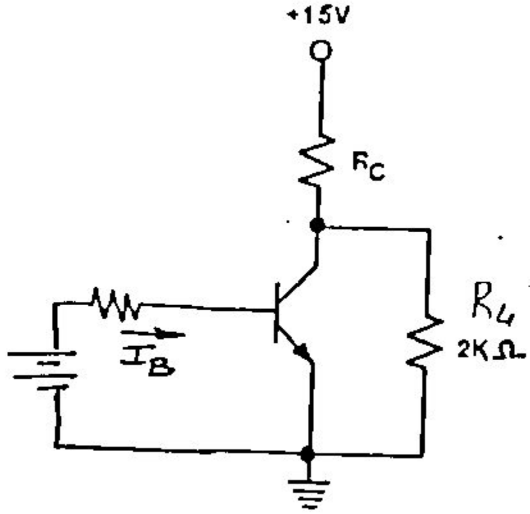


Solution:

$I_c = \beta I_B = 50 \times 0.054 = 2.7\,mA$

$V_B = 0.7V = V_C = 0.7V$

$I_{R_L} = \frac{0.7}{2{,}000} = 0.35\,mA$

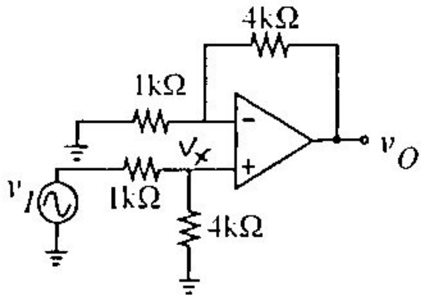
$I_{R_C} = I_C + I_{R_L} = 2.7 + 0.35 = 3.05\,mA$

$R_C = \frac{15 - 0.7}{3.05\,mA} \approx 4.7\,k\Omega$

$R_C = \underline{4.7\,k\Omega}$

Question 2:

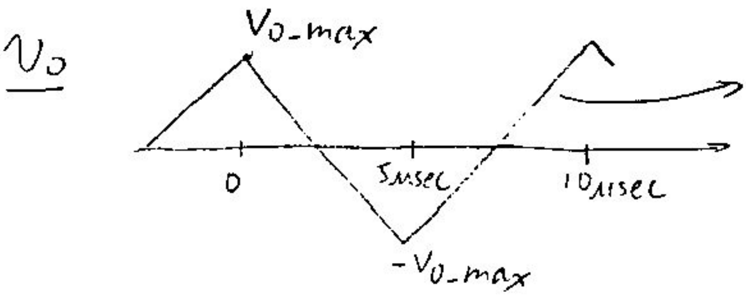
[8 marks] The op amp in the circuit has a unity-gain frequency, $f_t = 10MHz$ and an output slew rate of $\pm 5V/\mu sec$, but is otherwise ideal.



a) If the input signal v_I is a 100kHz triangular wave with no dc offset, what is its maximum peak-to-peak amplitude in order for the circuit to operate without slewing?

$v_{I(max, peak-to-peak)}$ =	6.25V

gain: $\frac{V_O}{V_I} = \frac{V_O}{V_x} \times \frac{V_x}{V_I} = \left(1 + \frac{4k}{1k}\right) \times \frac{4k}{1k+4k} = 4\ V/V$ ✓ ①



slope $= \frac{\Delta y}{\Delta x} = \frac{2 V_{O\_max}}{\frac{1}{2}\text{ period}}$

$= \frac{2 V_{O\_max}}{5\mu sec}$ ② ✓ ①

Set slope = SR

$\therefore \frac{2 V_{O\_max}}{5\mu sec} = 5 V/\mu sec$

$V_{O\_max} = 12.5V$ ①✓

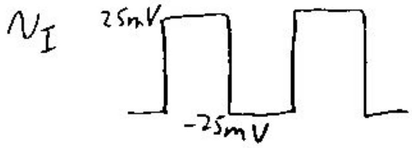
Refer back to input:

$V_{I(max, pk\text{-}pk)} = \frac{2 \times V_{O\_max}}{gain} = \frac{25V}{4 V/V} = 6.25V$ ① ✓

4 marks

Question 2(cont.)

b) Given that the input signal v_I is now a 1 MHz, 25mV(peak) square wave with no dc offset, sketch the output waveform, indicating key features of the curve (e.g. peak voltage, period, etc.). Is the output signal limited by the slew rate?



Closed loop bandwidth ✓

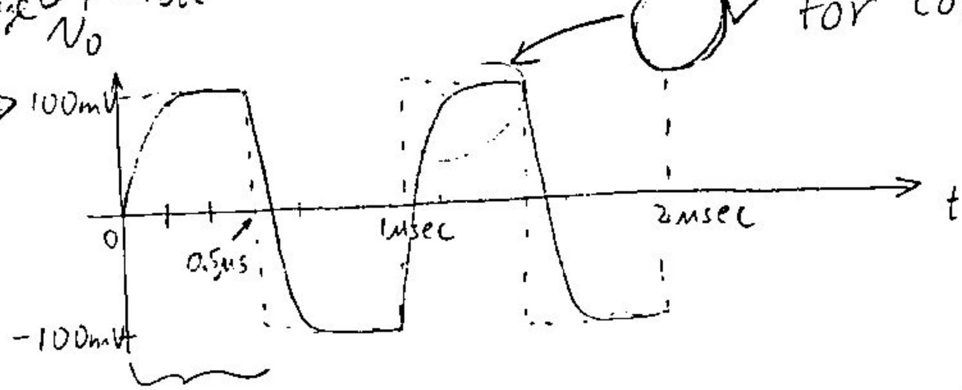
$$\omega_{CL} = \frac{\omega_t}{1 + 4k\Omega/1k\Omega} = 2\pi \times 2\ \text{MHz} \Rightarrow \tau = 79.6\text{nsec}$$

∴ Closed loop response

$$\frac{v_O}{v_I} = 4\ V/V \times \frac{1}{1 + s/\omega_{CL}}$$

correct peak voltage & period ✓ ⇒

✓ for correct settling time



Output is a 1st order LPF response ✓
with ½ period (0.5μsec) being 6.28 × τ
Waveform should settle to 90% by ⅓ of ½ period

Check If slewing: (1 mark)

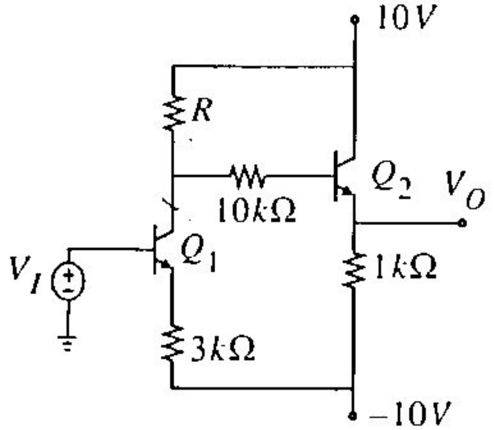
$$v_O = 0.2(e^{t/\tau} - 1) - 0.1$$

$$\therefore \text{max slope} = \frac{dv_O}{dt} = \frac{0.2V}{\tau} = \frac{0.2V}{79.6\text{nsec}} = 2.51\ V/\mu\text{sec} < SR$$

Not slewing

Question 3:

[6 marks] For the circuit shown below, find the value of R that sets $V_O = 0V$ when $V_I = 0V$. Assume $\beta = 100$ for Q_1, and β for = 50 and ignore the Early effect.



R = 2.2 kΩ

Solution: Assume Q1 & Q2 are in active mode

$V_{E_1} = -0.7V$

$I_{E_1} = \frac{-0.7-(-10)}{3000} = 3.1mA; \quad I_{C_1} = \frac{\beta_1}{\beta_1+1} I_{E_1} = 3.07mA$

$I_{E_2} = \frac{V_o-(-10)}{1000} = 10mA \quad I_{C2} = 9.8mA$

$I_{B2} = \frac{1}{\beta_2+1} I_{E2} = \frac{10mA}{51} \approx 0.2mA; \quad V_{CB_2} = 10-0.7 = 9.3V$ (Q_2-active) (Don't mark down)

$V_{C_1} = 0.7 + I_{B2} \cdot 10K = 0.7 + 0.2mA \times 10K = 2.7V$ (Q1-active)

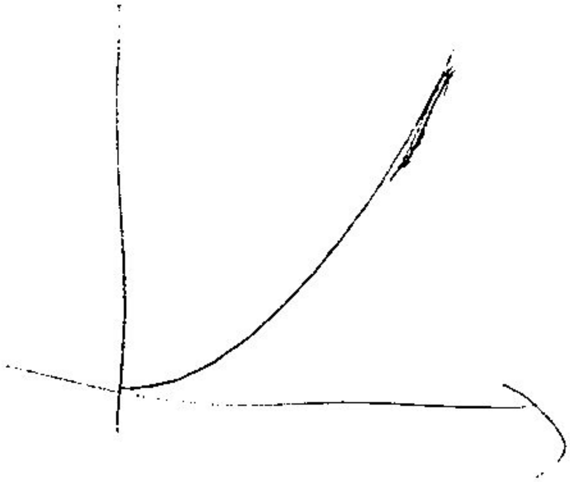
$I_R = I_{C_1} + I_{B2} = 3.07mA + 0.2mA = 3.27mA$

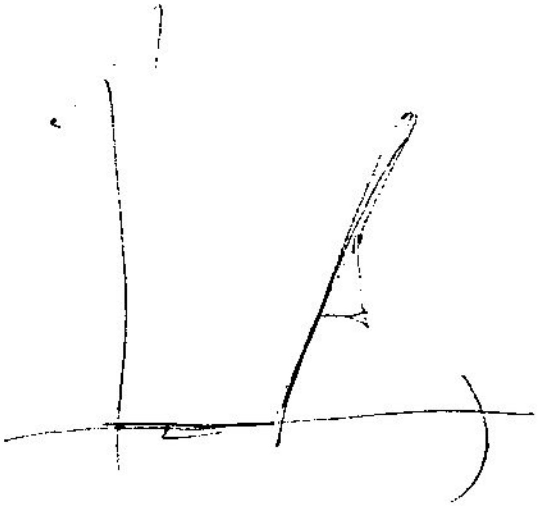
$R = \frac{10-V_{C_1}}{I_R} = \frac{10-2.7}{3.27mA} = 2.2k\Omega$

Total: 6

If ignore I_{B_2} −1 mark

If V_{B2} wrong −1 mark



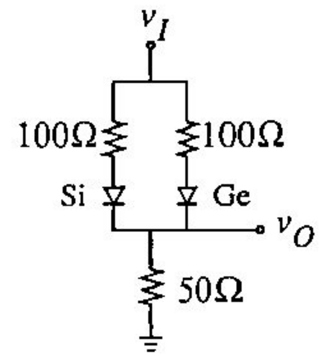


- Counting 370 papers
- Sort by last name
- Give

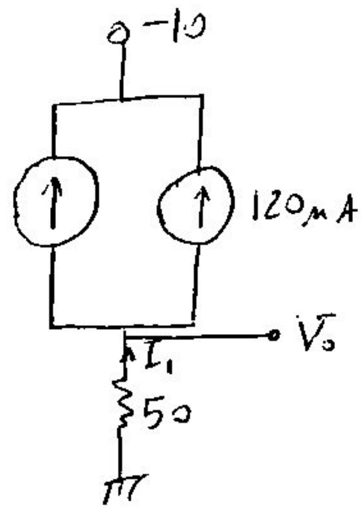
Last Name: Jahromi
[Marking + Solutions]

Question 4:

[8 marks] Consider the circuit shown below where 'Ge' and 'Si' represent semiconductor diodes made of germanium (n = 1) and silicon (n = 2) respectively. Assume when the diodes are forward biased and conducting current that the voltage drop is 0.7V for Si but only 0.3V for Ge. At room temperature and when reverse biased, the current is $120\mu A$ for the Ge diode and $30\mu A$ for the Si diode. The reverse break-down voltage is 100V for both diodes.



Part a)



(a) Calculate the output voltage if $v_I = -10V$.

v_O = −7.5 mV

$I_1 = 120\mu A + 30\mu A = 150\mu A$

$V_o = -50 I_1 = -7500\mu V = -7.5\ mV$

Question 4 (cont.)

b) Circle the correct answer to the following questions:

i. If v_I increases slightly, v_O will

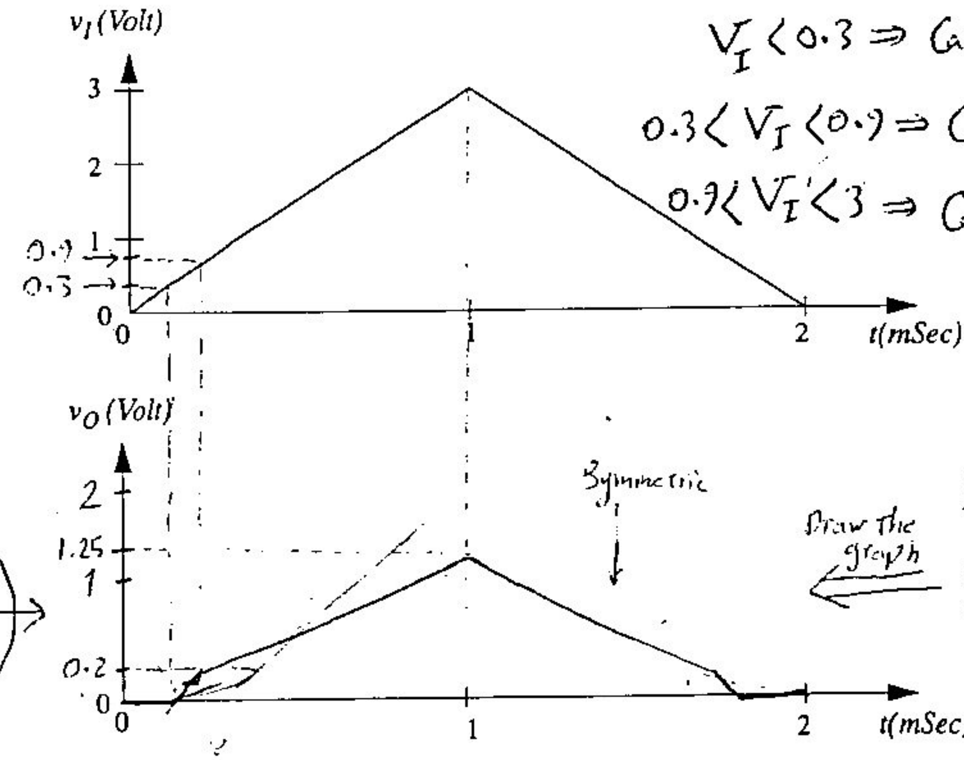
Increase **Decrease** **Remain constant**

ii. If the temperature increases slightly, v_O will

Increase **Decrease** **Remain constant**

Question 4 (cont.)

c) Plot v_O as a function of time when the input voltage v_I changes as shown in the figure below.
On your plot, indicate the value of v_O at significant points along the curve.



$V_I < 0.3 \Rightarrow$ Case A $\Rightarrow V_o = 0$

$0.3 < V_I < 0.9 \Rightarrow$ Case B $\Rightarrow V_o = \frac{1}{3}(V_I - 0.3)$

$0.9 < V_I < 3 \Rightarrow$ Case C $\Rightarrow V_o = \frac{1}{2}(V_I - 0.5)$

Key points

Draw the graph

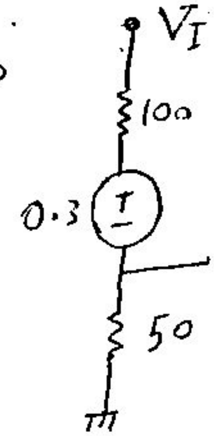
$\{V_o = 0$ where $V_I = 0.3\}$

$\{V_o = 0.2$ where $V_I = 0.9\}$

$\{V_o = 1.25$ where $V_I = 3\}$

Case A: $V_I < 0.3 \Rightarrow$ Si and Ge both off $\Rightarrow$ $\boxed{V_o = 0\,V}$

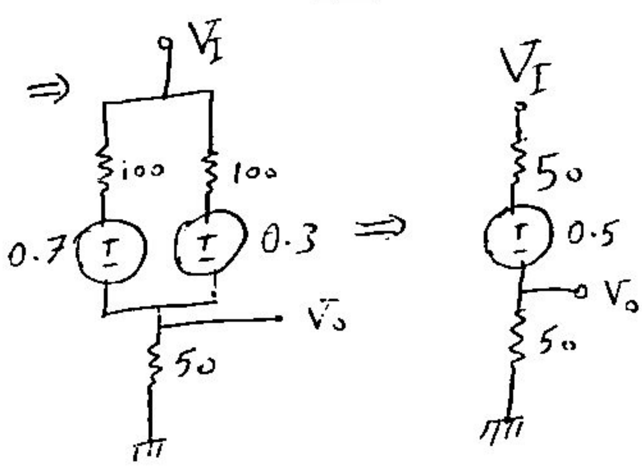
Case B: ~~[scribbled out]~~ Ge ON, Si off $\Rightarrow$



$\Rightarrow \boxed{V_o = \frac{1}{3}(V_I - 0}$

Gas C: Ge ON and Si ON

$\Rightarrow$

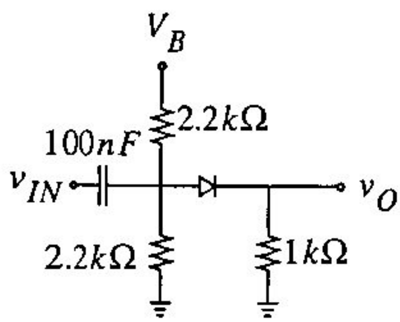


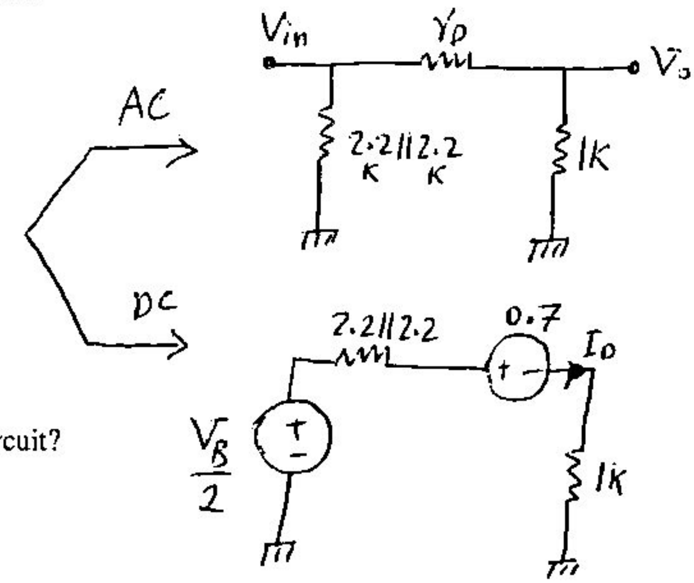
$\Rightarrow \boxed{V_o = \frac{1}{2}(V_I - 0.5)}$

See Top of the page

Question 5:

[7 marks] In the circuit shown below, V_B is a fixed DC voltage and v_{IN} is a sinusoidal voltage source whose amplitude is 11mV (peak-to-peak). The diode is made such that n = 1 and its voltage drop is about 0.7V when forward biased.





(a) For small-signals, what type of filter is this circuit?

High-Pass

(b) Find V_B such that the small-signal sinusoidal output is 10mV (peak-to-peak) at high frequencies. Do not neglect the small-signal resistance of the diode. (Hint: At high frequencies, the capacitor can be approximated by a short circuit).

AC Circuit → $\frac{V_o}{V_{in}} = \frac{1k}{1k + r_D} = \frac{10mV}{11mV}$

V_B = 2.45 V

→ $r_D = 100\Omega$

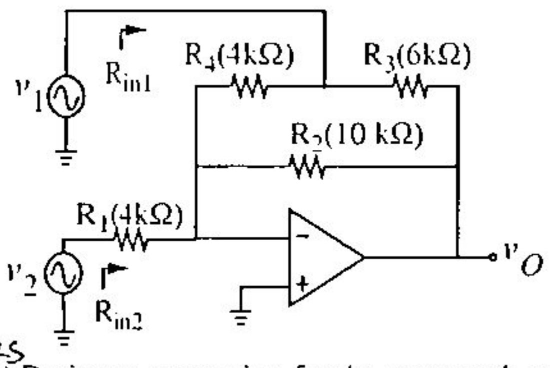
$r_D \triangleq \frac{n V_T}{I_D} \Rightarrow I_D$ must be $\frac{1 \times 25mV}{100\Omega} = 0.25mA$

DC Circuit → $\frac{V_B}{2} = (1.1k + 1k) I_D + 0.7 \Rightarrow V_B = 4.2K \times 0.25m + 1.4$

$\Rightarrow V_B = 1.05 + 1.4 = 2.45$

Question 6:

[6 marks] For the circuit below, assuming the op amp is ideal,

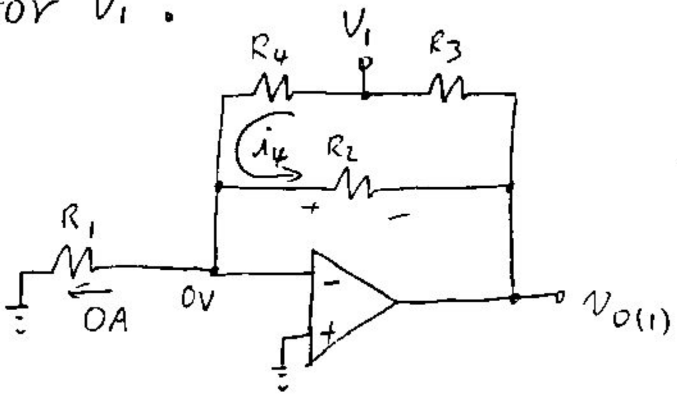


3 marks

a) Derive an expression for the output voltage in terms of signals v_1 and v_2.

Attempt at superposition ✓

for V_1:



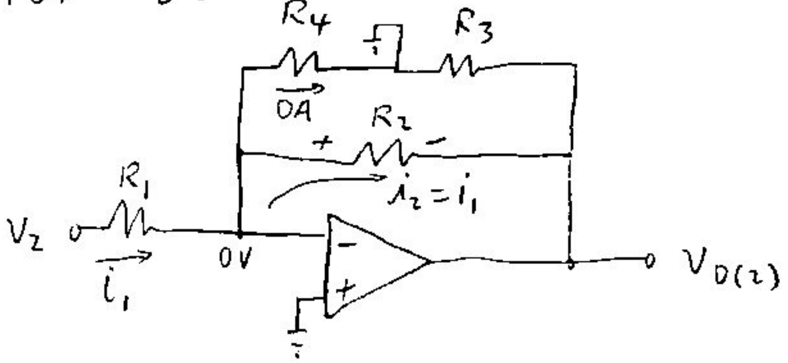
$i_4 = V_1/R_4$

$v_{O(1)} = 0V - i_4 R_2$

$\therefore v_{O(1)} = -\frac{R_2}{R_4} v_1$ ✓

R_3 does not affect $v_{O(1)}$

for V_2:



$i_1 = v_2/R_1$

$v_{O(2)} = 0V - i_2 R_2$

$= -\frac{R_2}{R_1} v_2$ ✓

R_3 does not affect $v_{O(2)}$

$$\text{Total } v_O = -\frac{R_2}{R_4} V_1 - \frac{R_2}{R_1} v_2$$

$$= -\frac{10k}{4k} V_1 - \frac{10k}{4k} v_2$$

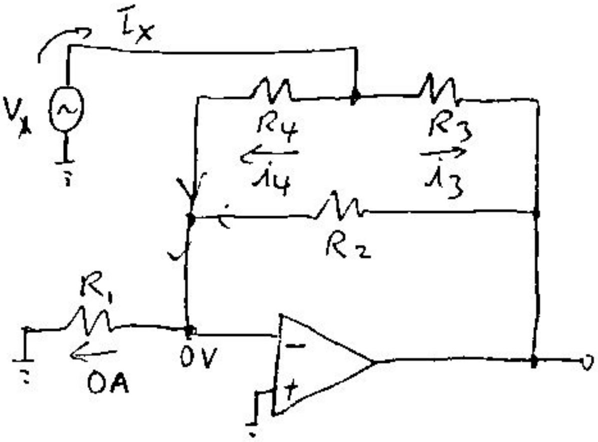
$$\boxed{v_O = -2.5(v_1 + v_2)}$$

Question 6 (cont.)

b) Calculate the input resistances, R_{in1} and R_{in2}, seen by signal sources v_1 and v_2 respectively.

R_{in1} =	R_{in2} =

For Rin1 :



$$R_{in1} \triangleq V_x / I_x$$

$$I_x = i_4 + i_3$$

$$i_4 = V_x / R_4$$

$$i_3 = \frac{V_x - V_0}{R_3} = \frac{V_x - \left(-\frac{R_2}{R_4} V_x\right)}{R_3}$$

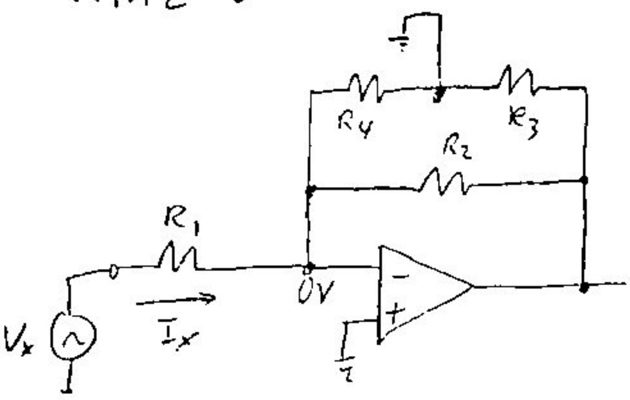
$$= \frac{\left(1 + {}^{10k}/_{4k}\right) V_x}{R_3} = \frac{3.5}{R_3} \times V_x$$

$$\therefore I_x = \left(\frac{1}{R_4} + \frac{3.5}{R_3}\right) V_x$$

$$\& \ R_{in1} = \frac{V_x}{I_x} = \left(\frac{1}{R_4} + \frac{3.5}{R_3}\right)^{-1} \ \text{or} \ R_4 // \frac{R_3}{3.5}$$

$$= 4k\Omega // \frac{6k\Omega}{3.5} = 1.2 k\Omega$$

Rin2 :



$$I_x = i_1 = V_x / R_1$$

$$\Rightarrow \therefore R_{in2} = \frac{V_x}{I_x} = R_1$$