Problem 1: Here is my data for output vs input for my amplifier. When I switched leads to measure negative input voltages, there was an offset of ± 28 volts. Note on the graph this is clear.

\[ V_{\text{out}} = 0.12 + 0.087 \, V_{\text{in}} \]

The gain is the slope:

\[ \frac{V_{\text{output}}}{V_{\text{input}}} = 0.087 \, \text{V/mV} \]

The gain does remain constant until -40 mV and +50 mV inputs.
Part b1) When the pot is turned \( \frac{2}{3} \) of the way in the direction of the +6 V, we mean that the 6 KΩ resistance is divided

\[
\begin{align*}
\text{+6} & \quad \text{--} \quad \text{6 V} \\
\end{align*}
\]

into "two" resistors \( R_4 = \frac{5}{3} \text{KΩ} \), \( R_5 = \frac{10}{3} \text{KΩ} \)

\[
\begin{align*}
\text{+6} & \quad \frac{1}{3} (5 \text{KΩ}) & \quad \frac{2}{3} (6 \text{KΩ}) & \quad \text{R}_4 & \quad \text{R}_5 & \quad \text{6 V} \\
\end{align*}
\]

So the circuit diagram looks like

\[
\begin{align*}
\text{common} & \quad \text{V}_\text{DC} & \quad \text{R}_7 & \quad R_2 = 1.3 \text{KΩ} & \quad \text{V}_\text{EC} & \quad \text{D} & \quad \text{R}_3 = 91 \text{KΩ} \quad \text{notice we can ignore the connection to the -6 V line.} \\
\text{V}_\text{in} & \quad \text{R}_4 = \frac{5}{3} \text{KΩ} & \quad \text{R}_5 & \quad \text{This circuit acts like a voltage divider} \\
\text{+6 V} & \quad \text{--} & \quad \text{--} & \quad \text{--} & \quad \text{--} & \quad \text{--} & \quad \text{--}
\end{align*}
\]
The 250 mV setting acts like a resistor. The resistance \( R_1 \) is determined as:

\[
R_1 = \left( \frac{20,000 \, \text{ohm}}{\text{max } V} \right) \left( 250 \, \text{mV} \right) = 5 \, \text{k\Omega}
\]

So,

\[
R_1 = \frac{1.3 \, \text{k}\Omega}{2} = \frac{1}{2} R_0'
\]

These two resistors have an equivalent resistance (parallel rule):

\[
R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(5 \, \text{k}\Omega)(1.3 \, \text{k}\Omega)}{5 \, \text{k}\Omega + 1.3 \, \text{k}\Omega} = 1.03 \, \text{k}\Omega
\]

We are trying to determine the voltage \( V_{EC} \).
\[ V_{FE} = V_F - V_E, \quad V_{EG} = V_E - V_G, \quad V_{EC} = V_E - V_C \]

\[ I_1 = \frac{V_{FE}}{R_4}, \quad I_2 = \frac{V_{EG}}{R_5} \]

\[ V_{FE} + V_{GE} = 12 \text{ V} \]

\[ I_1 = I_2 + I_3 \]

\[ R_{eq}' = \frac{R_1 R_2}{R_1 + R_2} = \frac{(5k\Omega)(1.3k\Omega)}{(6.3k\Omega)} = 1.03 \text{ k} \Omega \]

\[ R_{eq}'' = R_{eq}' + R_3 = (1.03 \text{ k} \Omega) + 91k\Omega = 92k\Omega \]

\[ I_3 = \frac{V_{EC}}{R_{eq}''} \]
\[ I_1 = I_2 + I_3 \]

becomes

\[ \frac{V_{FE}}{R_4} = \frac{V_{CE} + V_{EC}}{R_5} \]

Now

\[ V_{FE} + V_{EC} = 6 \text{ Volts} \]

\[ -V_{EC} + V_{EC} = -(V_{E} - V_{C}) + V_{E} - V_{C} = V_{C} - V_{C} = 6V \]

Thus

\[ V_{FE} = 6V - V_{EC} \]  \hspace{1cm} (2)

\[ V_{EC} = 6V + V_{EC} \]  \hspace{1cm} (3)

Then eq (1) becomes after substituting eq (2) and eq (3)

\[ \frac{6V - V_{EC}}{R_4} = \frac{6V + V_{EC}}{R_5} + \frac{V_{EC}}{R_{eq}} \]

Solving for \( V_{EC} \)

\[ 6V \left( \frac{1}{R_4} - \frac{1}{R_5} \right) = V_{EC} \left( \frac{1}{R_5} + \frac{1}{R_{eq}} + \frac{1}{R_4} \right) \]

\[ V_{EC} = \frac{6V \left( \frac{1}{R_4} - \frac{1}{R_5} \right)}{\frac{1}{R_5} + \frac{1}{R_{eq}} + \frac{1}{R_4}} \]

\[ V_{EC} = 1.98V \]
b2) From part b1) 

\[ V_{ec} = 1.98 \text{V}, \quad I_3 = \frac{V_{ec}}{R_{eq}} = \frac{1.98 \text{V}}{92 \text{k}\Omega} = 21.5 \text{mA} \]

\[ 91 \text{k}\Omega = R_3 \]

\[ V_{dc} = I_3 R_{eq} \]

\[ = \frac{V_{ec}}{R_{eq}} \cdot \left( \frac{1.98 \text{V}}{92 \text{k}\Omega} \right) = 22 \text{mV} \]

b3) When I set my pot to 63 mV input, (about \(2/3\)), my output was 5.20 volts. This is in the range where the amplifier was saturated (see graph)
Problem 2:

3

\[ V_{3,c} = V_{\text{in}} \]

\[ V_{2,c} \]

\[ V_{6,c} = V_{\text{out}} \]

This portion acts as an amplifier.

I. The first step is to subtract \( V_{2,c} \) from \( V_{3,c} \)

\[ (V_{3,c} - V_{2,c}) \]

This voltage is then amplified to get the output voltage

\[ A \left( V_{3,c} - V_{2,c} \right) = V_{6,c} = V_{\text{out}} \quad (1) \]

II. The voltage \( V_{2,c} \) is the result of a voltage divider, like the last problem

\[ V_{2,c} = V_{6,c} \cdot \frac{R_2}{R_1 + R_2} \]
The ratio \( \beta = \frac{R_2}{R_1 + R_2} = \frac{1 \text{ k}\Omega}{(9.1 \text{ k}\Omega + 1 \text{ k}\Omega)} = 9.2 \text{ k}\Omega \).

So
\[
V_{2,c} = \beta V_{6,c} = \beta V_{\text{out}} \quad (2)
\]

Combining these two results
\[
A(V_{3,c} - V_{2,c}) = V_{6,c}
\]

Note:
\[
\begin{align*}
V_{3,c} &= V_{\text{in}} \\
V_{6,c} &= V_{\text{out}} \\
V_{2,c} &= \beta V_{\text{out}}
\end{align*}
\]

So
\[
A(V_{\text{in}} - \beta V_{\text{out}}) = V_{\text{out}} \quad (3)
\]

Solve eq. (3) for \( G = \frac{V_{\text{out}}}{V_{\text{in}}} \)
\[
A V_{\text{in}} = V_{\text{out}} + A \beta V_{\text{out}}
= V_{\text{out}} (1 + A \beta)
\]
\[
\Rightarrow G = \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{A}{1 + A \beta} \quad (4)
\]

Now \( A \approx 10^5 \), \( \beta \approx 10^{-2} \) so
\[
A \beta \approx 10^3 \gg 1 \quad \text{Thus}
\]
\[
1 + A \beta \approx A \beta \quad (5)
\]
Therefore

\[ G = \frac{V_{out}}{V_{in}} = \frac{A}{1 + A_0} \approx \frac{A}{A_0} \approx \frac{1}{10} = 0.1 \]

The gain \( G \) is independent of the amplification \( A \) which will vary according to temp and other factors!

In problem 1, \( G \approx 87 \) \( \text{so} \)

this is pretty close in agreement to the theoretical prediction. (Note: values for resistors are accurate to 5\%)