This homework is based on lectures 9 through 11, and Chapter 5 of your textbook. The problems are in the order of your textbook chapter and are related to different sections of the text as noted below. Each problem is worth 10 points out of 100.

Textbook Section 5.2 on operational amplifiers

5.7

At node 1,

\[
\frac{V_S - V_1}{10 \, \text{k}} = \frac{V_1}{100 \, \text{k}} + \frac{(V_1 - V_0)}{100 \, \text{k}}
\]

\[
10 \, V_S - 10 \, V_1 = V_1 + V_1 - V_0
\]

which leads to

\[
V_1 = \frac{(10V_S + V_0)}{12}
\]

At node 2,

\[
\frac{(V_1 - V_0)}{100 \, \text{k}} = \frac{(V_0 - (-AV_d))}{100}
\]

But \( V_d = V_1 \) and \( A = 100,000 \),

\[
V_1 - V_0 = 1000 \, (V_0 + 100,000V_1)
\]

\[
0 = 1001V_0 + 99,999,999[(10V_S + V_0)/12]
\]

\[
0 = 83,333,332.5 \, V_S + 8,334,334.25 \, V_0
\]

which gives us \( (V_0/ V_S) = -10 \) (for all practical purposes)

If \( V_S = 1 \, \text{mV} \), then \( V_0 = -10 \, \text{mV} \)

Since \( V_0 = A \, V_d = 100,000 \, V_d \), then \( V_d = (V_0/10^5) \, V = -100 \, \text{nV} \)
Textbook Section 5.3 on Ideal Op Amps

5.10: Since no current enters the op amp, the voltage at the input of the op amp is \( v_s \). Hence

\[
v_s = v_o \left( \frac{10}{10 + 20} \right) = \frac{v_o}{3} \quad \rightarrow \quad \frac{v_o}{v_s} = 3
\]

5.14:

Transform the current source as shown below. At node 1,

\[
\frac{25 - v_1}{5} = \frac{v_1 - v_2}{20} + \frac{v_1 - v_o}{10}
\]

But \( v_2 = 0 \). Hence \( 100 - 4v_1 = v_1 + 2v_1 - 2v_o \quad \rightarrow \quad 100 = 7v_1 - 2v_o \) \hspace{1cm} (1)

At node 2, \( \frac{v_1 - v_2}{20} = \frac{v_2 - v_o}{10} \), \( v_2 = 0 \) or \( v_1 = -2v_o \) \hspace{1cm} (2)

From (1) and (2), \( 100 = -14v_o - 2v_o \quad \rightarrow \quad v_o = -6.25V \)
Textbook Section 5.4 on Inverting Op Amps

5.21: Let the voltage at the input of the op amp be \( v_a \).

\[
\begin{align*}
\frac{v_a}{4k} & = \frac{v_a - v_o}{10k} \\
\frac{3-1}{4} & = \frac{1-v_o}{10} \\
\end{align*}
\]

\( v_o = -4 \text{ V}. \)

Textbook Section 5.5 on Noninverting Op Amps

5.29:

\[
\begin{align*}
\frac{R_1}{R_2} v_a & = \frac{v_a}{R_1 + R_2} \\
\frac{v_o}{v_i} & = \frac{R_1}{R_2} \\
\end{align*}
\]

But \( v_a = v_b \)

\[
\begin{align*}
\frac{R_2}{R_1 + R_2} v_i & = \frac{R_1}{R_1 + R_2} v_o \\
\end{align*}
\]

or

\[
\begin{align*}
\frac{v_o}{v_i} & = \frac{R_2}{R_1} \\
\end{align*}
\]

5.33

After transforming the current source, the current is as shown below:
This is a non-inverting amplifier, so
\[
v_o = \left(1 + \frac{1}{2}\right)v_i = \frac{3}{2}v_i
\]

Since the current entering the op amp is 0, the source resistor has a OV potential drop. Hence \(v_i = 4\)V.
\[
v_o = \frac{3}{2}(4) = 18\text{V}
\]

Power dissipated by the 3k\(\Omega\) resistor is
\[
\frac{v_o^2}{R} = \frac{324}{3k} = 108\text{ mW}
\]
\[
i_X = \frac{v_s - v_o}{R} = \frac{12 - 18}{1k} = -6\text{mA}
\]

**Textbook Section 5.6 on summing amplifiers**

5.39 This is a summing amplifier, so:
\[
v_o = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \frac{R_f}{R_3}v_3\right) = -\left(\frac{50}{10}v_1 + \frac{50}{20}v_2 + \frac{50}{50}(-1)\right) = -9 -2.5v_2
\]
Thus,
\[
v_o = -16.5 = -9 - 2.5v_2 \quad \rightarrow \quad v_2 = 3\text{V}
\]

**Textbook Section 5.8 on cascaded op amps**

5.59 The first stage is a noninverting amplifier. If \(v_1\) is the output of the first op amp,
\[
v_1 = (1 + 3R/R)v_s = 4v_s
\]
The second stage is an inverting amplifier
\[
v_o = -(4R/R)v_1 = -4v_1 = -4(4v_s) = -16v_s
\]
\[
v_o/v_s = -16.
\]
Textbook Section 5.9 on Op Amp Applications

5.87:

The output, \( v_a \), of the first op amp is,

\[
v_a = (1 + (R_2/R_1))v_1 \quad (1)
\]

Also,

\[
v_o = (-R_4/R_3)v_a + (1 + (R_4/R_3))v_2 \quad (2)
\]

Substituting (1) into (2),

\[
v_o = (-R_4/R_3) \left( 1 + (R_2/R_1) \right)v_1 + (1 + (R_4/R_3))v_2
\]

Or,

\[
v_o = (1 + (R_4/R_3))v_2 - (1 + (R_4/R_3) + R_2/R_1)R_3) v_1
\]

If \( R_4 = R_1 \) and \( R_3 = R_2 \), then,

\[
v_o = (1 + (R_4/R_3))(v_2 - v_1)
\]

which is a subtractor with a gain of \( 1 + (R_4/R_3) \).

5.92:

The top op amp circuit is a non-inverter, while the lower one is an inverter. The output at the top op amp is

\[
v_1 = (1 + 60/30)v_i = 3v_i
\]

while the output of the lower op amp is

\[
v_2 = -(50/20)v_i = -2.5v_i
\]

Hence,

\[
v_o = v_1 - v_2 = 3v_i + 2.5v_i = 5.5v_i
\]

\[
v_o/v_i = 5.5
\]