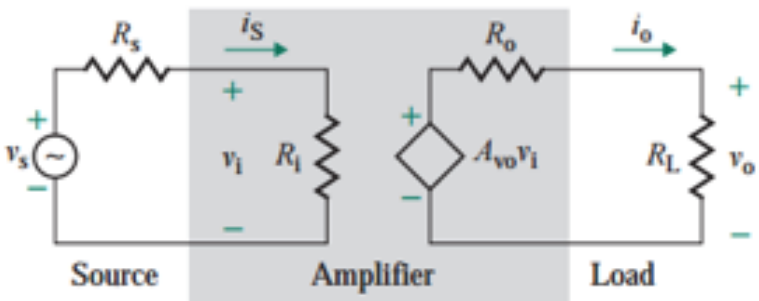
Deduct 0.5 marks per question incase of no units.

# Quiz 1: ES104 - Introduction to Analog and Digital Electronics

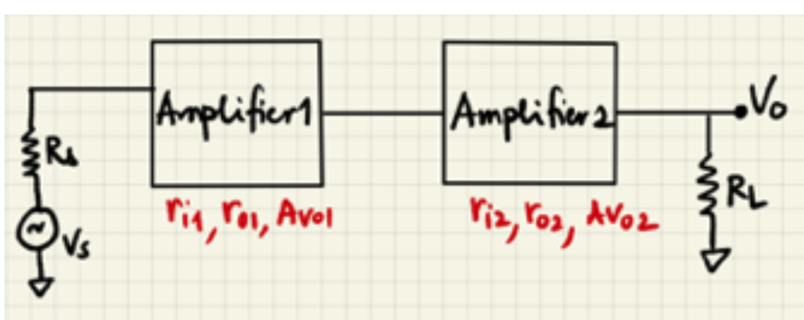
**Instructions:** The duration of the quiz is 75 minutes. After 75 minutes, you will be provided an additional 15 minutes to upload a scanned copy of your answers to Google classroom. The total marks are 30. Please show your working clearly.

**Honour code:** You are expected to abide by the honour code of IIT Gandhinagar. Do not communicate with your classmates in any manner and do not refer to any online or offline resources. Any malpractices will attract severe punitive action.

**Q.1.** A voltage amplifier is required to amplify the output signal from a communication receiver that produces a voltage signal of $V_s$ = 20 mV with an internal resistance of $R_s$ = 1.5 KΩ. The desired output voltage $V_o$ (across load, $R_L$=15 KΩ) is 10 V. The amplifier draws 1 μA from the receiver. The value of $V_o$ when the **load is disconnected** is 11 V. Determine $R_i$ and $R_o$ of the voltage amplifier. **[2+2 Marks]**

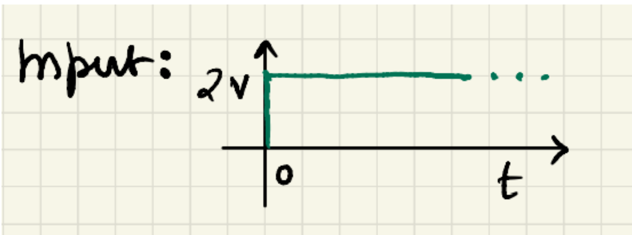


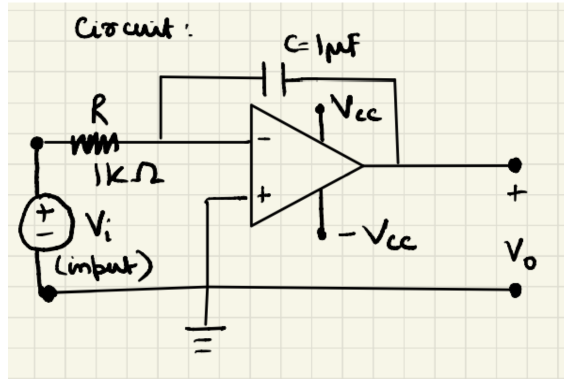

**Q.2.** The parameters of the cascaded voltage amplifier shown below are $R_s$ = 2 KΩ, $r_{o1}$ = $r_{o2}$ = 500 Ω, ri1 = ri2 = 1.5 KΩ, $R_L$ = 1.5 KΩ and $A_{v01}$ = $A_{v02}$ = 70. Calculate the effective voltage gain $A_v$ ($V_o/V_s$). **[4 Marks]**




Please check for Plagiarism.

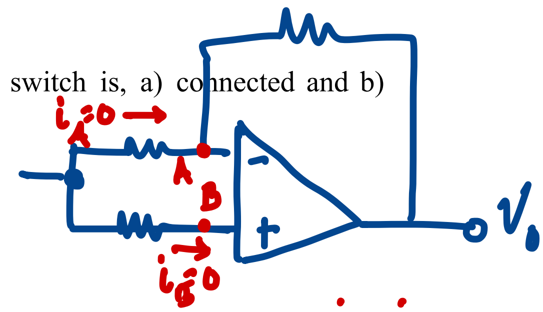
**Q.3.** The following input is applied to the given circuit. The operational amplifier is ideal. What is the output after **a very long period of time**? **[2 Marks]**

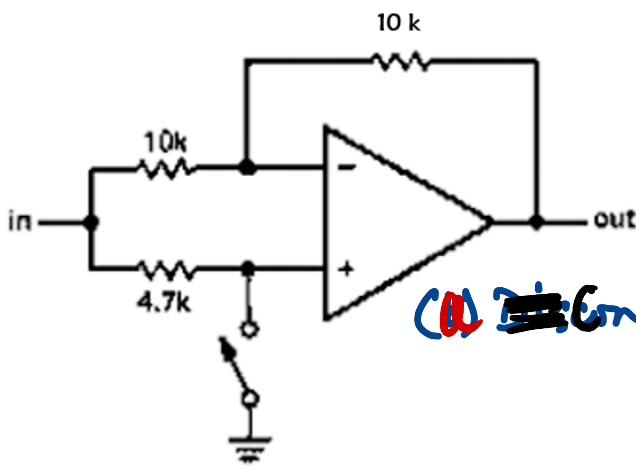



**Q.4.** In the circuit below, what is the output of the circuit when the switch is, a) connected and b) disconnected? **[2 Marks]**

(b) Dis Connected :



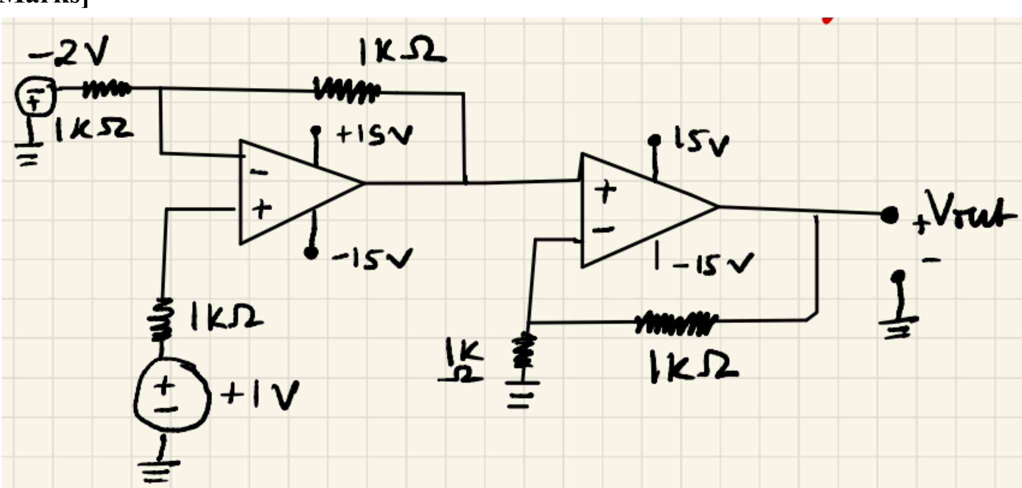

$\therefore V_A = V_B = Vin \Rightarrow i_A = i_B = 0$

$\therefore V_0 = V_A = Vin$

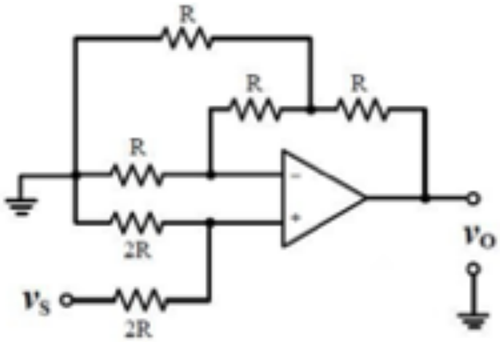
(a) Connected : Inverting amp : gain = −1

$V_0 = -Vin$

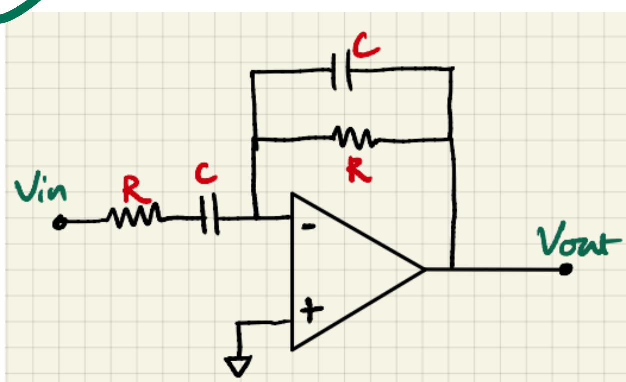
**Q.5.** Find the output voltage (Vout) for the circuit shown below. Assume that the OP-Amps are ideal. **[4 Marks]**



**Q.6.** For the figure below, what is the relation between $v_o$ and $v_s$? **[6 Marks]**



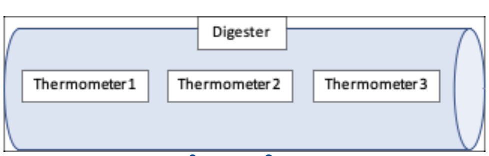

**Q.7.** What is the voltage again (in dB) at $\omega = 1/RC$? **[4 Marks]**

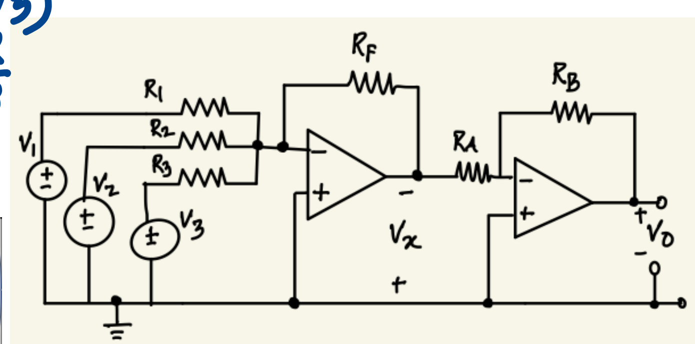



**Q.8.** The figure below shows the schematic of a high-temperature digester used in a paper mill in which wood chips are processed to produce pulp that is then used to make paper. Three thermometers are placed along the length of the digester to measure the temperature of the three regions of the digester. Each thermometer produces a voltage of 25 mV for a temperature rise of 1°C. We want to obtain the **average** of the three temperature values to find the overall digester temperature. Furthermore, 1V should appear at the output $V_0$ for every 10°C rise of the **average** temperature. Design such an averaging circuit using the opamp configuration shown below. The final output voltage must be positive. **[4 Marks]**

"Average" ⇒ $V_x = \frac{1}{3}(V_1+V_2+V_3)$

∴ Choose $R_1 = R_2 = R_3$ & $R_F = \frac{R}{3}$




Let there be a 10°C rise in the avg temp.

∴ $V_o = 1V$

$V_o = \frac{-R_B}{R_A} \cdot V_x$

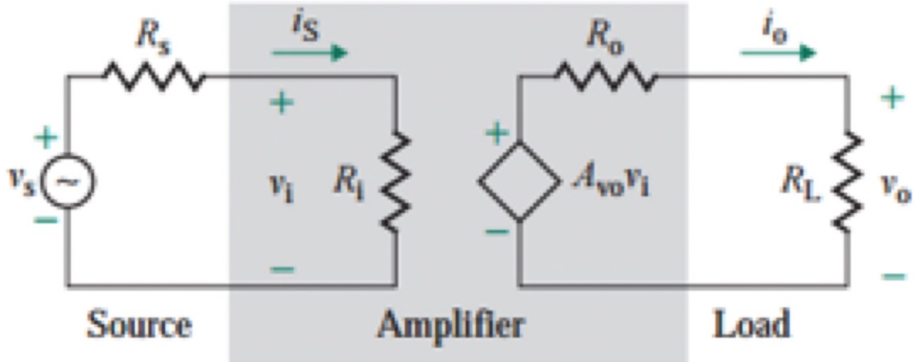
∴ $1V = -\frac{R_B}{R_A}(-250mV)$

∴ $R_B = 4R_A$

Now, $V_1$, $V_2$ & $V_3$ would each be $= 25mV/°C \times 10°C = 250mV$ ∴ $V_x = -250mV$

Now select suitable values of $R_A$ & $R_B$

**Q.1.** A voltage amplifier is required to amplify the output signal from a communication receiver that produces a voltage signal of $V_s$ = 20 mV with an internal resistance of $R_s$ = 1.5 KΩ. The desired output voltage $V_o$ (across load, $R_L$=15 KΩ) is 10 V. The amplifier draws 1 μA from the receiver. The value of $V_o$ when the **load is disconnected** is 11 V. Determine $R_i$ and $R_o$ of the voltage amplifier. **[2+2 Marks]**




Ans:

$$i_s = \frac{V_s}{R_s + R_i} = 1\,\mu A$$

$$R_s + R_i = 20\,K\Omega$$

$$R_i = 20\,K\Omega - 1.5\,K\Omega = 18.5\,K\Omega \quad 2$$

$$V_i = \frac{20mV}{20\,K\Omega} \cdot 18.5\,K\Omega = 18.5\,mV$$

$$A_{vo} V_i = 11V$$

$$V_o = \frac{A_{vo} V_i}{R_o + R_L} R_L$$

$$\frac{R_o + R_L}{R_L} = \frac{A_{vo} V_i}{V_o} = \frac{11}{10} = 1.1$$

$$1 + \frac{R_o}{R_L} = 1.1$$

$$\frac{R_o}{R_L} = 0.1$$

$$R_o = 0.1 \times 15\,K\Omega$$

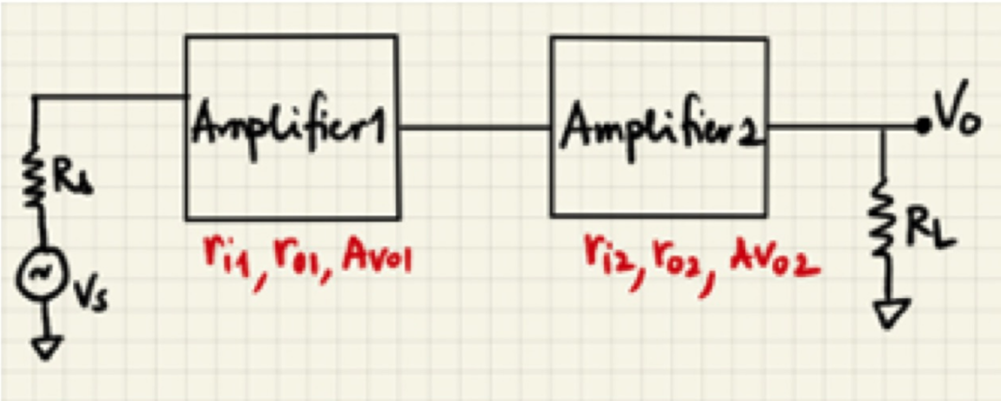
$$= 1.5\,K\Omega$$

2

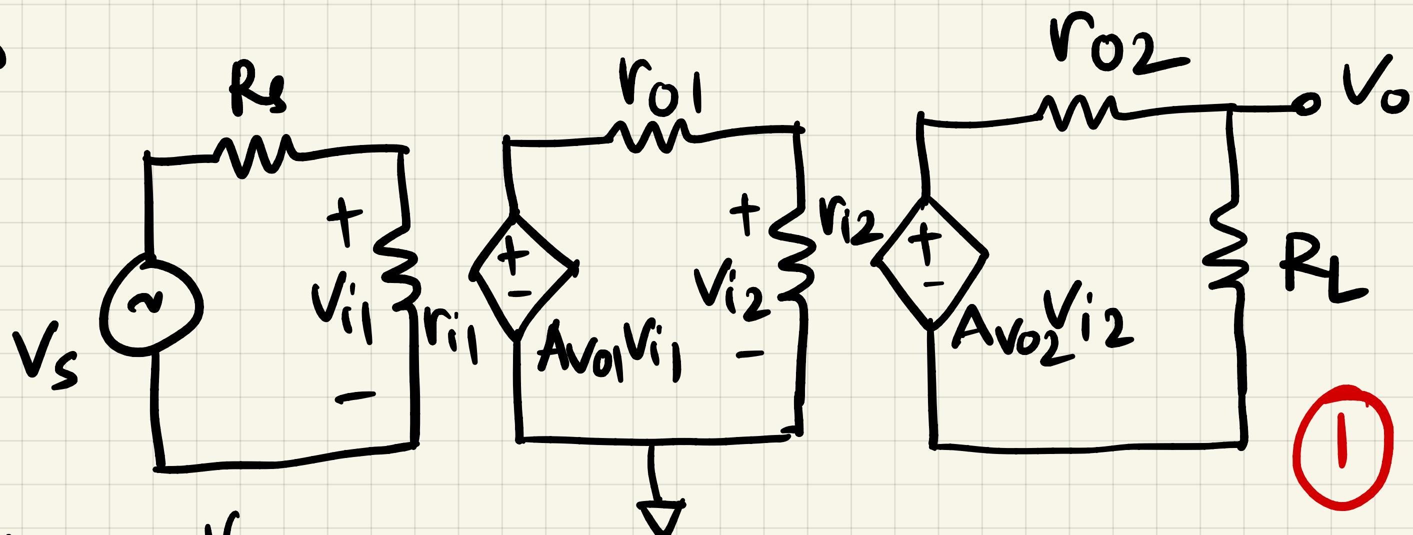
Ans

Deduct 1 mark if there are any silly mistakes.

**Q.2.** The parameters of the cascaded voltage amplifier shown below are $R_s = 2\ K\Omega$, $r_{o1} = r_{o2} = 500\ \Omega$, ri1 = ri2 = 1.5 KΩ, $R_L = 1.5\ K\Omega$ and $A_{v01} = A_{v02} = 70$. Calculate the effective voltage gain $A_v$ ($V_o/V_s$). **[4 Marks]**




<u>Ans</u>




1

$$V_{i1} = \frac{V_s}{R_s + r_{i1}} r_{i1} \quad — 1$$

$$V_{i2} = A_{vo1} V_{i1} \left( \frac{r_{i2}}{r_{o1} + r_{i2}} \right)$$

$$= A_{vo1} \cdot V_s \cdot \left( \frac{r_{i1}}{R_s + r_{i1}} \right) \left( \frac{r_{i2}}{r_{o1} + r_{i2}} \right) \quad — 1$$

$$V_o = A_{vo2} V_{i2} \frac{R_L}{r_{o2} + R_L}$$

$$= A_{vo2} \cdot A_{vo1} \cdot V_s \left(\frac{r_{i1}}{R_s + r_{i1}}\right)\left(\frac{r_{i2}}{r_{o1} + r_{i2}}\right)\left(\frac{R_L}{r_{o2} + R_L}\right)$$

$$\frac{V_o}{V_s} = A_{vo2} \cdot A_{vo1} \cdot \left(\frac{r_{i1}}{R_s + r_{i1}}\right)\left(\frac{r_{i2}}{r_{o1} + r_{i2}}\right)\left(\frac{R_L}{r_{o2} + R_L}\right) \quad \text{—} (1)$$

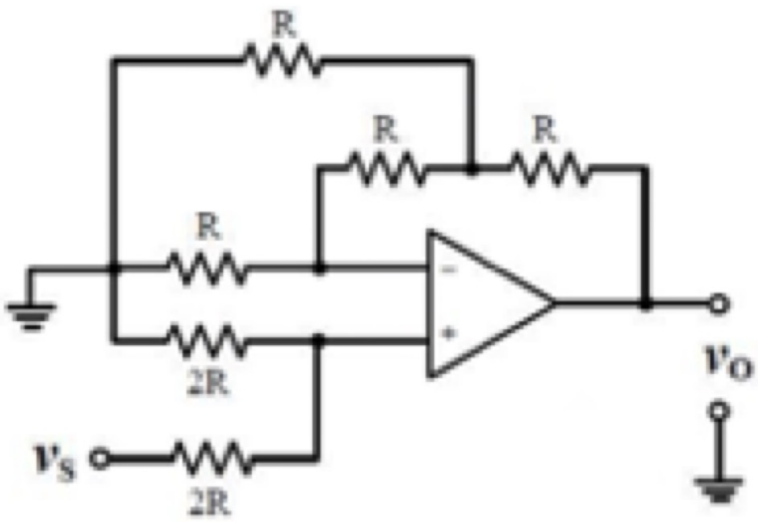
$$= 70 \cdot 70 \cdot \left(\frac{1500}{2000+1500}\right)\left(\frac{1500}{500+1500}\right)\left(\frac{1500}{500+1500}\right)$$

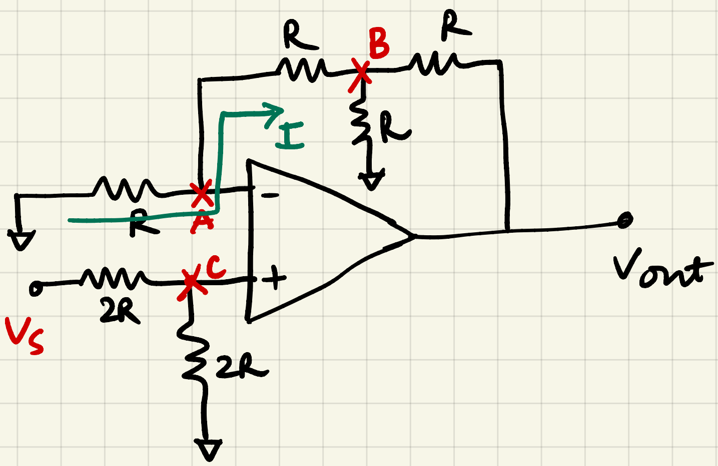
$$= 4900 \cdot \frac{3}{7} \cdot \frac{3}{4} \cdot \frac{3}{4}$$

$$= 1181.25$$

Ans

**Q.6.** For the figure below, what is the relation between $v_o$ and $v_s$? **[6 Marks]**




1 $V_C = \frac{V_s}{2}$ , $V_A = \frac{V_s}{2}$

$$I = -\frac{V_A}{R} = -\frac{V_s}{2R}$$

1

$$V_B = V_A - IR = \frac{V_s}{2} + \frac{V_s}{2R} \cdot R = V_s$$

1

KCL at node B

$$I = \frac{V_B}{R} + \frac{V_B - V_{out}}{R} = \frac{2V_B}{R} - \frac{V_{out}}{R}$$

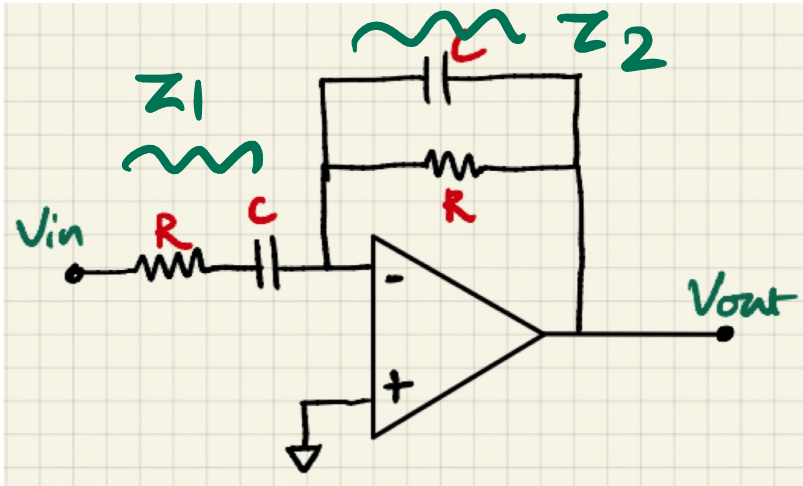
$$-\frac{V_s}{2\cancel{R}} = \frac{2}{\cancel{R}} V_s - \frac{V_{out}}{\cancel{R}} \Rightarrow V_{out} = 2V_s + 0.5V_s$$

3

$$= 2.5V_s$$

(Ans)

**Q.7.** What is the voltage again (in dB) at $\omega = 1/RC$? **[4 Marks]**




$$Z_1 = R + \frac{1}{sC} = \frac{1+sRC}{sC}$$

$$Z_2 = R \parallel \frac{1}{sC} = \frac{R \times \frac{1}{sC}}{R + \frac{1}{sC}} = \frac{\frac{R}{sC}}{\frac{1+sRC}{sC}} = \frac{R}{1+sRC}$$

$$\frac{V_{out}}{V_{in}} = -\frac{Z_2}{Z_1} = -\frac{R}{1+sRC} \cdot \frac{sC}{1+sRC}$$

$$= \frac{-sRC}{(1+sRC)^2} = \frac{-j\omega RC}{(1+j\omega RC)^2}$$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{\omega RC}{\left(\sqrt{1+\omega^2R^2C^2}\right)^2}$$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{\omega RC}{1+\omega^2 R^2 C^2}$$

$$\left|\frac{V_{out}}{V_{in}}\right|_{\omega=\frac{1}{RC}} = \frac{1}{2}.$$

$$= -6\,\text{dB}$$

Ans

Q 3. This ckt is an integrator. A dc step input is given. Therefore, after a long time, the o/p will approach ∞. [If the student has given this point, it is sufficient for full marks. However, we can solve like this:]

it may not be needed.

$$\frac{V_o(s)}{V_i(s)} = -\frac{\left(\frac{1}{sC}\right)}{R}$$

$$\frac{V_o(s)}{V_I(s)} = -\frac{1}{sCR}$$

at $s = jW$

$$\frac{V_o(jW)}{V_I(jW)} = -\frac{1}{jWRC}$$

~~at $W=0$, the o/p approaches ∞~~

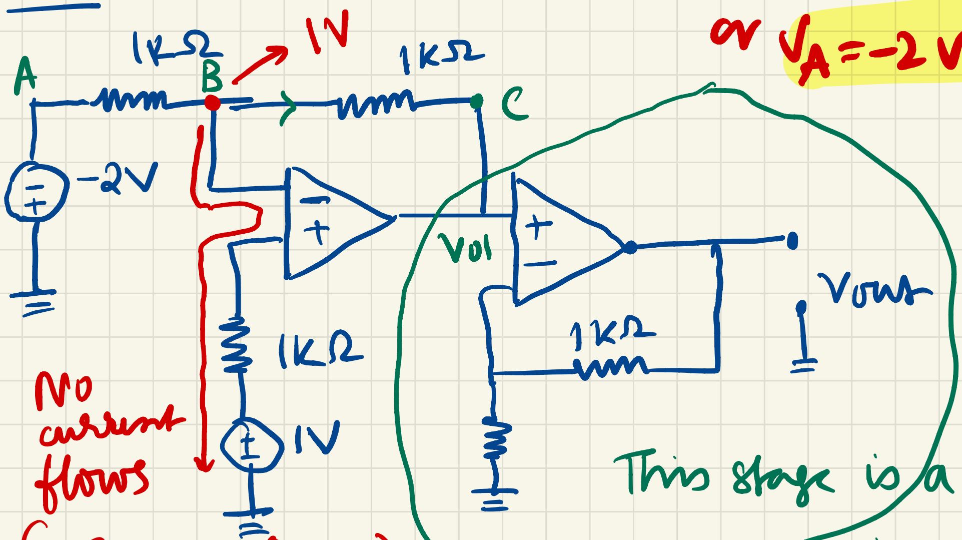
output will be $-V_{CC}$.

* The student can also solve using first principles to get the same ans.

$V_A = 2V, V_{out} = 4V$

or $V_A = -2V, V_{out} = 8V$

Q 5.




No current flows (∞ impedance)

This stage is a non inverting amp. with gain $= \left(1 + \frac{1}{1}\right)$ $= 2$

No voltage drop - virtual short

KCL at B

$$\frac{1-(-2)}{1k\Omega} + \frac{V_{01}-1}{1k\Omega} = 0$$

(no current flows to op-amp)

$$V01 = 4\,V$$

Now, second stage has gain = 2 (non-inverting amp)

Thus

$$V_{out} = 4 \times 2 = \underline{\underline{8V}}$$