the voltage difference of \( V_c - V_B \)

\[ 2V_y = V_y + V_x \quad \therefore V_y = V_x \]
Problem 3 (con’t)

Turn current source on and independent voltage source off. You can choose another technique to solve for \( V_x \) and \( V_y \) in this circuit. I tend to use the same technique for all circuits when doing superposition (personal preference), but will use mesh analysis in this circuit to provide another example on this technique.
Problem 3 (con’t)

Mesh #1
\[ + 2V_y + V_I + V_1 = 0 \]

Mesh #2
\[ - V_x + V_x = 0 \quad \text{← trivial} \]

Mesh #3
\[ + V_x - 2V_y + V_y = 0 \quad \text{← } V_x = V_y \]

Mesh #4
\[ + V_y - V_y = 0 \quad \text{← trivial} \]
\[ V_1 = i_1 (1 \text{kN}) \quad i_1 = -3 \text{A} \quad V_1 = -3 \text{kV} \]

\[ V_x = 8 \text{kn} \dot{i}_2 \quad V_x = 3 \text{kn} (i_3 - i_2) \]

\[ V_y = 2 \text{kn} (i_3 - i_4) \quad i_4 = -4V_x \]

\[ V_y = 2 \text{kn} (i_3 + 4(A) V_x) \]

\[ 8 \text{kn} \dot{i}_2 = 3 \text{kn} (i_3 - i_2) \]

\[ i_3 = \frac{11}{3} \quad i_2 = \frac{11}{3} \frac{V_x}{8 \text{kn}} \]

Since \( V_x = V_y \) and

\[ V_x = 2 \text{kn} \dot{i}_3 + 8 \text{kV} \frac{V_x}{V} \]

\[ 2V_x + V_1 - 3 \text{kV} = 0 \]

\[ i_3 = \frac{11}{3} \frac{V_x}{8 \text{kn}} \]
Solution for V_x and V_y in original circuit is the addition of the results obtained from the two circuits.
Problem 4 (con’t)

No value for $V^+$ or $V^-$ given so don’t worry that the output voltage will saturate – assume that the op amp is in its linear region.

Always assume (1) current does not flow into the input terminals of the op amp.

(2) $V_2 = V_1$
In series can be added.
Since \( V_1 = V_2 \), the voltage across the 1k\( \Omega \) resistor must equal the voltage across the 4k\( \Omega \) resistor.

\[
\begin{align*}
SV - V_1 &= i_2 \\
\frac{SV - V_1}{1k\Omega} &= i_2 \\
\frac{SV - V_2}{4k\Omega} &= i_3 \\
1k\Omega \cdot i_2 &= 4k\Omega \cdot i_3
\end{align*}
\]
Redrawing part of the circuit, you can see that the 5V source is in parallel with the series combination of the 4kΩ resistor, the 2kΩ resistor, and the 1V source.

\[ 5V = 4kΩi_3 + 2kΩi_3 - 1V \]

\[ i_3 = \frac{6V}{6kΩ} = 1mA \]

\[ \therefore i_2 = 4mA \]
$U_f = i_2 = 4mA$

$U_2 = 5V - 4k\Omega (i_3) = 5V - 4V = 1V$

$U_1 = 5V - 1k\Omega (i_2) = 5V - 4V = 1V$
The voltage across the 25kΩ resistor is:

\[ V_1 - V_0 = i_f (25\text{kΩ}) \]

Substituting in

\[ V_1 = 1\text{V} \text{ and } i_f = 4\text{mA} \]

\[ 1\text{V} - V_0 = 4\text{mA} (25\text{kΩ}) \]

\[ V_0 = 99\text{V} \]

The assumption that the op amp is in the linear region is likely not valid. But, you have to use it since you do not know \( V^+ \).
Problem

- There are three sources in this circuit so you will need to draw three circuits when applying superposition.
Problem \( \frac{5}{x} \) (con’t)

1. Keep voltage source on. Turn off current sources (replace w/ open circuits).

Since \( R_4 \) isn’t connected to the circuit at both ends, it should be deleted.
Problem 5/2 (con't)

#2 Turn off voltage source (short-circuit) and turn one current source back on.
Problem \( \frac{5}{3} \) (con't)

#3  Keep the voltage source off. 
Turn the other current source on 
and turn off the 1st current source.
Problem 5 (con’t)

Again, $R_4$ has one terminal that is not connected to the rest of the circuit.

Review the slides for the answer to part b.
Problem 86

- There are several ways to approach this problem. I will use source conversion to find a single power supply and equivalent resistor to replace the component network that is connected to the load (5Ω resistor).
Problem (con’t)
Problem 6 (con’t)

First, I identify Norton and Thévenin equivalents in the circuit.
Problem \( \text{(con't)} \)

If I convert the 2 Norton equivalents to Thévenin equivalents, I will be able to combine voltage sources to get one Thévenin equivalent.
Problem 6 (con’t)

Note that the arrowhead on the current source determines the polarity of the voltage source (where the larger line on the symbol is).
Problem 6 (con’t)

Thevinin equivalent for #1 Norton equivalent

4A(3n)
Problem 6 (con’t)

We can switch positions of voltage sources and resistors without affecting the circuit. However, the polarity of the voltage sources must stay unchanged.
since the voltage sources are in series, they can be combined.

Because the polarity of the voltage sources are opposite to one another, we subtract.
Need to convert to a Norton equivalent to eliminate the 40Ω resistor.

Arrow head of the current source points towards the + side of the voltage source (larger plate).
To complete the problem, you should do a Thévenin transformation of the Norton source on the right and then combine the Thévenin resistor with the 2n resistor and the Thévenin voltage source with the 0.4V source in series.
Thevenin Transformation

\[ 8 \Omega \quad 0.2A \quad 8 \Omega \quad 1.6V \]

\[ 5 \Omega \quad 1.6V \]

\[ 0.4V \]
you are allowed to rearrange the order of the components in series.

Note that the positive plate of the 1.78V source is connected to the negative plate of the 0.4V source so they add!
Norton

\[ V = 1.2 \text{ V} \]

\[ I_N = \frac{V_{th}}{R_{th}} = \frac{1.2 \text{ V}}{10 \Omega} \]

\[ I_N = 0.12 \text{ A} \]