Use engineering paper. Work only on one side of the paper. Use this sheet as your cover sheet, placed on top of your work and stapled in the top left-hand corner. Number the problems at the top of the page, in the center of the sheet. Do neat work. Underline your answers. Show how you got your equations. Be sure to show how you got your answers. Each problem counts 10 points, Except problem 5.12, 5.58, and 5.72 count 15 points each.

5.8 (a) Ans: \( v_o = -2 \text{ V} \)  
(b) \( v_o = -1 \text{ V} \)

5.11 Ans: \( v_o = -2 \text{ V} \), \( i_o = -1 \text{ mA} \)

5.12 Ans: \( \frac{v_o}{v_{in}} = -5 \): Also do this problem by using P-Spice. Assume a 741 op-amp. Use a 1 volt signal input and show that the output is \(-5 \text{ V}\). Include a printout of your simulation to verify the results.

5.19 Ans: \( i_o = -0.375 \text{ mA} \)

5.21 Ans: \( v_o = -4 \text{ V} \)

5.25 Ans: \( v_o = 1.25 \text{ V} \)

5.28 Ans: \( v_o = 2.4 \text{ V} \), \( i_o = 120 \mu \text{A} \)

5.58 Ans: \( i_o = 0.685 \text{ mA} \): Also simulate with P-Spice. Use a 741 op-amp. Show your simulation diagram with values on the diagram to verify your work.

5.72 Ans: \( v_L = -1 \text{ V} \): Also simulate with P-Spice. Use a 741 op-amp. Show your simulation diagram with values on the diagram to verify your work.

5.73 Ans: \( v_L = 10.8 \text{ V} \)

Note: For all problems that require P-Spice, use the \( \mu \text{A741} \) op-amp. This op-amp is found under Add Library/EVAL/\( \mu \text{A741} \) (at the very bottom of the parts list).
5.8

(a) Obtain $V_o$ for the following op amp.

\[ V_o + V_2 = 0 \]  
\[ \text{but } V_2 = 2V = 1mA \times 2k \]

So
\[ V_o = -V_2 \]
\[ V_o = -2V \]

(b) Obtain $V_o$ for the following op amp.

\[ V_o = 1V \]
\[ V_o = 2 - I \times 10k - V_o = 0 \]
\[ I = 0 \]

Then
\[ V_o = V_a - 2 = 1 - 2 \]
\[ V_o = -1V \]
Find $V_o$ and $I_o$ for the following op amp circuit.

$$V_a = \frac{3 \times 10k}{10k + 5k} = 2V = V_2$$

$$A = V_o$$

$$\frac{2 - 3}{2k} + \frac{2 - V_o}{8k} = 0$$

$$-4 + 2 - V_o = 0$$

$$V_o = -2V$$

$$I_1 = \frac{2 - V_o}{8k} = \frac{-4}{8k} = 0.5 mA$$

$$I_2 = \frac{V_o}{4k} = \frac{-2}{4k} = -0.5 mA$$

KCL: $I_o + I_1 = I_2$

$$I_o = I_2 - I_1 = -0.5 mA - 0.5 mA$$

$$I_o = -1 mA$$
5.12

Find \( \frac{V_o}{V_b} \) for the op amp below.

At point a:

\[
\frac{0-V_b}{5K} + \frac{0-V_o}{25K} = 0
\]

\[\Rightarrow 5V_b + V_o = 0\]

\[\frac{V_o}{V_b} = -5\]
Problem 5.12: Alexander
Determine \( V_{TH} \) and \( R_{TH} \). Connect the \( R_{TH} \) to the \( 4 \, k\Omega \) resistor and redraw the circuit.

\[
V_{TH} = \frac{1 \times 4k}{2k + 4k} = \frac{2}{3} \, V = 0.667 \, V
\]

\[
R_{TH} = 8k / 6k = \frac{4}{3} \, k\Omega = 1.33 \, k\Omega
\]

\[
10k \, i_1 + V_0 = 0
\]

\[
6m\Omega \cdot (0.667 + (15.33k) \times i_1) + V_0 = 0
\]

\[
\begin{bmatrix}
10k & 1 \\
15.33k & 1
\end{bmatrix}
\begin{bmatrix}
i_1 \\
V_0
\end{bmatrix}
= \begin{bmatrix}
0 \\
0.667
\end{bmatrix}
\]

\[
i_1 = 0.125 \, mA; \quad V_0 = -1.25 \, V
\]
\[ i_2 = \frac{V_0}{5k} = -1.25 \text{ mA} \]

**ECL:**
\[ i_0 + i_1 = i_2 \]
\[ i_0 = i_2 - i_1 \]
\[ i_0 = -0.25 \text{ mA} - 0.125 \text{ mA} \]
\[ i_0 = -0.375 \text{ mA} \]
Determine $V_0$ in the following op amp circuit.

At point $a$:

$$20k \left( \frac{1-3}{4k} + \frac{1-V_0}{10k} \right) = 0$$

$$-10 + 2 - 2V_0 = 0$$

$$2V_0 = -8$$

$$V_0 = -4 \text{ V}$$
5.25 Find $V_o$ in the following op amp circuit.

By inspection, $V_i = 2V$

By voltage division:

$$V_o = \frac{V_i \times 20k}{20k + 12k} = \frac{2 \times 20}{32}$$

$$V_o = 1.25\ V$$
Find $I_0$ in the op amp circuit below.

At $a$:

$$50k\left(\frac{0.4}{10k} + \frac{0.4-V_0}{50k} = 0\right)$$

$$2 + 0.4 - V_0 = 0$$

$\frac{V_0}{2.4V}$

$I_0 = \frac{V_0}{20k}$

$I_0 = \frac{2.4}{20k}$

$I_0 = 120\mu A$
5.58 Calculate \( V_o \) in the op amp circuit below. Also simulate with PSpice, verify your answer.

\[
\text{Make a Thévenin equivalent to the left of a-b:} \quad V_{TH} = \frac{1 \times 3k}{4k} = 0.75V \\
R_{TH} = \frac{(3k)\Omega (1k)}{3k} = 0.75k\Omega
\]

\[
V_A = \frac{0.45 \times 5k}{5k + 0.75k} = 0.3913V \\
V_B = V_A \\
V_o = -\frac{10k}{2k} \times V_B - \frac{10k}{5k} \times V_B
\]
\[ V_D = -0.3913 \times (5+2) = -2.739 V \]

\[ I_0 = \frac{-V_D}{4K} = \frac{2.739}{4K} \]

\[ I_0 = 0.685 mA \]
5.72 Find the input voltage $V_L$ in the following op amp circuit. Also, simulate using PSpice and verify your answer.

\[ V_L = -0.4 \times \frac{250k}{100k} \]

\[ V_L = -1 \text{ V} \]
Determine the voltage $V_L$ in the following circuit.

The voltage at point $a = 1.8 \, V$.
Therefore the voltage at $b = 1.8 \, V$.

At $b$:

$$\frac{50k}{10k} \left( \frac{1.8 + 1.8 - V_c}{50k} \right) = 9.0 + 1.8 - V_c = 0$$

$V_c = 10.8 \, V$

The voltage at $d = V_c = V_L$

$V_L = 10.8 \, V$