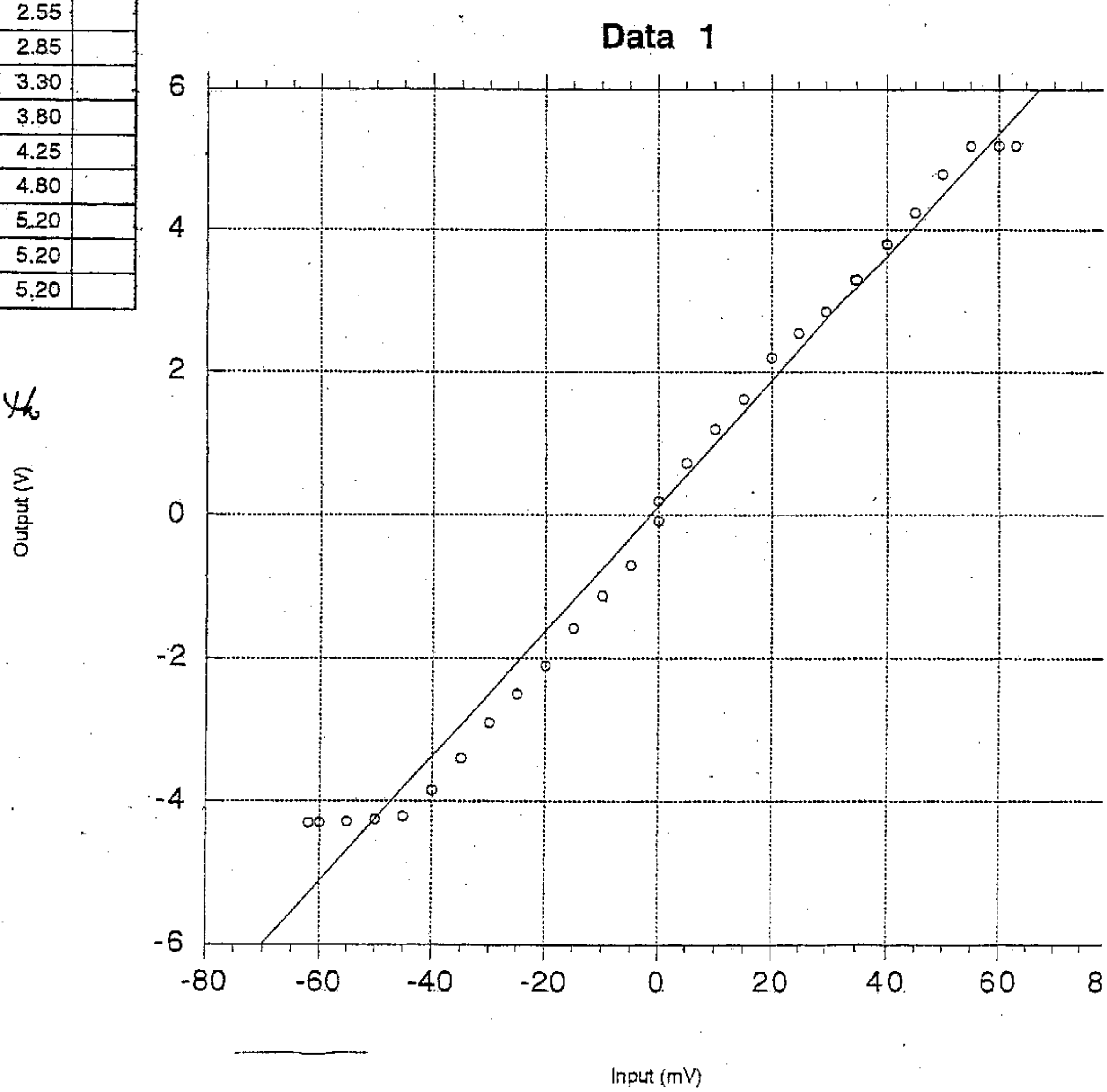
Experiment Amp Solutions

	Input (mV)	Output (V)	C
0	-62	-4.30	
1	-60	-4.30	
2	-55	-4.28	
3	-50	-4.25	
4	-45	-4.21	
5	-40	-3.85	
6	-35	-3.40	
7	-30	-2.90	
8	-25	-2.50	
9	-20	-2.10	
10	-15	-1.58	
11	-10	-1.12	
12	-5.0	-0.700	
13	0.0	-0.0800	
14	0.0	0.200	
15	5.0	0.730	
16	10	1.20	
17	15	1.62	
18	20	2.20	
19	25	2.55	
20	30	2.85	
21	35	3.30	
22	40	3.80	
23	45	4.25	
24	50	4.80	
25	55	5.20	
26	60	5.20	
27	63	5.20	

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.

$V_{out} = 0.12 + 0.087\, V_{in}$

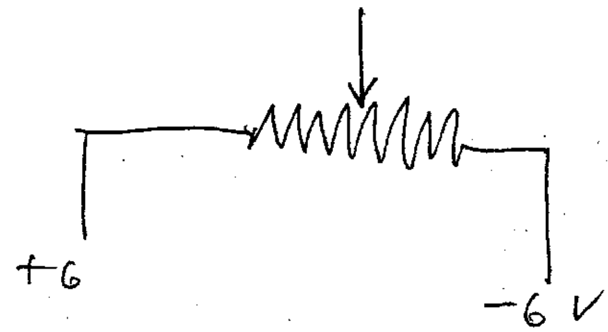


The gain is the slope

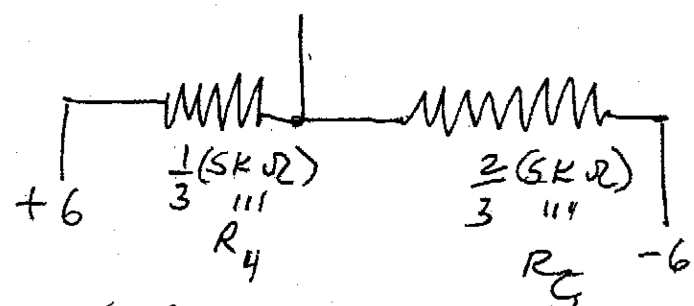
$$\frac{V_{output}}{V_{input}} = .087 \frac{V}{mV}$$

$= 87$

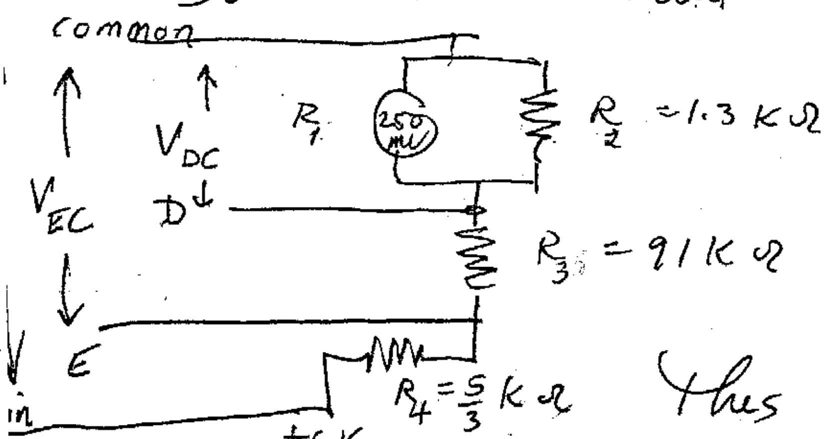
The gain does remain constant until -40 mV and $+50$ mV inputs part b1) when the pot is turned 2/3 of the way in the direction of the +6 V line, we mean that the 5 kΩ resistance is divided



into "two" resistors $R_4 = \frac{5}{3}\,k\Omega$, $R_5 = \frac{10}{3}\,k\Omega$



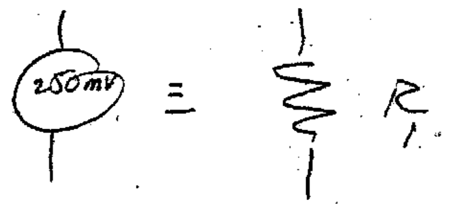
So the circuit diagram looks like



notice we can ignore the connection to the -6 V line.

This circuit acts like a voltage divider the 250 mV setting acts like a resistor

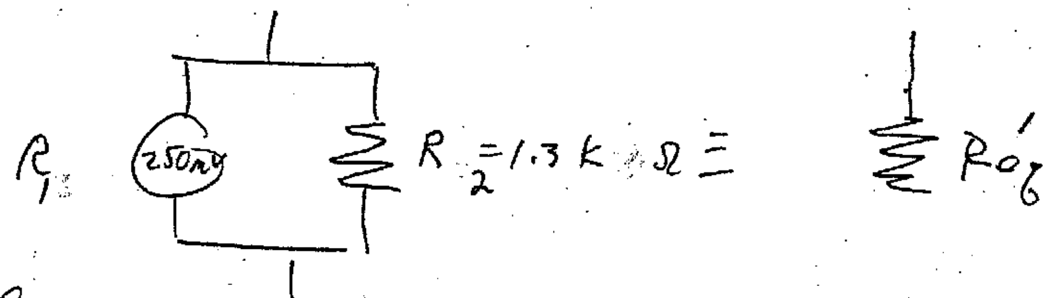
the



has a

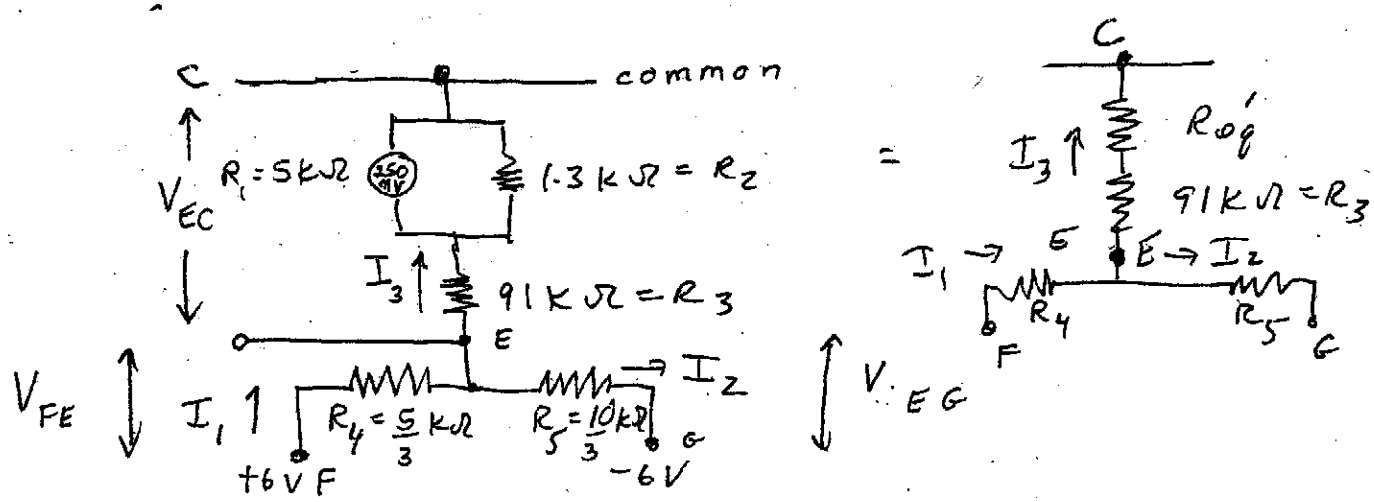
resistance $R_1 = \left(\frac{20{,}000\ \Omega}{\max V}\right)\left(250\ mV\right) = 5K\Omega$

So



these two resistors have an equivalent resistance (parallel rule)

$$R_{eq}' = \frac{R_1 R_2}{R_1 + R_2} = \frac{(5K\Omega)(1.3K\Omega)}{5K\Omega + 1.3K\Omega} = 1.03\ K\Omega$$



We are trying to determine the voltage V_{EC}

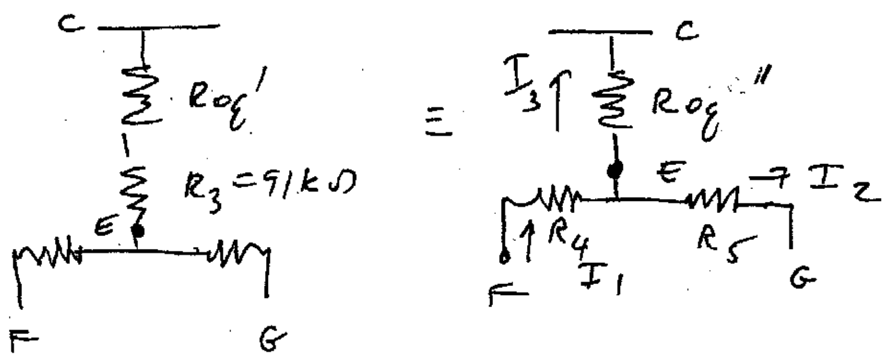
let $V_{FE} = V_F - V_E$, $V_{EG} = V_E - V_G$, $V_{EC} = V_E - V_C$

$$I_1 = \frac{V_{FE}}{R_4} \qquad I_2 = \frac{V_{EG}}{R_5}$$

$$V_{FE} + V_{GE} = 12 \text{ Volts}$$

$$I_1 = I_2 + I_3$$

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



$$R_{eq}'' = R_{eq}' + R_3 = (1.03\ k\Omega) + 91K\Omega = 92K\Omega$$

$$I_3 = \frac{V_{EC}}{R_{eq}''}$$

$I_1 = I_2 + I_3$ becomes

$$\frac{V_{FE}}{R_4} = \frac{V_{GE}}{R_5} + \frac{V_{EC}}{R_{eq}^2} \qquad (1)$$

Now

$$V_{FE} + V_{EC} = 6 \text{ Volts}$$

$$-V_{EC} + V_{EG} = -(V_E - V_C) + V_E - V_G = V_C - V_G = 6\,V$$

Thus

$$V_{FE} = 6\,V - V_{EC} \qquad (2)$$

$$V_{EG} = 6\,V + V_{EC} \qquad (3)$$

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

$$\frac{6V - V_{EC}}{R_4} = \frac{6V + V_{EC}}{R_5} + \frac{V_{EC}}{R_{eq}^2}$$

solving for V_{EC}

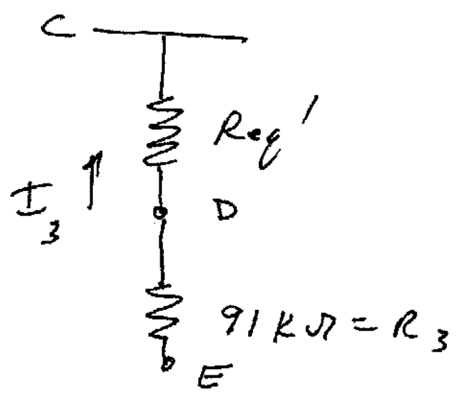
$$6V\left(\frac{1}{R_4} - \frac{1}{R_5}\right) = V_{EC}\left(\frac{1}{R_5} + \frac{1}{R_{eq}^2} + \frac{1}{R_4}\right)$$

$$V_{EC} = \frac{6\,V\left(\frac{1}{R_4} - \frac{1}{R_5}\right)}{\frac{1}{R_5} + \frac{1}{R_{eq}^2} + \frac{1}{R_4}} = \frac{6\,V\left(\frac{1}{\frac{5}{3}k\Omega} - \frac{1}{\frac{10}{3}k\Omega}\right)}{\left(\frac{1}{\frac{5}{3}k\Omega} + \frac{1}{92\,k\Omega} + \frac{1}{\frac{10}{3}k\Omega}\right)}$$

$$V_{EC} = 1.98\,V$$

b2) From part b1)

$$V_{EC} = 1.98\text{ V} \quad , \quad I_3 = \frac{V_{EC}}{R_{eq}''} = \frac{1.98\text{V}}{92\text{k}\Omega} = 21.5\text{mA}$$

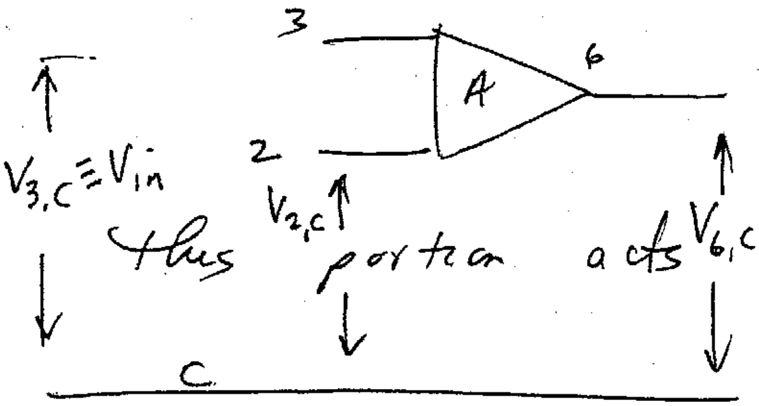


$$V_{DC} = I_3 R_{eq}'$$

$$= V_{EC}\frac{R_{eq}'}{R_{eq}''} = (1.98\text{V})\left(\frac{1.03\text{k}\Omega}{92\text{ k}\Omega}\right) = 22\text{ mV}$$

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:



this portion acts as an amplifier.

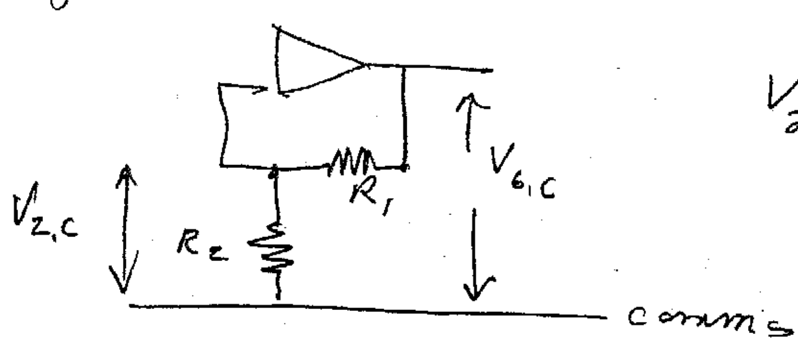
I. the first step is to subtract $V_{2,c}$ from $V_{3,c}$

$$(V_{3,c} - V_{2,c})$$

this voltage is then amplified to get the output voltage

$$A\,(V_{3,c} - V_{2,c}) = V_{6,c} \equiv V_{out} \qquad (1)$$

II. the voltage $V_{2,c}$ is the result of a voltage divider like the last problem



$$V_{2,c} = V_{6,c}\,\frac{R_2}{R_1 + R_2}$$

the ratio $\beta \equiv \frac{R_2}{R_1+R_2} = \frac{.1\,K\Omega}{(9.1K\Omega + .1K\Omega)} = \frac{1}{92}$

So
$$V_{2,c} = \beta V_{6,c} = \beta V_{out} \qquad (2)$$

III Combining these two results

$$A(V_{3,c} - V_{2,c}) = V_{6,c}$$

note:
$V_{3,c} \equiv V_{in}$
$V_{6,c} = V_{out}$
$V_{2,c} = \beta V_{out}$

So
$$A(V_{in} - \beta V_{out}) = V_{out} \qquad (3)$$

Solve eq (3) for $G = V_{out}/V_{in}$

$$A V_{in} = V_{out} + A\beta V_{out}$$
$$= V_{out}(1 + A\beta)$$

$$\Rightarrow G = \frac{V_{out}}{V_{in}} = \frac{A}{1+A\beta} \qquad (4)$$

Now $A \simeq 10^5$, $\beta \simeq 10^{-2}$ so

$A\beta \simeq 10^3 >> 1$ thus

$$1 + A\beta \simeq A\beta \qquad (5)$$

therefore

$$G = \frac{V_{out}}{V_{in}} = \frac{A}{1+A\beta} \simeq \frac{A}{A\beta} \simeq \frac{1}{\beta} = 92$$

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

In problem 1, $G \simeq 87$ so this is pretty close in agreement to the theoretical prediction. (note: values for resistors are accurate to 5%)