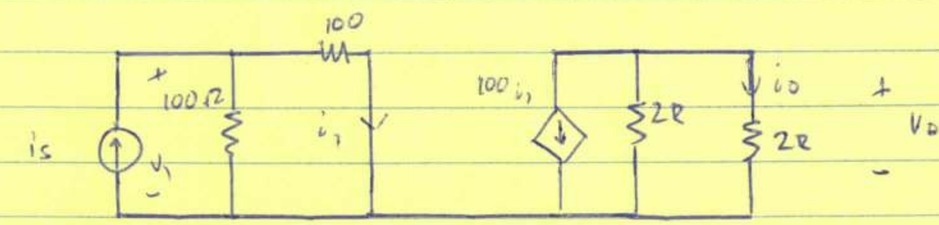
HW #5 SOLUTIONS,

AMIT PANDEY

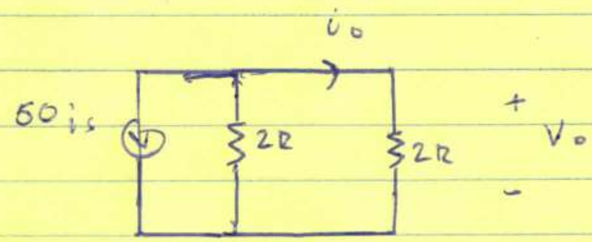
4.2.



① Find an expression for i_1.

→ We have a current divider between two equal valued resistors, so $i_1 = \dfrac{i_s}{2}$

Redraw second half of circuit with value of current source



We have another current divider with two equal valued resistances. ⇒ $i_o = \dfrac{-50 i_s}{2}$, $\dfrac{i_o}{i_s} = -25$

Now we want to find the voltage gain.

$v_s = i_s \cdot 50$

$v_o = 2R\, i_o$

$$\frac{v_o}{v_s} = \frac{2R\, i_o}{50\, i_s}$$

$$= \frac{2N}{50}(-25)$$

$$= -1000$$

Now for $i_s = 5mA$, we want to find the power supplied and the power delivered.

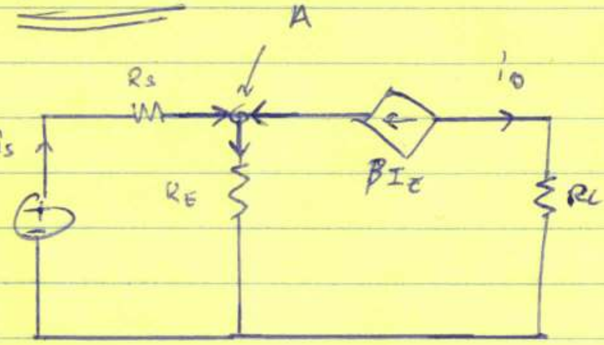
POWER SUPPLIED

$$P = I^2 R$$
$$= 50 \times (5 \times 10^{-3})^2$$
$$= \underline{\underline{1.25mW}}$$

POWER DELIVERED

$$P = V \cdot I$$
$$= 2k\, i_o \cdot -\frac{50\, i_s}{2}$$
$$= 2k\left(\frac{-50}{2} i_s\right)^2$$
$$= \underline{\underline{31.25W}}$$

4.6



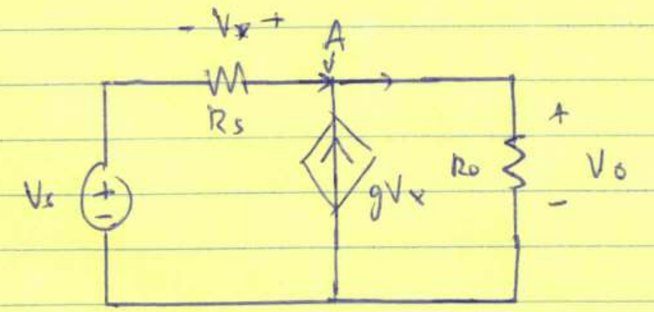
$$\frac{V_A - V_s}{R_s} + \beta I_E = \frac{V_A}{R_E}$$] nodal analysis at A.

$$\underbrace{i_s}_{} + \beta I_E = I_E$$] Convert to currents because we want to find the current gain.

$$i_s = I_E(1-\beta), \quad i_o = -\beta I_E$$
$$I_E = \frac{-i_o}{\beta}$$

$$\Rightarrow i_s = \frac{-i_o}{\beta}(1-\beta), \quad \frac{i_o}{i_s} = -\frac{\beta}{1-\beta} = \frac{\beta}{\beta - 1}$$

4.9) Find an expression for the voltage gain V_o/V_s.



Nodal Analysis at A:

$$\frac{V_s - V_A}{R_s} + gV_x = \frac{V_A}{R_o}$$

$$V_A = V_o$$

$$V_x = V_o - V_s$$

$$\Rightarrow \quad \frac{V_s - V_o}{R_s} + g(V_o - V_s) = \frac{V_o}{R_o}$$

$$V_s\left(\frac{1}{R_s} - g\right) = V_o\left(\frac{1}{R_o} + \frac{1}{R_s} - g\right)$$

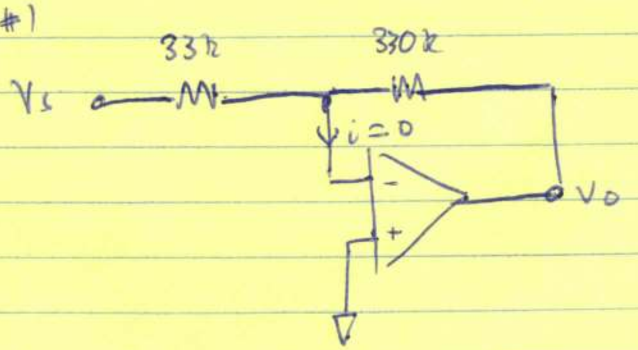
$$\frac{V_o}{V_s} = \frac{1 - gR_s}{R_s} \div \left(\frac{1}{R_o} + \frac{1}{R_s} - g\right)$$

$$= \frac{1 - gR_s}{R_s} \div \left(\frac{R_s + R_o - gR_oR_s}{R_oR_s}\right)$$

$$= \frac{(1 - gR_s)R_o}{(R_s + R_o - gR_oR_s)}$$

4.23

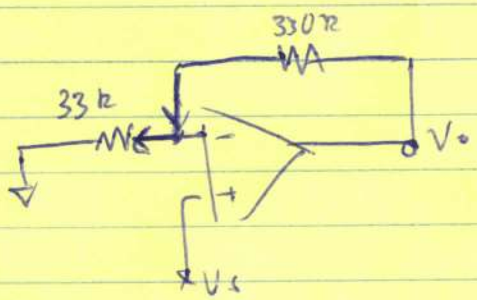
OPAMP #1



$$V_+ = V_- = 0$$

$$\frac{V_s}{33k} = \frac{-V_o}{330k}, \qquad \frac{V_o}{V_s} = \underline{\underline{-10}}$$

OPAMP #2

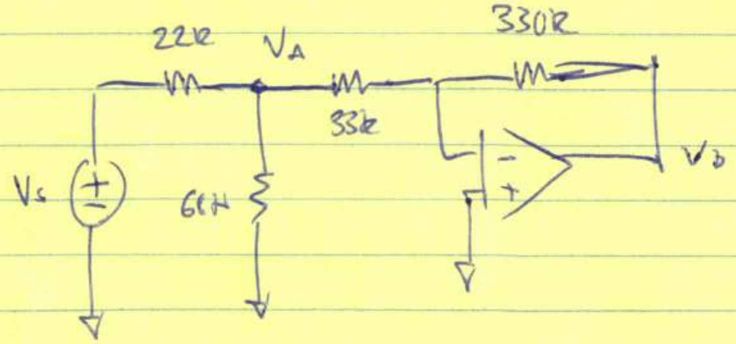


$$\frac{V_s}{33k} = -\left(\frac{V_s - V_o}{330k}\right), \quad \Rightarrow \quad V_s\left(\frac{1}{33k} + \frac{1}{330k}\right) = \frac{+V_o}{330k}$$

$$\frac{V_o}{V_s} = 330k\left(\frac{1}{33k} + \frac{1}{330k}\right)$$

$$\frac{V_o}{V_s} = \underline{\underline{11}}$$

4.27)



Find expression for $\frac{V_o}{V_s}$.

Nodal analysis at A:

$$\frac{V_s - V_A}{22k} = \left(\frac{1}{68k} + \frac{1}{33k}\right) V_A$$

$$\frac{V_s}{22k} = V_A\left(\frac{1}{68k} + \frac{1}{33k} + \frac{1}{22k}\right)$$

$$\frac{V_A}{V_s} = \frac{1}{22k} \div \left(\frac{1}{68k} + \frac{1}{33k} + \frac{1}{22k}\right)$$

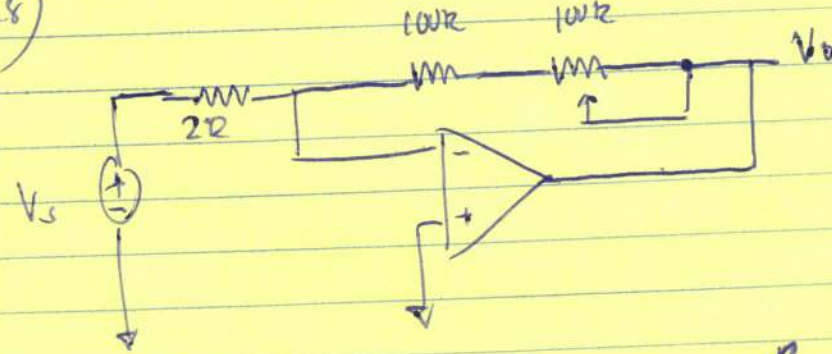
$$\frac{V_A}{33k} = -\frac{V_o}{330k}$$

$$V_o = -10 V_A \quad , \quad V_A = \frac{-V_o}{10}$$

$$\Rightarrow \quad \frac{V_o}{V_s} = \frac{-10}{22k} \div \left(\frac{1}{68k} + \frac{1}{33k} + \frac{1}{22k}\right)$$

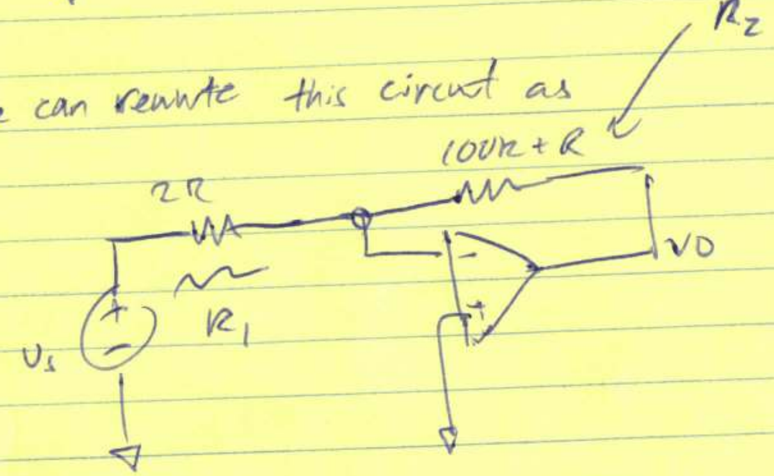
$$= \underline{\underline{-5.02}}$$

4.28)



We can rewrite this circuit as

$0 \le R \le 100k$



This is now an inverting amplifier gain: $\frac{-R_2}{R_1}$

$$g = \frac{-100k + R}{2k}$$

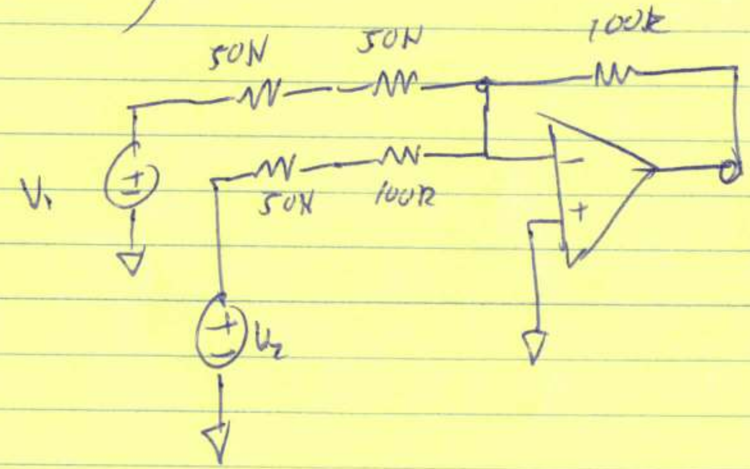
So gain can vary between $\boxed{-50, \rightarrow -100}$

$$-100 \le \frac{V_O}{V_s} \le -50$$

4.32)

When gain = 10, output voltage = 20V but Vcc = 15V, so the amplifier saturates. Fix would be to increase Vcc to above $2V \times 10 = 20V$.

4.34)



This is an inverting summer:

$$V_o = -V_1 - \frac{100k}{150k} V_2$$

(a) $$V_o = -\left(V_1 + \frac{2}{3} V_2\right)$$

(b) $$V_o = -1 - \frac{2}{3} V_2$$

Max rail:

$$15 = -1 - \frac{2}{3} V_2$$

$$16 = \frac{-2}{3} V_2 \qquad V_2 = -24V$$

Min rail

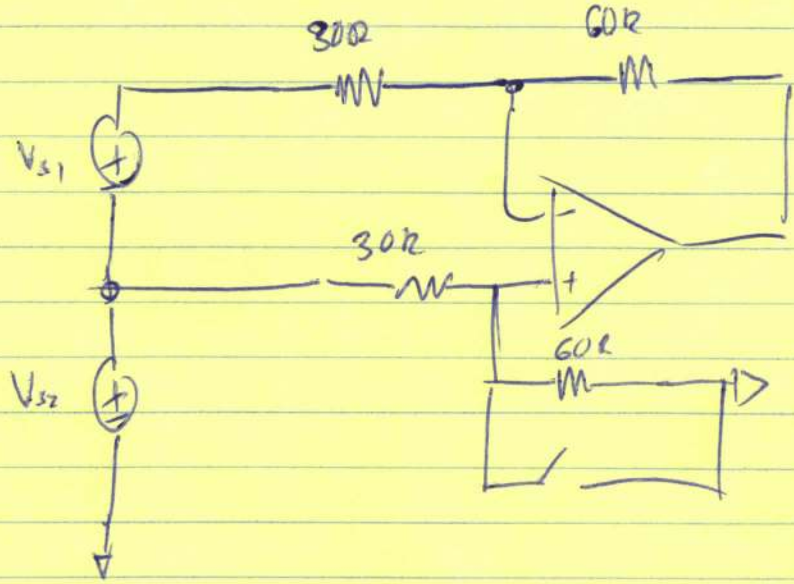
$$-15 = -1 - \frac{2}{3} V_2$$

$$V_2 = 21V$$

so:

$$-24V \leq V_2 \leq 21V$$

4.37)



Switch open:

$$V_+ = \frac{V_{s2}}{90k} \cdot 60k = \frac{2}{3} V_{s2} = V_-$$

$$\frac{V_{s1} + V_{s2} - \frac{2}{3}V_{s2}}{30k} = \frac{\frac{2}{3}V_{s2} - V_o}{60k}$$

$$\frac{V_{s1}}{30k} + \frac{V_{s2}}{30k} - \frac{2V_{s2}}{90k} = \frac{2V_{s2}}{180k} - \frac{V_o}{60k}$$

$$\Rightarrow \quad \frac{V_{s1}}{30k} = \frac{-V_o}{60k} \quad \Rightarrow \quad V_o = -2V_{s1}$$

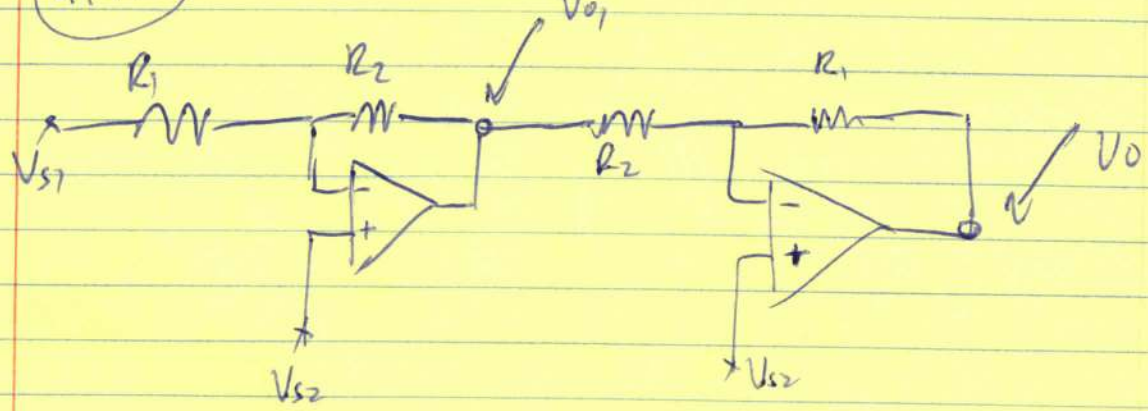
Switch closed:

$V_+ = 0 = V_-$

$$\frac{V_{s1} + V_{s2}}{30k} = \frac{-V_0}{60k}$$

$$\underline{V_0 = -2(V_{s1} + V_{s2})}$$

(4.47)



(1) $$\frac{V_{s1} - V_{s2}}{R_1} = \frac{V_{s2} - V_{o1}}{R_2}$$

$$-R_2\left[\frac{V_{s1}}{R_1} - \frac{V_{s2}}{R_1} - \frac{V_{s2}}{R_2}\right] = V_{o1}$$

(2) $$\frac{V_{o1} - V_{s2}}{R_2} = \frac{V_{s2} - V_o}{R_1}$$

$$V_o = -R_1\left[\frac{V_{o1}}{R_2} - \frac{V_{s2}}{R_2} - \frac{V_{s2}}{R_1}\right]$$

$$= -R_1\left[\frac{V_{s1}}{R_1} \cancel{+\frac{V_{s2}}{R_1}} \cancel{+\frac{V_{s2}}{R_2}} \cancel{-\frac{V_{s2}}{R_2}} \cancel{-\frac{V_{s2}}{R_1}}\right]$$

$$= -R_1\left[\frac{V_{s1}}{R_1}\right]$$

$$= \underline{\underline{-V_{s1}}}$$