NUMERICALS (op-amp)

Q1) The two input terminals of an op-amp are connected to voltage signals of strength 745 μV and 740 μV respectively. The gain of op-amp in differential mode is 5×10^5 and its CMRR is 80 db. Calculate :-

(1) Differential Input
(2) Common mode Input
(3) Differential o/p
(4) Common mode o/p
(5) output voltage
(6) % Error due to Common mode

Sol^n:- Given

$V_1 = 745\ \mu V$ CMRR = 80db
$V_2 = 740\ \mu V$
$A_d = 5 \times 10^5$

① **Differential Input :-** $V_d = |V_1 - V_2|$

$= |745 - 740|$

$\boxed{V_d = 5\ \mu V}$

② **Common mode Input :-** $V_{CM} = \left|\frac{V_1 + V_2}{2}\right| = \left|\frac{745 + 740}{2}\right|$

$\boxed{V_{CM} = 742.5\ \mu V}$

A_{CM} :-   We know

$$\text{CMRR in db} = 20\log_{10}\frac{A_d}{A_{CM}}$$

$$80 = 20\log_{10}\frac{5\times10^5}{A_{CM}}$$

$$4 = \log_{10}\frac{5\times10^5}{A_{CM}} \Rightarrow 10^4 = \frac{5\times10^5}{A_{CM}}$$

$$\Rightarrow \boxed{A_{CM} = 50}$$

(3) Differential o/p :-   Differential o/p $= A_d V_d$

$$= 5\times10^5 \times 5\,\mu V$$
$$= 5\times10^5 \times 5\times10^{-6}$$
$$= 25\times10^{-1}$$

$$\boxed{\text{Diffrential o/p} = 2.5V}$$

(4) Common mode o/p :-   Commonmode o/p $= A_{CM} V_{CM}$

$$= 50\times 742.5\,\mu V$$
$$= 50\times 742.5\times10^{-6}$$
$$= 37125\times10^{-6}$$

$$\boxed{\text{Commonmode o/p} = .0371\ V}$$

⑤ Output voltage :-

$$V_o = A_d V_d + A_{CM} V_{CM}$$

$$V_o = 2.5V + .0371V$$

$$\boxed{V_o = 2.53\ V}$$

⑥ % Error due to Common mode :-

$$\%\ Error = \frac{A_{CM} V_{CM}}{A_d V_d + A_{CM} V_{CM}} \times 100$$

$$= \frac{.0371}{2.53} \times 100$$

$$\boxed{\%\ Error = 1.466\%}$$

Ans

Q2:- Find CMRR if $A_d = 80\ db$ and $A_{CM} = 2 \times 10^3$.

Solⁿ:- We know $CMRR = \frac{A_d}{A_{CM}}$.

but $A_d = 80\ db$. First we need to convert A_d from db to without db.

A_d in db $= 20\log_{10} A_d$

$80 = 20\log_{10} A_d$

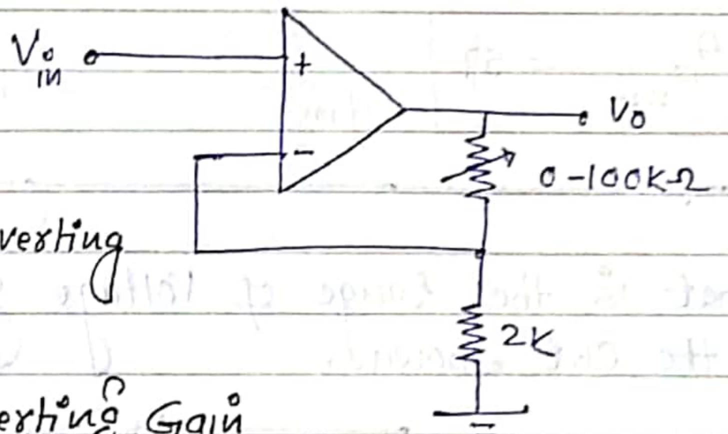
$4 = \log_{10} A_d \Rightarrow \boxed{A_d = 10^4}$

Now

$$CMRR = \frac{10^4}{2\times10^3}$$

$\boxed{CMRR = 5}$ Ans

Q3:- The Variable Resistance Varies from zero to 100 kΩ. Find the maximum and minimum closed loop Voltage gain.



Sol:-

Given op-amp is Non- Inverting amplifier.

We know For Non-Inverting Gain

$$\boxed{A_F = 1 + \frac{R_F}{R_1}}$$

Here $R_F = 0 - 100k\Omega$ (Variable) & $R_1 = 2K$

① Minimum Gain :-

① $$\boxed{A_{F_{min}} = 1 + \frac{R_{F_{min}}}{R_1}}$$

$$= 1 + \frac{0}{2K}$$

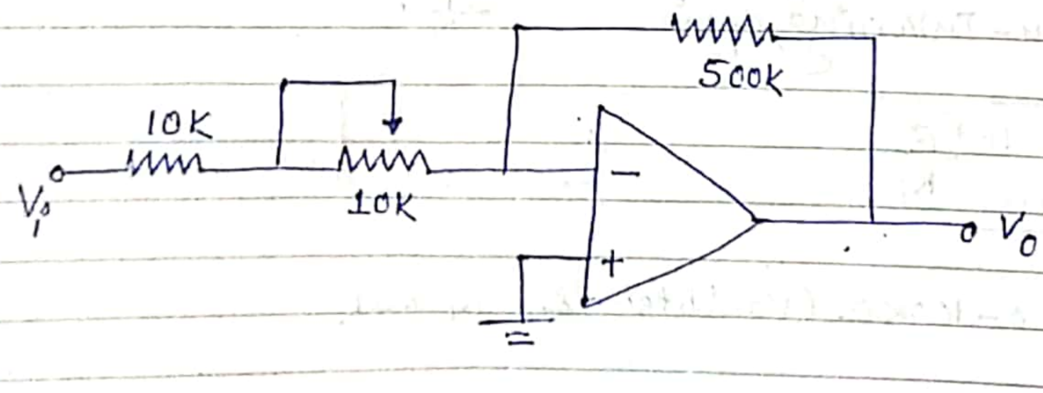
$$\boxed{A_{F_{min}} = 1}$$

② Maximum Gain :- $$\boxed{A_{F_{max}} = 1 + \frac{R_{F_{max}}}{R_1}}$$

$$= 1 + \frac{100K}{2K}$$

$$\boxed{A_{F_{max}} = 51}$$ Ans

Q4) What is the range of voltage gain adjustment in the ckt shown.



Sol^n:- This is Inverting op-amp, whose voltage gain is given by :-

$$\boxed{A_F = -\frac{R_F}{R_1}}$$, Here R_F is Fixed in the ckt diagram.

① Minimum Gain $$\boxed{A_{F_{min}} = -\frac{R_F}{R_{1_{max}}}}$$

$$= -\frac{500K}{10+10}$$

$$\boxed{A_{F_{min}} = -25}$$

② Maximum Gain $$\boxed{A_{F_{max}} = -\frac{R_F}{R_{1(min)}}}$$

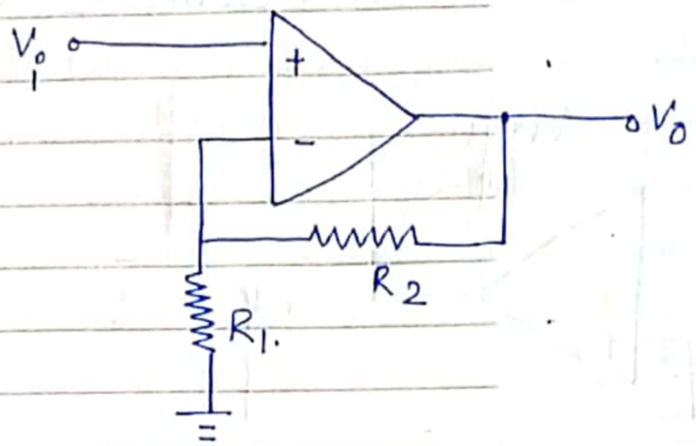
$$= -\frac{500K}{10+0}$$

$$\boxed{A_{F_{(max)}} = -50}$$

∴ Range of Voltage Gain = -25 To -50

Ans

QNo6) Determine output of the ckt shown below.



Sol^n:- This is Non-Inverting op-amp. The Gain of Non-Inverting op-amp is given by:-

$$\boxed{A_F = 1 + \frac{R_F}{R_1}}$$

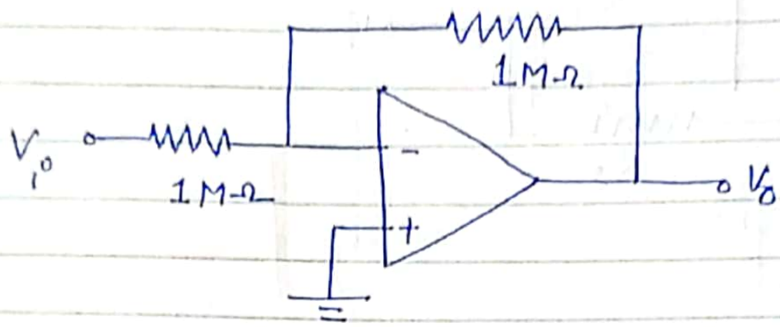
Here $R_F = R_2$
$R_1 = R_1$

$\therefore A_F = 1 + \frac{R_2}{R_1}$ but Gain $A_F = \frac{V_o}{V_i}$

$$\therefore \frac{V_o}{V_i} = 1 + \frac{R_2}{R_1}$$

$$\therefore \boxed{V_o = \left(1 + \frac{R_2}{R_1}\right) V_i}$$ Ans

QNo7 Compute Input Impedance and voltage gain of the amplifier ckt shown below:- op-amp is Ideal.



Sol^n:- This is Inverting op-amp whose gain

$$\boxed{A_F = -\frac{R_F}{R_1}}$$

Where $R_F = 1M\Omega$
$R_1 = 1M\Omega$

$\therefore \boxed{A_F = -1}$

Input Impedance:- Input Impedance $= R_1$

$\boxed{I/P \text{ Impedance} = 1M\Omega}$ Ans

Q8> Design an Non-Inverting op-amp with a gain of +15. Assume ideal op-amp and Resistances should not exceed 30 KΩ.

Sol^n:- Gain of Non-Inverting op-amp is given by :-

$$A_F = 1 + \frac{R_F}{R_1}$$

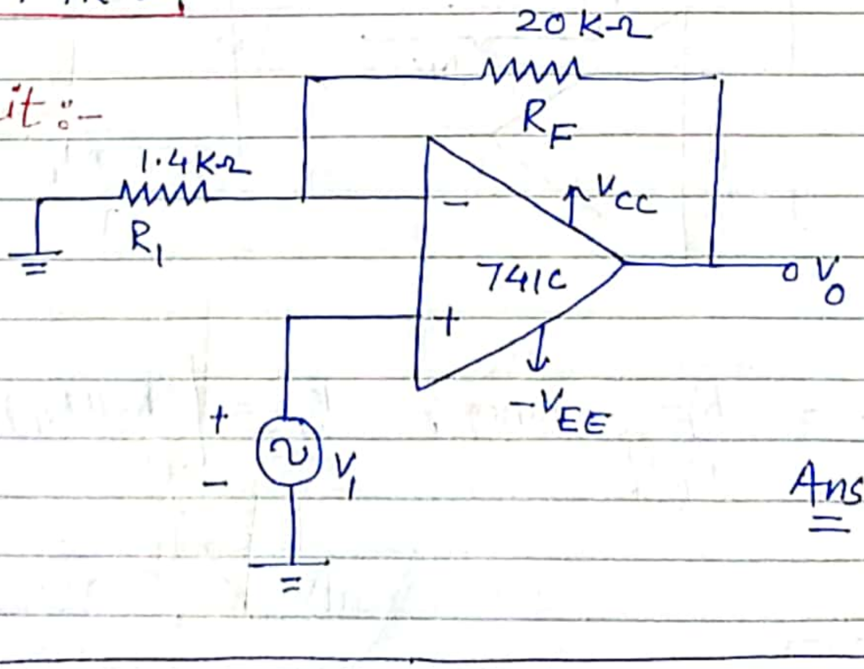
$$15 = 1 + \frac{R_F}{R_1}$$

Assume $\boxed{R_F = 20\,K\Omega}$

$$15 = 1 + \frac{20}{R_1}$$

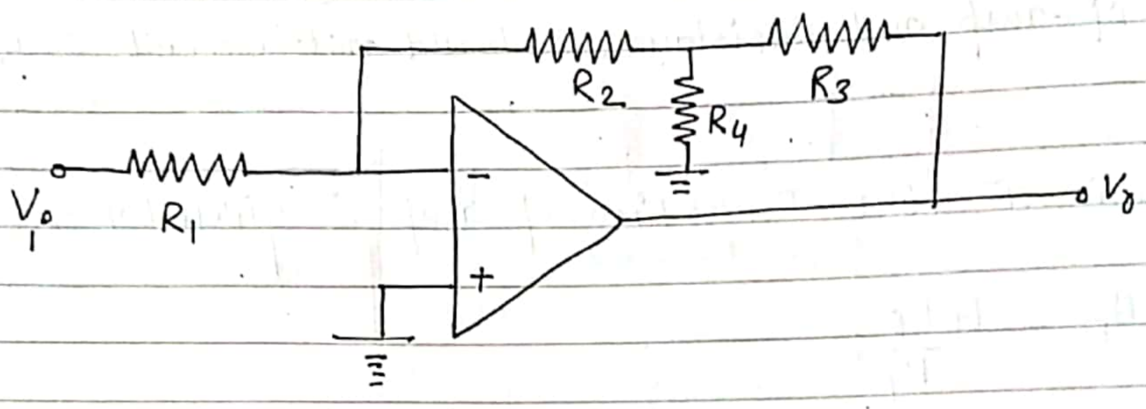
$$\boxed{R_1 = 1.4\,K\Omega}$$

Design Circuit :-



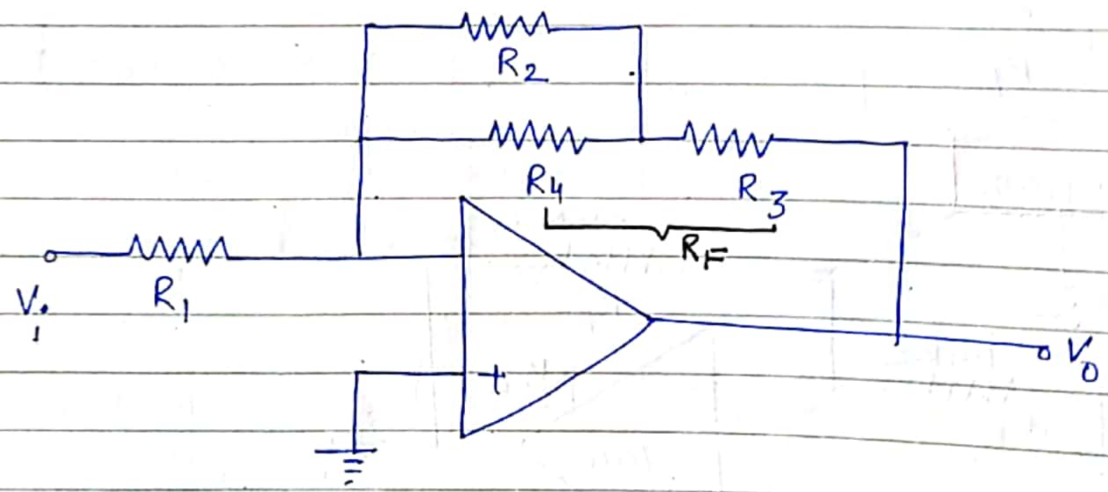
Ans

Q9> For the ckt shown, Find out V_0.



Sol^n:- Here $(R_2 \parallel R_4)$ which is in series with R_3.

→ This is Inverting op-amp, its simplified ckt is shown below:-



Gain $\boxed{A_F = \frac{-R_F}{R_1}}$ where $R_F = \left[(R_2 \parallel R_4) + R_3\right]$

$$\therefore \frac{V_o}{V_i} = A_F = -\frac{[(R_2 \| R_4) + R_3]}{R_1}$$

$$\boxed{V_o = -\frac{[(R_2 \| R_4) + R_3]}{R_1} \times V_i}$$

Ans

Q10) For an inverting op-amp, the input voltage is sine wave with a peak voltage of 2V peak and Freq. of 1 KHz.
Assume $R_1 = 1\,k\Omega$, $R_F = 10\,k\Omega$ and supply voltage to be $\pm 15V$. Draw Input and output voltage wave-forms and explain them.

Soln:-

This is a Inverting op-amp whose Gain is –

$$\boxed{A_F = \frac{-R_F}{R_1}}$$ Here $R_F = 10k\Omega$, $R_1 = 1k\Omega$

$$\therefore A_F = \frac{V_o}{V_i} = -\frac{R_F}{R_1}$$

$$\boxed{V_o = -\frac{R_F}{R_1} \times V_i}$$ put all values.

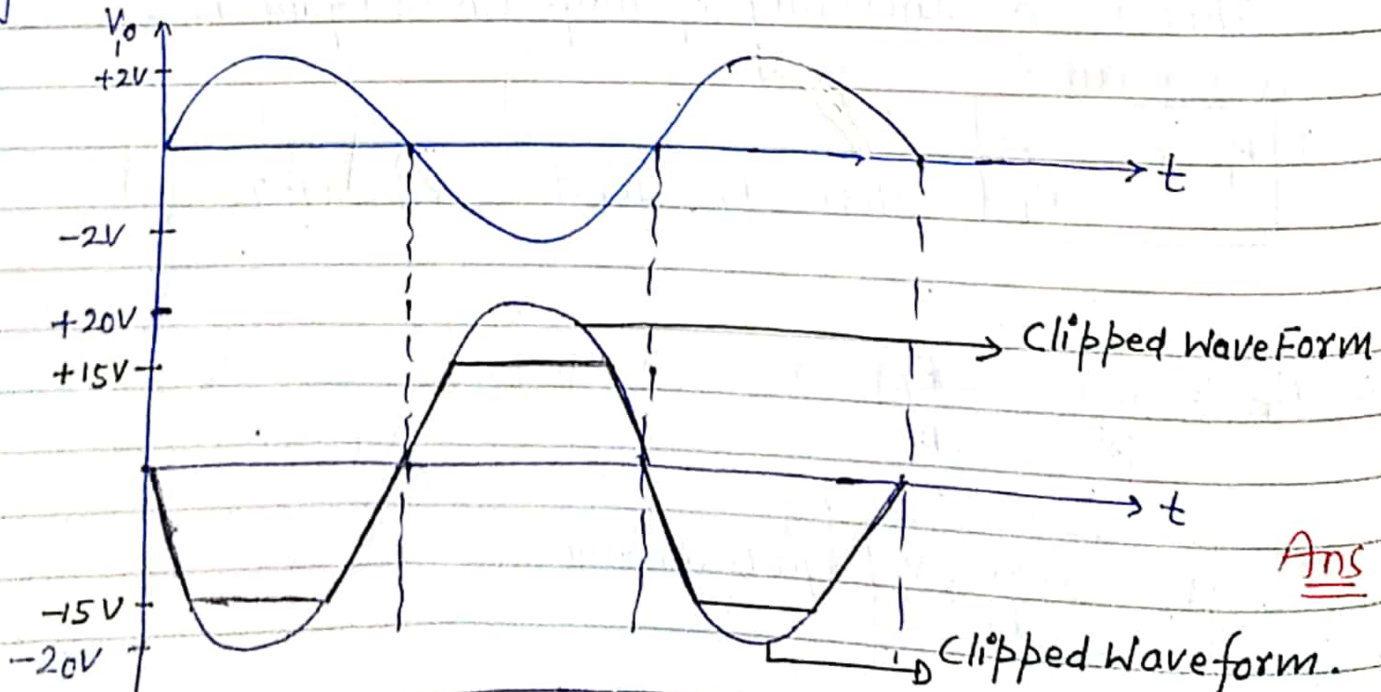
$V_0 = -\frac{10}{1} \times 2V$. (As Input $V_i = 2V$)

$\boxed{V_0 = -20V}$

but As we know, o/p-amp is restricted to amplify the input voltage to $\pm V_{sat}$ only.

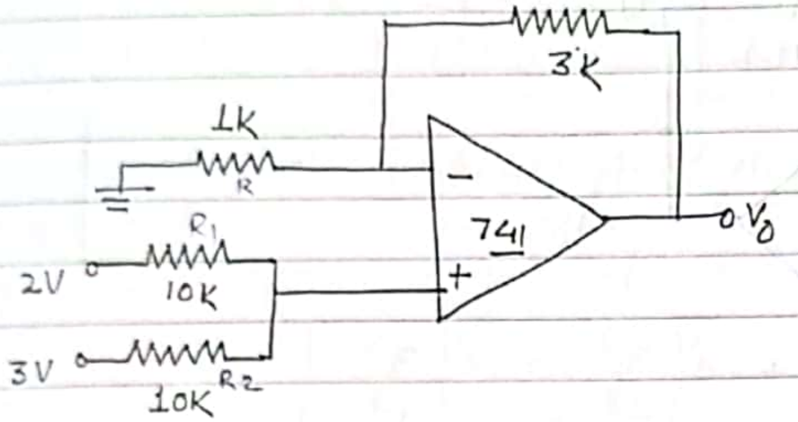
Here $\boxed{+V_{sat} = +V_{cc}}$ where $+V_{cc} = +15$ & $-V_{EE} = -15$ } Given

$\boxed{-V_{sat} = -V_{EE}}$ means o/p voltage is restricted to ±15V only. Hence o/p voltage ($V_0 = 20V$) gets clipped off after ±15V.



Ans

Q No 11) Find out V_0 For the given ckt.



Sol^n :- This is Non-Inverting Summing Amp^r whose

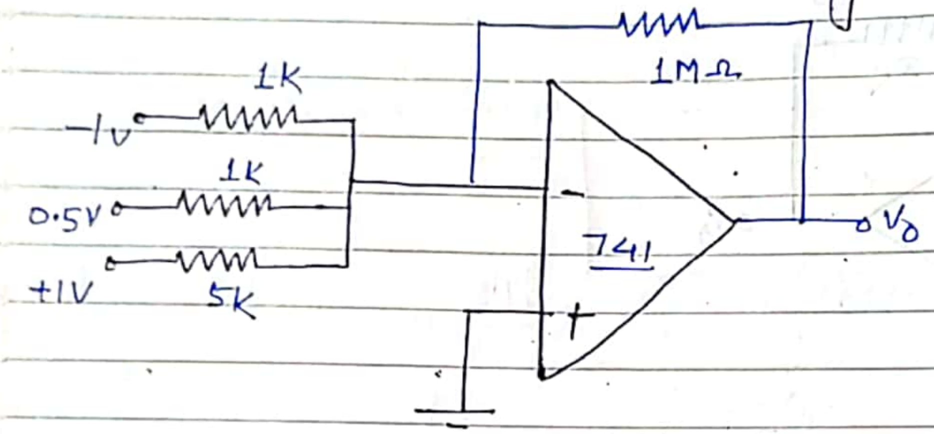
$$V_0 = \left[\frac{R_2 V_1 + R_1 V_2}{R_1 + R_2}\right]\left[1 + \frac{R_F}{R}\right]$$

$$= \frac{10\times2 + 10\times3}{10+10} \times 1 + \frac{3}{1}$$

$$= \frac{20+30}{20} \times 4$$

$$= \frac{50\times4}{20} = 10 \text{ Volts Ans}$$

Q.NO12) Findout V_0 For the given ckt.



Sol^n:- This is Inverting Summing Amplifier whose

$$V_0 = -\left[\frac{R_F}{R_1}V_1 + \frac{R_F}{R_2}V_2 + \frac{R_F}{R_3}V_3\right]$$

$$= -\left[\frac{10K\Omega}{1K}\times(-1) + \frac{10K}{1K}(0.5) + \frac{10K}{5K}\times(1V)\right]$$

$$V_0 = -(-10+5+2)$$

$$\boxed{V_0 = 3V}$$ Ans

Q.NO13) Design a Inverting summing Amp^r whose V_0 is given by -

$$\boxed{V_0 = -2V_a + 3V_b - 5V_c}$$

Resistances used should not exceed 30 KΩ.

Sol^n:- Given $V_0 = -2V_a + 3V_b - 5V_c$

We know $\boxed{V_0 = -(2V_a - 3V_b + 5V_c)}$ → ①

V_0 of Inverting Ampr Adder is given by :-

$$V_0 = -\left[\frac{R_F}{R_1}V_a + \frac{R_F}{R_2}V_b + \frac{R_F}{R_3}V_c\right] \rightarrow ②$$

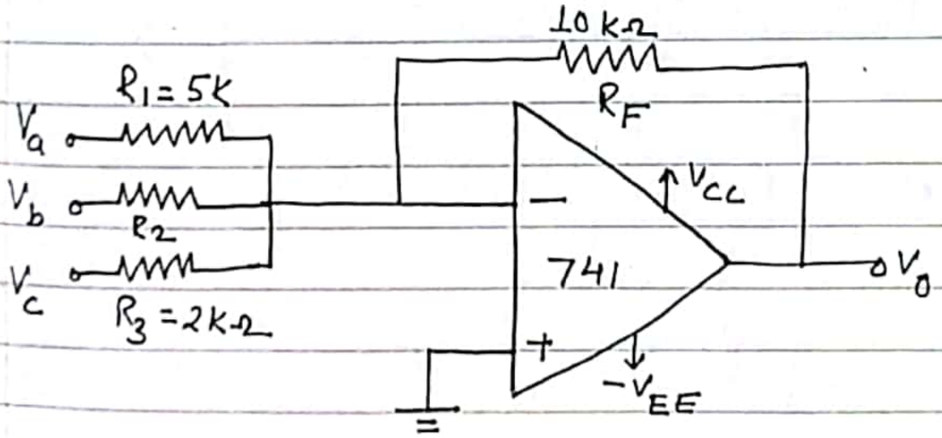
By Comparing Equations ① & ② :-

$\boxed{\frac{R_F}{R_1} = 2}$, $\boxed{\frac{R_F}{R_2} = 3}$ Ignore (-ve) sign as R can't be negative

$\boxed{\frac{R_F}{R_3} = 5}$

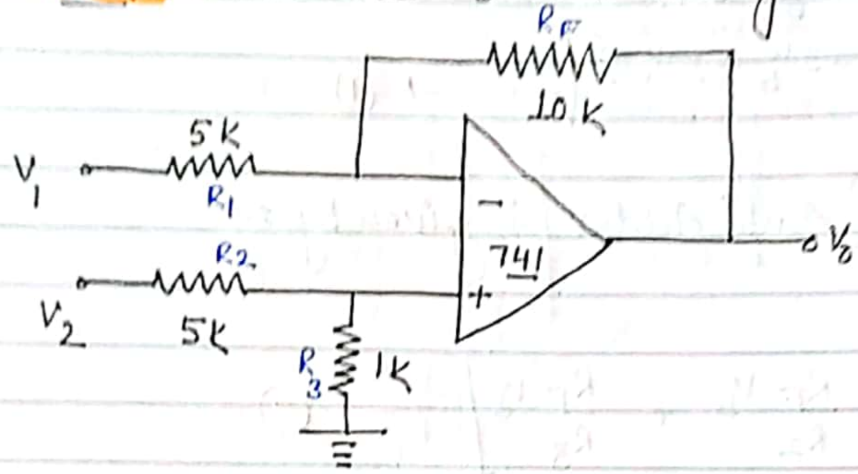
Assume $\boxed{R_F = 10\,k\Omega}$ $\boxed{R_1 = \frac{10}{2} = 5\,k\Omega}$ $\boxed{R_3 = 2\,k\Omega}$

$\boxed{R_2 = 3.3\,k\Omega}$



Ans

Q No 14) Find the V_o For the given ckt :-



Sol^n:- This is op-amp As subtractor whose V_o can be Calculated by appling superposition theorm.

Step 1:- Consider Input V_1, $\boxed{V_2 = 0}$, o/p is V_{01}.

$$\boxed{V_{01} = -\frac{R_F}{R_1} \times V_1}$$

$$= -\frac{10K}{5K} \times V_1$$

$$\boxed{V_{01} = -2V_1}$$

step2 :- Consider Input V_2, $\boxed{V_1 = 0}$

& o/p due to Input V_2 = V_{02}

$$\therefore V_{02} = \left(1 + \frac{R_F}{R_1}\right) V_2 \left(\frac{R_3}{R_2 + R_3}\right)$$

$$= \left(1 + \frac{10k}{5k}\right) V_2 \left(\frac{1}{1+5}\right)$$

$$= 3 V_2 \times \frac{1}{6}$$

$$\boxed{V_{02} = .5 V_2}$$

$$\therefore \text{Total } V_0 = V_{01} + V_{02}$$

$$\boxed{V_0 = -2V_1 + .5V_2}$$ Ans

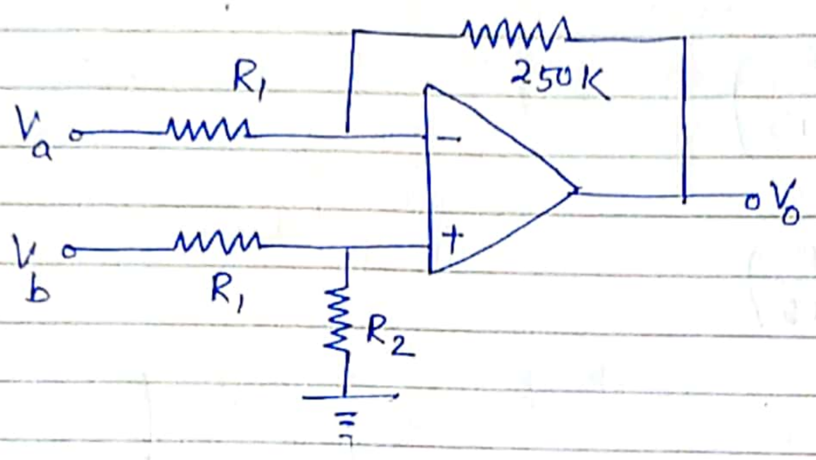
OR (when asked For 2 marks)

We know V_0 For op-amp as subtractor is given by :-

$$V_0 = \left(\frac{-R_F}{R_1}\right) V_1 + \left[1 + \frac{R_F}{R_1}\right] V_2 \left[\frac{R_3}{R_2 + R_3}\right]$$, put all values :-

$$V_0 = -\frac{10}{5} \times V_1 + \left[1 + \frac{10}{5}\right] V_2 \left[\frac{1}{1+5}\right] \Rightarrow \boxed{V_0 = -2V_1 + .5V_2}$$ Ans

QM015) Find the Values of R_1 & R_2 For the o/p to be $\boxed{V_0 = -5V_a + 3V_b}$ For the ckt shown below.



Solⁿ:- This is op-amp as subtractor whose V_0 is —

$$\boxed{V_0 = -\frac{R_F}{R_1} \times V_a + \left[1 + \frac{R_F}{R_1}\right] V_b \left[\frac{R_2}{R_1 + R_2}\right]} \longrightarrow (1)$$

Given $\boxed{V_0 = -5V_a + 3V_b} \longrightarrow (2)$

Compare Eqⁿs (1) & (2) :-

$$+\frac{R_F}{R_1} = 5$$

$$R_1 = \frac{R_F}{5} = \frac{250K}{5} \Rightarrow \boxed{R_1 = 50K}$$

& $\left[1+\frac{R_F}{R_1}\right]\left[\frac{R_2}{R_1+R_2}\right] = 3$

$$\left(1+\frac{250}{50}\right)\left(\frac{R_2}{50+R_2}\right) = 3$$

$$06 \times \frac{R_2}{50+R_2} = 3$$

$$\frac{R_2}{50+R_2} = \frac{1}{2} \Rightarrow \boxed{R_2 = 50\,K\Omega}$$ Ans

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QNO16> A sinusoidal signal with peak value 6 mV and 2KHZ Freq. is applied to the input of an ideal op-amp integrator with R_{in} = 100 Kohm and $C_f = 1\mu F$. Find o/p voltage.

Solⁿ:- Given $V_m = 6mV$, $R_{in} = 100K\Omega$, $C_f = 1\mu F$, $f = 2KHZ$

The o/p voltage of an Integrator is given by -

$$\boxed{V_o = -\frac{1}{R_{in}C_f}\int A\sin\omega t\,dt} \longrightarrow \text{for sinusoidal Input}$$

$$= -\frac{1}{R_{in}C_f}\int A\sin(2\pi f)t\,dt \qquad \because (\omega = 2\pi f)$$

& $\left[1+\frac{R_F}{R_1}\right]\left[\frac{R_2}{R_1+R_2}\right] = 3$

$$\left(1+\frac{250}{50}\right)\left(\frac{R_2}{50+R_2}\right) = 3$$

$$06 \times \frac{R_2}{50+R_2} = 3$$

$$\frac{R_2}{50+R_2} = \frac{1}{2} \Rightarrow \boxed{R_2 = 50\,k\Omega}$$ Ans

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QNO16> A sinusoidal signal with peak value 6 mV and 2 KHZ Freq. is applied to the input of an ideal op-amp integrator with $R_{in} = 100$ kohm and $C_f = 1\mu F$. Find o/p voltage.

Solⁿ:- Given $V_m = 6\,mV$, $R_{in} = 100\,K\Omega$, $C_f = 1\mu F$, $f = 2\,KHZ$

The o/p voltage of an Integrator is given by -

$$\boxed{V_o = -\frac{1}{R_{in}C_f}\int A\sin\omega t\, dt} \longrightarrow \text{for sinusoidal Input}$$

$$= -\frac{1}{R_{in}C_f}\int A\sin(2\pi f)t\, dt \quad \because (\omega = 2\pi f)$$

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$$= -\frac{1}{R_{in} C_f}\left[\frac{A}{2\pi f}(-\cos 2\pi f)t\right]$$, put all values:-

$$= \frac{1}{100\times10^{3}\times 1\times10^{-6}}\left[\frac{6\times10^{-3}}{2\times\pi\times 2\times10^{3}} \cos(2\pi\times2\times10^{3})t\right]$$

$$= 10\left[.477\times10^{-6}\cos(4000\pi t)\right]$$

$$\boxed{V_0 = 4.77\times10^{-6}\cos(4000\pi t)}$$

Ans

QNo17 An op-amp has a slew Rate of 15V/μsec. What is the power bandwidth For a peak o/p voltage of 10 V.

Sol^n:- Given S. Rate = 15V/μsec

$V_{Peak\ to\ Peak} = 10V$

$$V_m = \frac{V_{P-P}}{2}$$

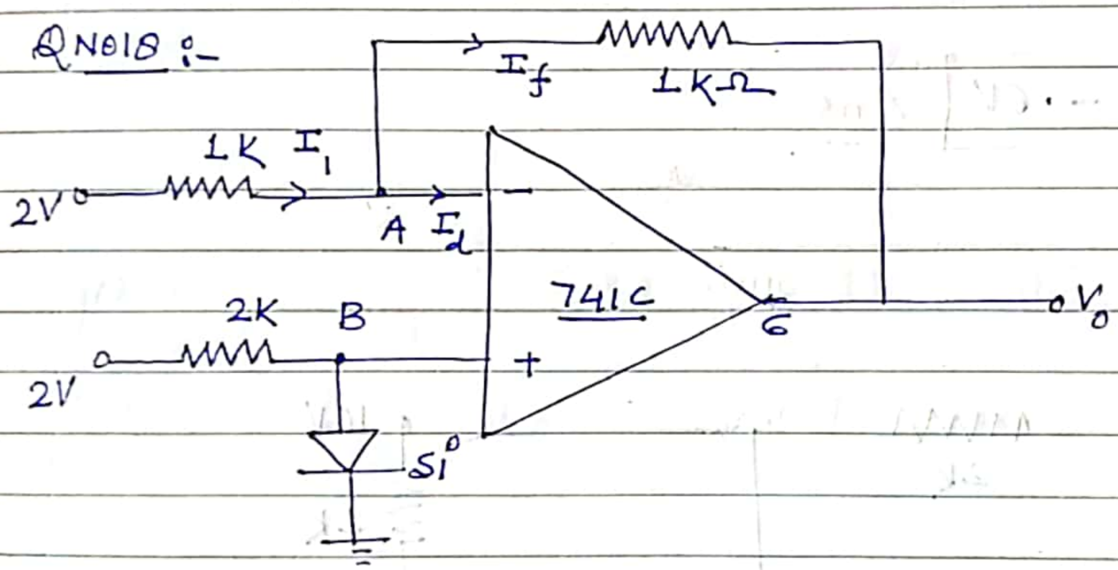
$$\boxed{V_m = \frac{10}{2} = 5V}$$

We know $S.Rate = 2\pi f V_m$

$\therefore$ Power Bandwidth $f = \dfrac{S.Rate}{2\pi V_m} = \dfrac{15\times10^{-6}}{2\times\pi\times5}$

$$\boxed{f = 477.46\ KHz}$$ Ans

QNo18 :-



Find V_o.

Sol^n :- KCL at node A :- $I_1 = I_d + I_f$

but $I_d = 0$, As $R_i = \infty$ of an ideal op-amp

$\therefore I_1 = I_f$

$$\frac{2 - V_A}{1K} = \frac{V_A - V_o}{1K}$$

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$$2 - V_A = V_A - V_0$$

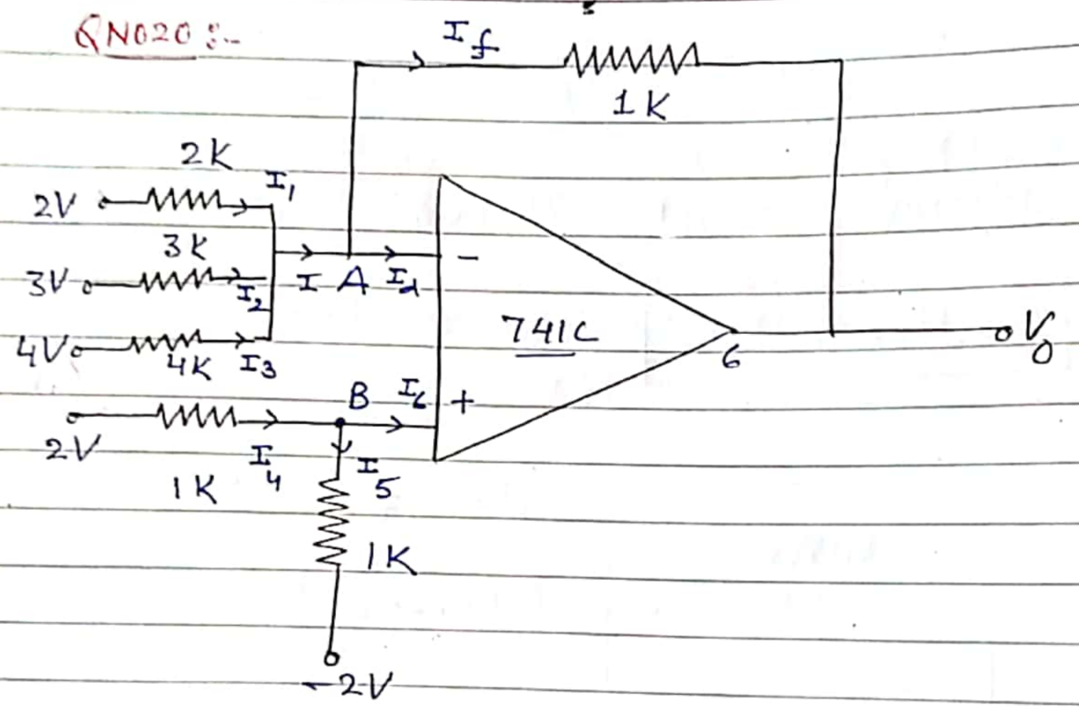
but from virtual short concept $\boxed{V_A = V_B}$

and here $\boxed{V_B = 0.7V}$ $\therefore$ $\boxed{V_A = 0.7V}$

$$2 - .7 = .7 - V_0$$

$\boxed{V_0 = -.6V}$ Ans

QNo20 :-



Calculate the o/p of op-amp ckt.

Sol^n :- Apply KCL at B

$I_4 = I_5 + I_6$

but $I_6 = 0$, b'coz $R_i = \infty$ of op-amp

$\therefore \ I_4 = I_5$

$$\frac{2 - V_B}{1} = \frac{V_B - (-2)}{1}$$

$2 - V_B = V_B + 2 \Rightarrow \boxed{V_B = 0}$

From Virtual Ground Concept $\boxed{V_A = V_B}$

$\therefore \boxed{V_A = 0}$.

→ Apply KCL at A :-

$$I = I_d + I_f$$

but $I = I_1 + I_2 + I_3$

& $I_d = 0$, b'coz $R_i = \infty$

$$\therefore \quad I = I_f$$

$$I_1 + I_2 + I_3 = I_f$$

$$\frac{2 - V_A}{2} + \frac{3 - V_A}{3} + \frac{4 - V_A}{4} = \frac{V_A - V_0}{1}$$

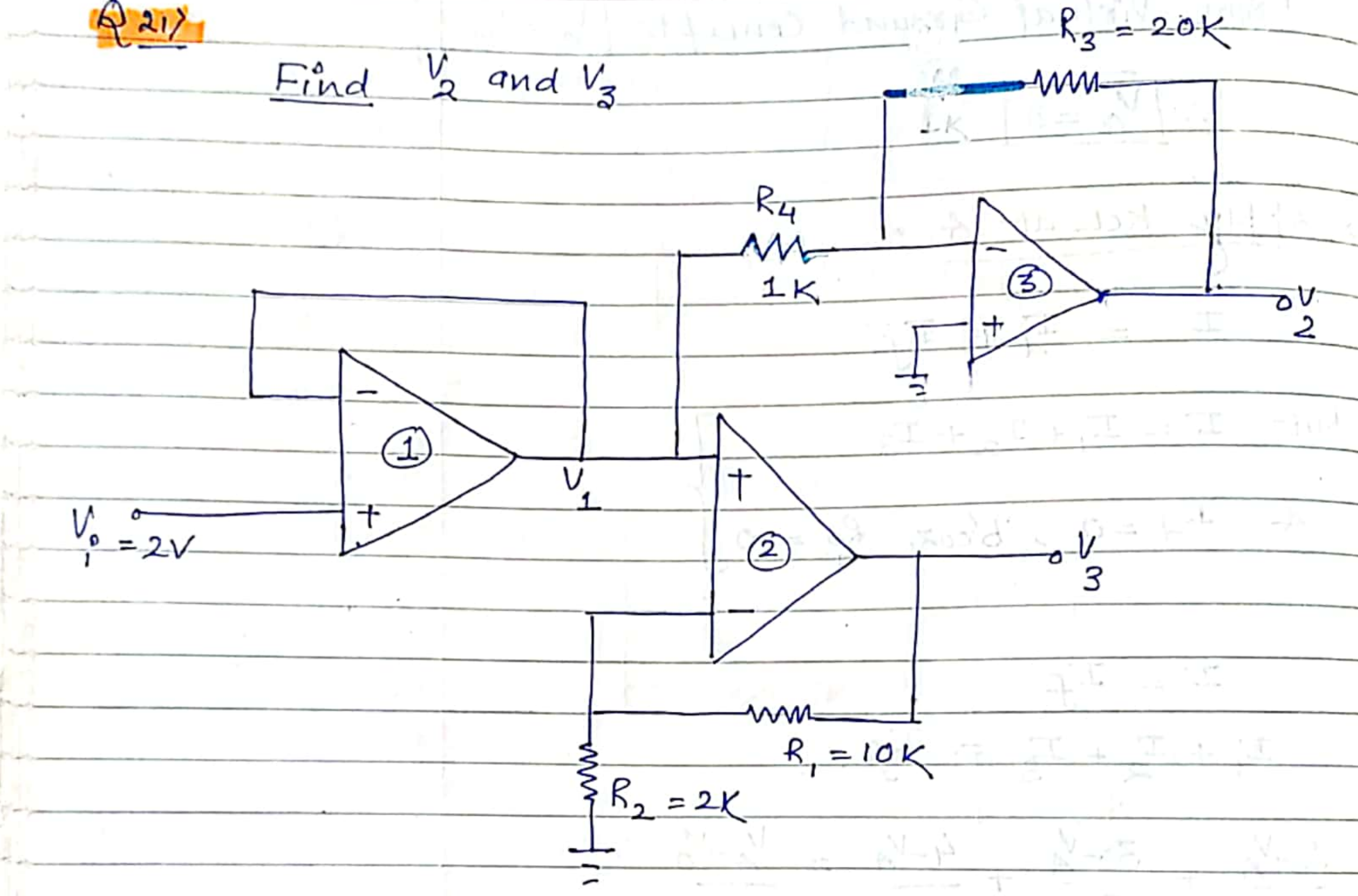
put $\boxed{V_A = 0}$ $\quad 1 + 1 + 1 = -V_0$

$$\boxed{V_0 = -3V}$$

Ans

Q 21)

Find V_2 and V_3



→ op-amp 1, is voltage follower whose o/p $V_1 = V_{i}$

$$\boxed{V_1 = 2V}$$

→ op-amp 2, is Non-inverting op-amp whose o/p is given by —

$$V_3 = \left(1 + \frac{R_f}{R_1}\right) V_1$$

$$= \left(1 + \frac{10}{2}\right) \times 2V$$

$$= (1 + 5) \times 2$$

$$\boxed{V_3 = 12V}$$

→ op-amp 3, is inverting op-amp, whose output is given by:-

$$V_2 = -\frac{R_f}{R_1} \times V_1$$

$$= -\frac{20}{1} \times 2V$$

$$\boxed{V_2 = -40V}$$

Ans