Midterm Exam #2 (Form A)

Instructions:
1. This is a closed-book closed-note exam. No study materials should be visible or accessible during the exam.
2. The exam is comprised of five (5) problems, some with multiple parts.
3. The exam has twelve (12) pages including this cover-page and a blank page at the end to be used in the event that you do not have sufficient space for your answer to one or more problems.
4. You must turn in all eleven pages of the exam.
5. You must show all work and box your answers.
6. You have 90 minutes to complete the exam.

DO NOT WRITE BELOW THIS LINE:

Problem 1 (20 points)____________
Problem 2 (20 points)____________
Problem 3 (20 points)____________
Problem 4 (20 points)____________
Problem 5 (20 points)____________

TOTAL (100 points): ______________
1. Please circle the one best answer for each of the sub-problems a. through e. on this page and the next page.

   a. What is the approximate output voltage of the op-amp circuit shown to the right? (4 points)
      \[ \left( -\frac{2}{3} \right) \left( \left| \frac{15}{V} \right| \right) = -12 < -10 \]
      \[ \boxed{\text{12 V}} \]
      \[ \boxed{\text{10 V}} \]
      \[ \boxed{\text{9 V}} \]
      \[ \boxed{\text{-10 V}} \]
      \[ \text{-12 V} \]

   b. A linear resistive circuit has two independent sources and a single output, as shown to the right. If \( I_{s1} = 1 \text{ A} \) and \( V_{s2} = 1 \text{ V} \), then \( V_{out} = 3 \text{ V} \). If \( I_{s1} = 0 \text{ A} \) and \( V_{s2} = 2 \text{ V} \), then \( V_{out} = -1 \text{ V} \). When \( I_{s1} = 2 \text{ A} \) and \( V_{s2} = 4 \text{ V} \), the value of \( V_{out} \) is ... (4 points)
      \[ \boxed{\text{0 V}} \]
      \[ \text{2 V} \]
      \[ \boxed{\text{5 V}} \]
      \[ \text{6 V} \]
      \[ \text{-2 V} \]

   c. A typical value for the saturation current \( I_s \) of a diode is ... (4 points)
      \[ \boxed{-10^{15} \text{ A}} \]
      \[ \boxed{-10^{-15} \text{ A}} \]
      \[ \text{1 A} \]
      \[ \boxed{10^{-15} \text{ A}} \]
      \[ \boxed{10^{15} \text{ A}} \]
1. (cont.)

For Parts d. and e. consider the open-circuit and short-circuit tests of a linear network inside a black box as depicted below. Note that in addition to the standard electrical measurements, a calorimeter has been used to measure the energy and then compute the power dissipated by the linear network during each test.

\[ P = 32 \text{ W} \]

\[ V_{oc} = 8 \text{ V} \]

\[ P = 0 \text{ W} \]

\[ I_{sc} = 4 \text{ A} \]

\[ R_{HL} = \frac{E}{i} = 2 \Omega \]

\[ P = \left(\frac{4}{2}\right)^2 \cdot 2 = 8 \]

d. What is the maximum power that can be delivered by the linear network to an appropriately sized load resistor? (4 points)

1. 0
2. 2 W
3. **8 W**
4. 16 W
5. 32 W

\[ P = \left(\frac{4}{2}\right)^2 \cdot 2 = 8 \]

e. Which one of the following statements best describes the contents of the black box? (4 points)

1. It is a practical voltage source (i.e., a resistor in series with an ideal independent voltage source).
2. **It is a practical current source (i.e., a resistor in parallel with an ideal independent current source).**
3. It cannot be either a practical voltage source or a practical current source; the given data is not consistent with either one.
4. It can be either a practical voltage source or a practical current source; the given data is not sufficient to distinguish between the two.
2. This problem involves two separate networks that contain op amps, one on this page and one on the next page.

a. Determine the values for $V_A$, $V_B$, $V_C$, and $V_D$ in the network shown below. If you use the formula for the gain of a canonical amplifier, you must indicate clearly the type of amplifier. (8 points)

\[
\begin{align*}
\frac{1}{V_A} & = -2 \\
\frac{1}{V_B} & = -1 \\
\frac{1}{V_C} & = -4 \\
\frac{1}{V_D} & = -2
\end{align*}
\]

\[\text{inverting amplifier} \quad 2 \, \text{kΩ} \quad \text{non-inverting amplifier} \]

\[\text{Voltage divider} \]

\[\begin{align*}
V_A &= \frac{1}{1+1} \cdot 2 = 1 \, V \\
V_B &= -\frac{2}{1} \cdot V_A = -2 \, V \\
V_C &= \frac{4}{4+4} \cdot V_B = -1 \, V \\
V_D &= \left(1 + \frac{3}{1}\right) V_C = -4 \, V
\end{align*}\]
2. (cont.)

For Parts b. and c., consider the circuit shown to the right and determine the value of $V_{out}$.

b. Assume that the op amp is to be modeled as non-ideal with the following parameters: $A = 10^5$ V/V, $R_{in} = 100$ kΩ, and $R_{out} = 100$ Ω. (8 points)

$$V_+ - V_- = \frac{100}{100 + 400} (3 - 3.00005) = -1 \times 10^{-5}$$

$$V_{out} = \frac{100}{100 + 100} (10^5 - 10^{-5}) = -0.5 \text{ V}$$

c. Now, assume that op amp is to be modeled as ideal but with a saturation voltage of $V_{sat} = 15$ V. (4 points)

$$V_- > V_+ \Rightarrow V_{out} < 0$$

$$V_{out} = -15$$
3. This problem has four independent parts, two on this page and two on the next page.

a. A linear resistive circuit has two independent sources and a single output, as shown to the right. If $I_{s1} = 1 \text{ A}$ and $V_{s2} = 2 \text{ V}$, then $V_{out} = 5 \text{ V}$. If $I_{s1} = 2 \text{ A}$ and $V_{s2} = 4 \text{ V}$, then $V_{out} = 10 \text{ V}$. What is the value of $V_{out}$ when $I_{s1} = -3 \text{ A}$ and $V_{s2} = -6 \text{ V}$? (5 points)

\[\begin{array}{cccc}
1 & 2 & 5 \\
2 & 4 & 10 \\
-3 & -6 & -15
\end{array}\]

b. Determine the value of $V_z$ in the network shown below. (5 points)
3. (cont.)

c. Using superposition, determine $I_x$ in the circuit shown to the right. Show all work. (5 points)

\[
I_x \bigg|_{4V} = \frac{4V}{4 \Omega} = 1 \text{ A}
\]

\[
I_x \bigg|_{4A} = 2 \text{ A}
\]

\[
I_x = 1 + 2 = 3 \text{ A}
\]

d. Determine the value of $V_x$ in the network shown to the right. (5 points)

\[4V_x = (2 \Omega)(2 \text{ A})\]

\[V_x = 1 \text{ V}\]
4. This problem has three independent parts, two on this page and one on the next page.

a. Determine the value of $R_{th}$ for the network shown to the right. (5 points)

\[
R_{th} = R_{eq} = \frac{3}{(2+4)+3} = \frac{2+3}{5} = 1 \Omega
\]

b. Determine the value of $R_{in}$ for the network shown to the right. (5 points)

\[
I_x = 1 A
\]

\[
V_s = 2 \cdot 1 - 6 I_x + 3 \cdot 1 = -1 V
\]

\[
R_{in} = \frac{V_s}{I_x} = \frac{-1}{1} = -1 \Omega
\]
4. (cont.)

c. Determine and then draw the complete Thevenin equivalent circuit for the network shown to the right. (10 points)

\[ -18 + 3I_x - 3I_x + 9I_x = 0 \]
\[ I_x = 2 \]
\[ V_{oc} = 18 - 3 \cdot 2 = 12 \text{ V} \]
\[ I_x = \frac{18}{3} = 6 \text{ A} \]
\[ I_{sc} = I_x - \frac{3 \cdot I_x}{9} = 4 \text{ A} \]

\[ R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{12 \text{ V}}{4 \text{ A}} = 3 \Omega \]
5. This problem has two independent parts, one on this page and one on the next page.
a. Determine the values for $I_{D1}$, $V_{D1}$, $I_{D2}$, and $V_{D2}$ in the circuit shown to the right.
(10 points)

Assume D1 off and D2 on

\[ -V_{D1} + 15V \]
\[ -5k\Omega \downarrow \frac{15}{5} = 3mA \]
\[ 0V \]
\[ 5k\Omega \downarrow \frac{5}{5} = 1mA \]
\[ -5V \]

\[ I_{D2} = 3 - 1 = 2mA > 0 \quad \checkmark \]
\[ V_{D1} = 0 - 10 = -10V < 0 \quad \checkmark \]

$V_{D2} = 0 \quad \checkmark$

$I_{D1} = 0 \quad A$
5. (cont.)

b. Consider the circuit shown to the right, in which the switch and diode are to be modeled as being ideal. The switch is opened and closed periodically, with each period comprised of 3 ms closed followed by 1 ms open. (10 points)

i. Sketch one period of the resulting waveforms for $i_1$ and $v_2$ using the axes provided below the circuit. Be sure to include an appropriate scale for each vertical axis.

ii. Determine the average values $I_1$ and $V_2$.

\[ V_D = -E V < 0 \] 
\[ i_1 = 4 \text{ A} \]
\[ V_2 = E V \]

\[ i_D = 4 \text{ A} > 0 \]
\[ i_1 = 0 \]
\[ V_2 = 0 \]

\[ I_1 = \frac{4 \cdot 3}{4} = 3 \text{ A} \]
\[ V_2 = \frac{8 \cdot 3}{4} = 6 \text{ V} \]