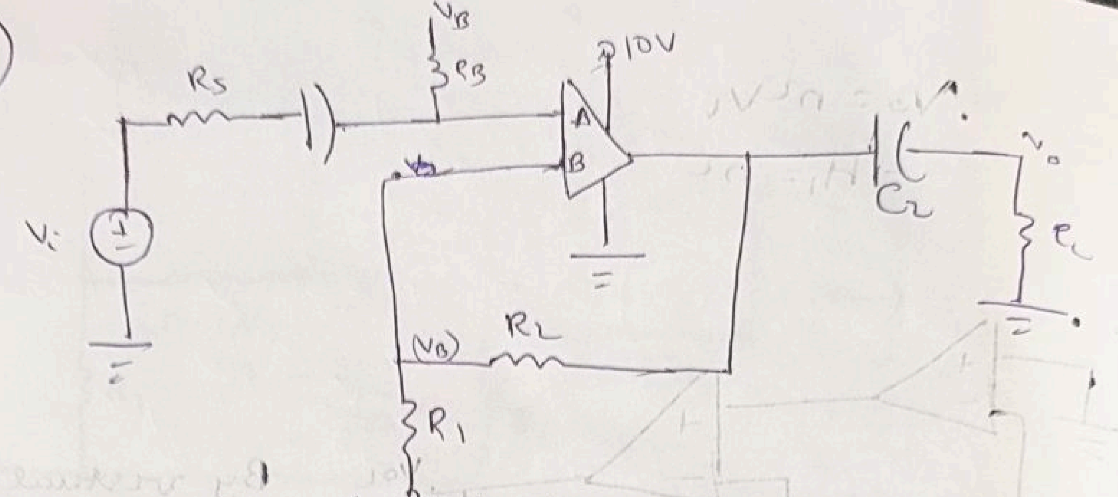
10.)



$(0.5)(V_{dd}) = 5$

Lowest frequency = 20Hz

1) Signs $B = -ve$ and $A = +ve$

~~For No current to flow through R_1 ⇒ $V_B = 5V$~~

~~By applying virtual short $V_A = V_B = 5V$~~

$$\Rightarrow (V_B - V_i) = i\left(R_B + R_S + \frac{1}{SC_1}\right)$$

$$i = \frac{V_i - V_B}{\left(R_B + R_S + \frac{1}{SC_1}\right)}$$

Since V_B is only DC Source we can make it zero

$$\text{or } i = \frac{V_i}{R_B + R_S + \frac{1}{SC_1}}$$

∴ Potential across the Capacitor

$$\Rightarrow \frac{1}{SC_1} \times \left(\frac{V_i}{R_B + R_S + \frac{1}{SC_1}}\right)$$

$$\Rightarrow \frac{V_i}{1 + SC_1(R_B + R_S)} \le (0.01)(V_i)$$

$$\frac{1}{1 + j(2\pi \times 20)(1 \times 10^{-6})[R_B + 50]10^3} \le (0.01)$$

$$\frac{1}{\sqrt{(1)^2+\left(2\pi 20\times10^{-6}(R_B+50)10^3\right)^2}} \le \left(\frac{1}{10}\right)^2$$

$$(10)^2 \le \sqrt{(1)^2+\left(2\pi(20)(10^{-6})(10^3)(R_B+50)\right)^2}$$

By solving we get

$$R_B = 745.77\,k\Omega$$

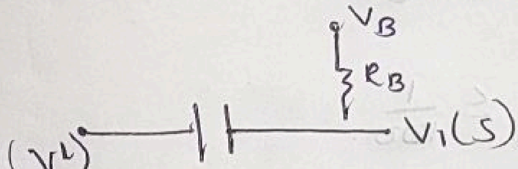
(b) ~~$R_1 = 10k$, $R_S = 80k$, $R_L = 1k$, $C_1 = 1\mu F$.~~

For No. current of flow through R_1

$V_B(DC) = 5V$

and By applying virtual short

$V_A(DC) = 5V$



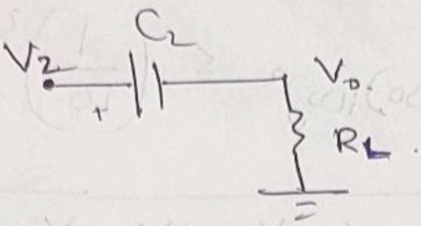
$$\frac{V^1 - V_1(S)}{1/SC_1} = \frac{V_1(S)-V_B}{R_B}$$

Zero $\Rightarrow V_1(S) = V^1(S)\cdot\frac{SR_BC_1}{(1+SR_BC_1)} + V_B\cdot\frac{1}{(1+SR_BC_1)}$

$\therefore V_1(dc) = V_B$

$\therefore \boxed{V_B = 5V}$

(c)



~~we are~~ Voltage across capacitor $= V_2 - V_2$

$$\Rightarrow \frac{V_2 - V_0}{\frac{1}{SC_2}} = \frac{V_0}{R_L}$$

$$\Rightarrow (V_2 - V_0) SC_2 = \frac{V_0}{R_L}$$

$$\Rightarrow V_2 = \left(\frac{V_0}{SC_2R_2} + V_0\right)$$

Voltage across capacitor $V_2 - V_0$.

$$\Rightarrow \frac{V_0}{SCR_2} + V_0 - V_0 = \frac{V_0}{SCR_2} \leq (0.01)V_0$$

$$\Rightarrow \frac{1}{SC_2R_2} \leq \frac{1}{100}$$

$$\Rightarrow 100 \leq SC_2R_2$$

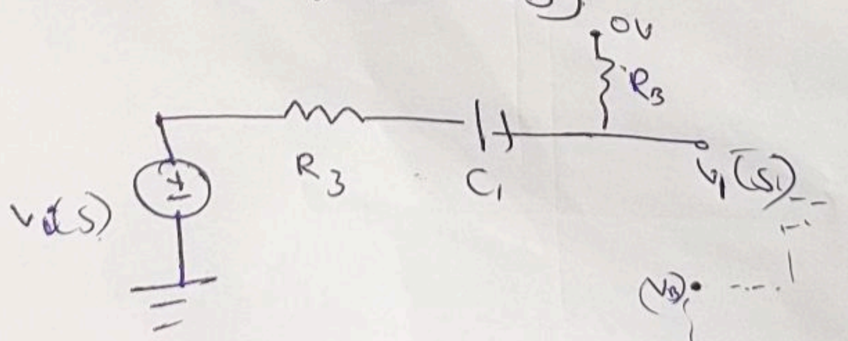
$$\Rightarrow 100 \leq 4\pi(C_2)(10^3)$$ [Considering magnitude]

$$\Rightarrow \frac{1}{400\pi} \leq C_2.$$

$$\therefore C_2 > 7.957 \times 10^{-4} F$$

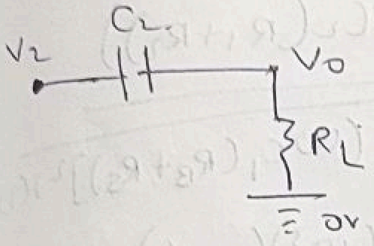
(d) we need to Achieve AC gain = 50

we know $V_B = 5V$ [For AC analysis we can Short V_B]



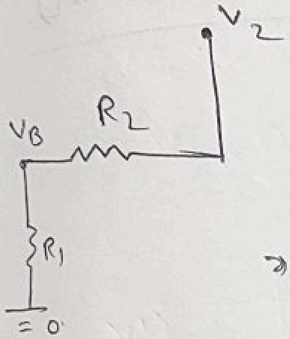
$$V_1(S) = \frac{V_i(S) \cdot R_B}{R_B + R_S + \frac{1}{SC_1}}$$

$$V_1(S) = \frac{V_i(S) . R_B SC_1}{(R_S + R_B) SC_1 + 1} \rightarrow (1)$$



$$\Rightarrow V_2 = \frac{V_0}{SC_2R_L} + V_0 .$$

$$\Rightarrow \boxed{V_2 = V_0\left[\frac{1 + SC_2R_L}{SC_2R_L}\right]} .$$



$$\frac{V_2 - V_B}{R_2} = \frac{V_B}{R_1}$$

$$\Rightarrow \frac{V_B}{R_1} + \frac{V_B}{R_2} = \frac{V_2}{R_2} .$$

$$\Rightarrow V_B\left(\frac{R_1 + R_2}{R_1 \cancel{R_2}}\right) = \frac{V_2}{\cancel{R_2}}$$

$$V_B = V_2\left(\frac{R_1}{R_1 + R_2}\right)$$

$$V_B = V_0\left[\frac{1 + SC_2R_L}{SC_2R_L}\right]\left[\frac{R_1}{R_1 + R_2}\right] \rightarrow (2)$$

By Virtual short $V_1(S) = V_B$. [(1) and (2)]

$$\Rightarrow \frac{V_i(S) . R_B SC_1}{(R_B + R_S)SC_1 + 1} = \left(\frac{R_1}{R_1 + R_2}\right)\left(\frac{1 + SC_2R_L}{SC_2R_L}\right) V_0(S)$$

$$\frac{V_0(S)}{V_i(S)} = \frac{R_B SC_1 (SC_2R_L)(R_1 + R_2)}{[1 + (R_B + R_S)SC_1 + 1][R_1)(1 + SC_2R_L)]}$$

$$H(s) = \frac{V_o}{V_{in}} = \frac{R_B R_L C_1 C_2 (R_1+R_2) s^2}{R_1 (s R_L C_2 + 1)\left[(R_B + R_S)(sC_1) + 1\right]}$$

$|H(s)| = 50$ at $f = \cancel{8}20\,Hz$ $\omega = 40\pi$

$$\Rightarrow 50 = \frac{(4\pi^2)(20)^2 \left(R_B R_L C_1 C_2 (R_1+R_2)\right)}{\sqrt{\left[(1)^2 + (R_L C_2 \omega)^2\right]} \times R_1 \times \sqrt{\left[\omega C_1 (R_B + R_S)\right]^2 + (1)^2}}$$

$$\Rightarrow 50 = \frac{(4\pi^2)(20)^2 (745.5 \times 10^3)(10^3)(10^{-6}) \times 7.957 \times 10^{-7} \times (R_1 + R_2)}{R_1}$$

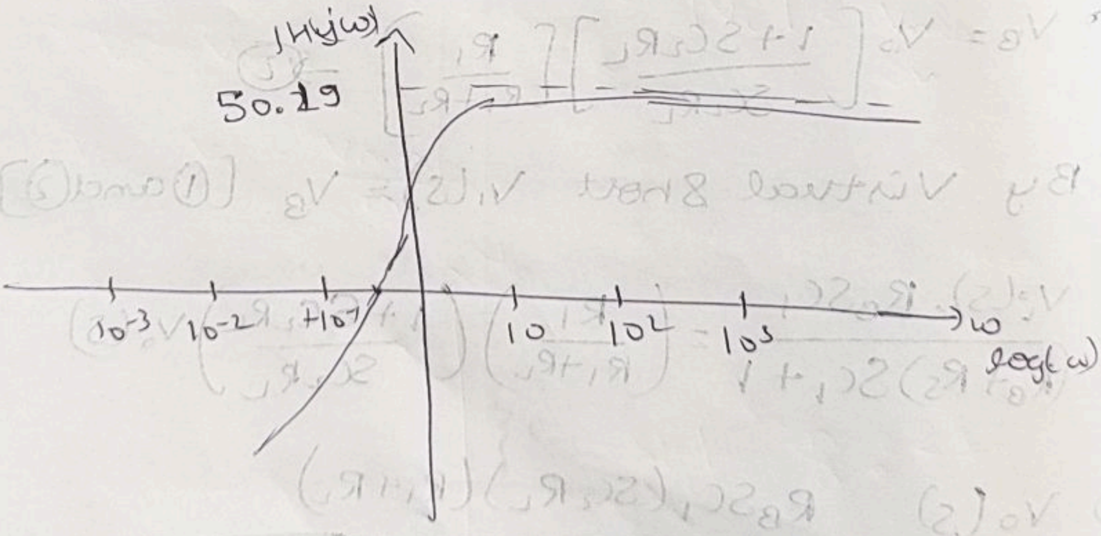
$$\Rightarrow 50 = (0.9370)\left(\frac{R_1 + R_2}{R_1}\right)$$

$$\Rightarrow 1 + \frac{R_2}{R_1} = 53.3575$$

$$\Rightarrow \boxed{R_2 = 52.3575 \times R_1}$$

But $R_1 = 10\,K\Omega$

$$\boxed{R_2 = 523.575 \times 10^3\,\Omega}$$



(c.) There is no DC current in R_1 (as well as R_2) DC level of V_2 as well as V_{out} will be 5V.

$\therefore$ If the input AC has an amplitude A then output of opamp will be

$$(\text{AC gain}) \times A + \underbrace{\text{DC offset}}_{5V}$$

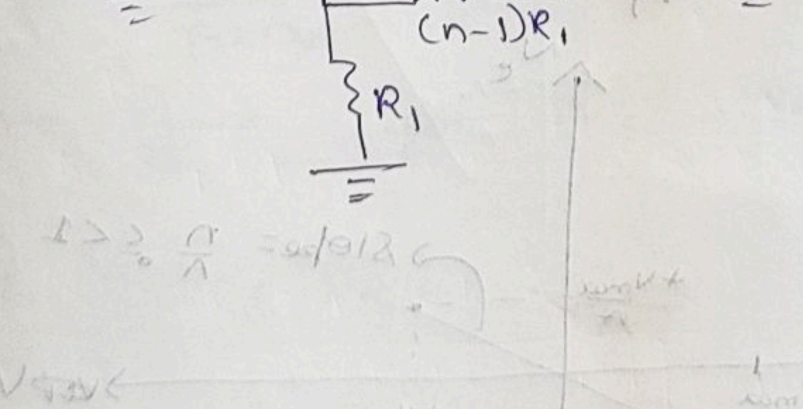
- $\text{AC gain}\Big|_{\omega = 2\pi \times 10^3} = 50.19$

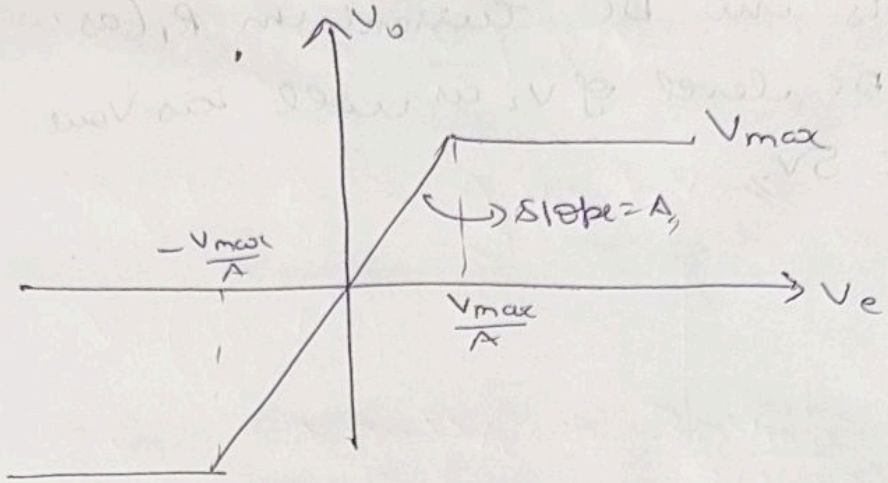
$$1V \le 50.19A + 5 \le 9V$$

$$-4 \le 50.19A \le 4V$$

$$|A| \le 0.0796$$

11.





$\Rightarrow$ For $|V_e| \leq \frac{V_{max}}{A}$

$A V_e' = V_{max}$

$\Rightarrow V_e' = \frac{V_{max}}{A}$

$\Rightarrow V_o = A(V_{i+} - V_{i-})$

$\Rightarrow V_o = A\left(V_i - \frac{V_o}{n}\right)$

$V_e = V_i - \frac{V_o}{n}$

$\frac{A}{n} \geq 1.$

$\Rightarrow V_o\left(1 + \frac{A}{n}\right) = A V_i$

$\Rightarrow \boxed{V_o = \frac{A n V_i}{A+n}}$

$\Rightarrow V_e = \left(\frac{n V_i}{A+n}\right) \simeq \frac{n V_i}{A}$

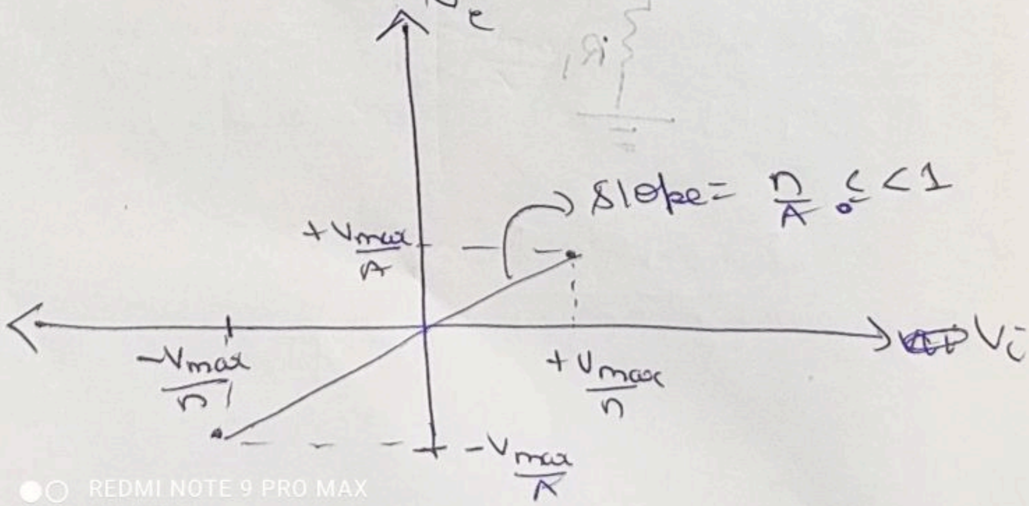
$|V_e| \leq \frac{V_{max}}{A}$

$\Rightarrow |V_i| \leq \frac{V_{max}}{n}$

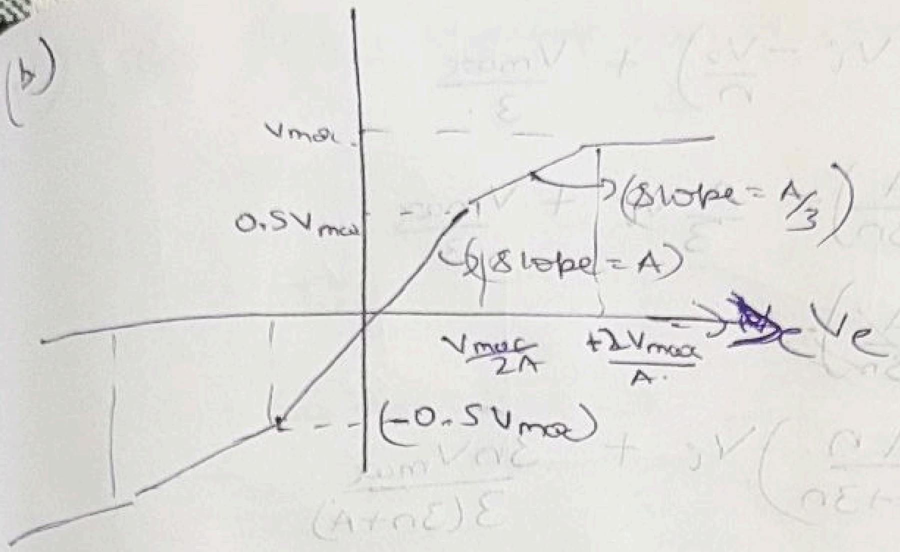
For $|V_e| > \frac{V_{max}}{A}$

$\Rightarrow V_o = V_{max}$

$\Rightarrow V_e = V_i - \frac{V_{max}}{n}$



(b)



$\Rightarrow 0.5V_{max} = AV_e.$

$\Rightarrow V_e = \frac{V_{max}}{2A}.$

$V_{max} - 0.5V_{max} = \frac{A}{3}\left(V_e - \frac{V_{max}}{2A}\right)$

$\Rightarrow \frac{3V_{max}}{2A} = V_e - \frac{V_{max}}{2A}.$

$\Rightarrow \boxed{V_e = \frac{2V_{max}}{A}}$

(i) For $|V_e| < \frac{V_{max}}{2A}.$

$\rightarrow V_o = A\left(V_i - \frac{V_o}{n}\right)$

$\Rightarrow V_o = \left(\frac{An}{A+n}\right)V_i$

$\Rightarrow V_e = V_i - \frac{AV_i}{A+n}$

$\Rightarrow V_e = \frac{nV_i}{A+n}$ //.

$V_e \simeq \frac{n}{A}V_i$ for $|V_i| \leq \frac{V_{max}}{2n}$

(ii) $\frac{V_{max}}{2A} \leq |V_e| \leq \frac{2V_{max}}{A}$

$$V_o = \frac{A}{3}\left(V_i - \frac{V_o}{n}\right) + \frac{V_{max}}{3}.$$

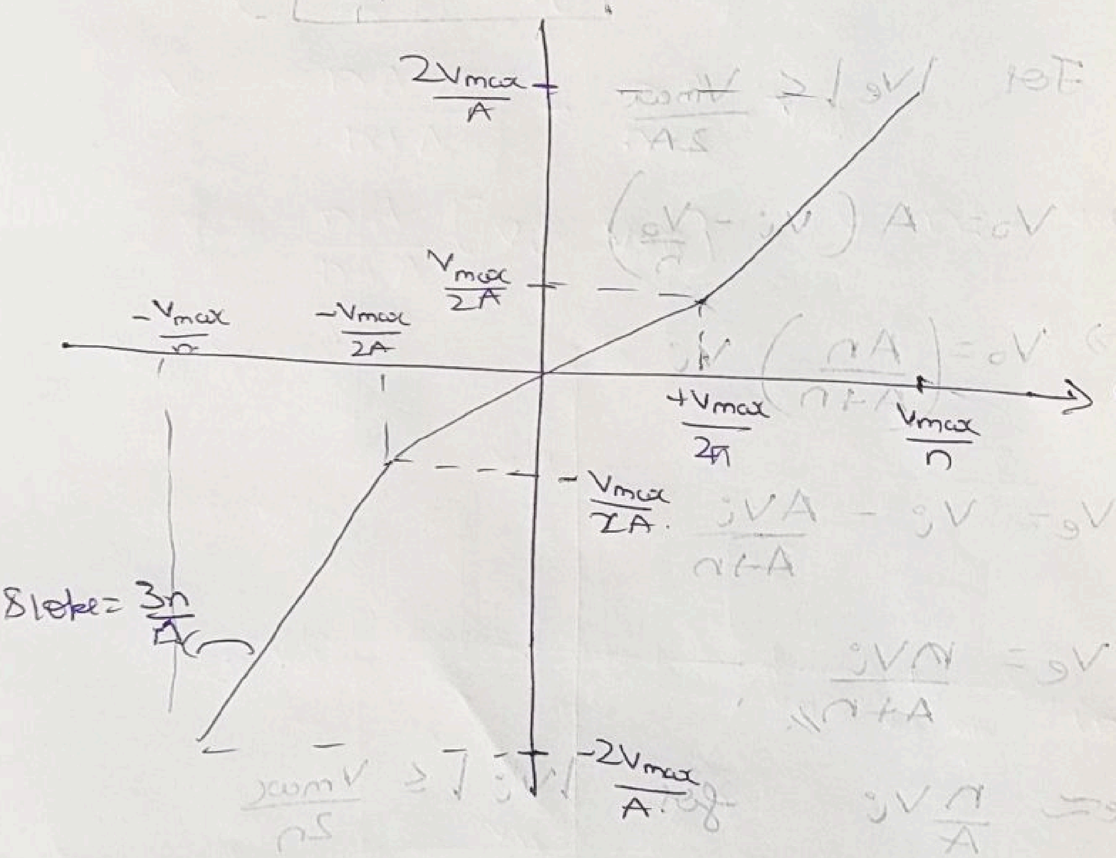
$$\Rightarrow V_o\left(1 + \frac{A}{3n}\right) = \frac{A}{3}V_i + \frac{V_{max}}{3}$$

$$\Rightarrow V_o \cancel{\left(1 + \frac{A}{3n}\right)} =$$

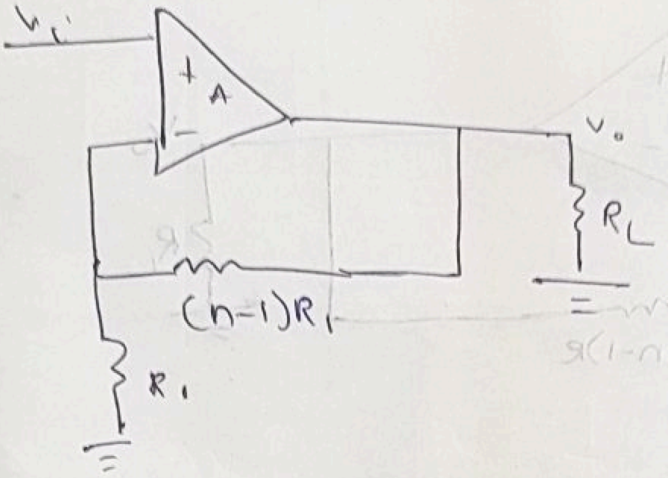
$$\Rightarrow V_o = \left(\frac{An}{A+3n}\right)V_i + \frac{3nV_{max}}{3(3n+A)}$$

$$\Rightarrow V_e = \left(\frac{3n}{A+3n}\right)\left(V_i - \frac{3V_{max}}{3(3n+A)}\right. \cdot \frac{3n(V_i)}{A} - \frac{V_{max}}{A}$$

$$\Rightarrow \frac{V_{max}}{2n} < |V_i| \leq \frac{V_{max}}{n}.$$



(12.) An Ideal opamp has '0' offset



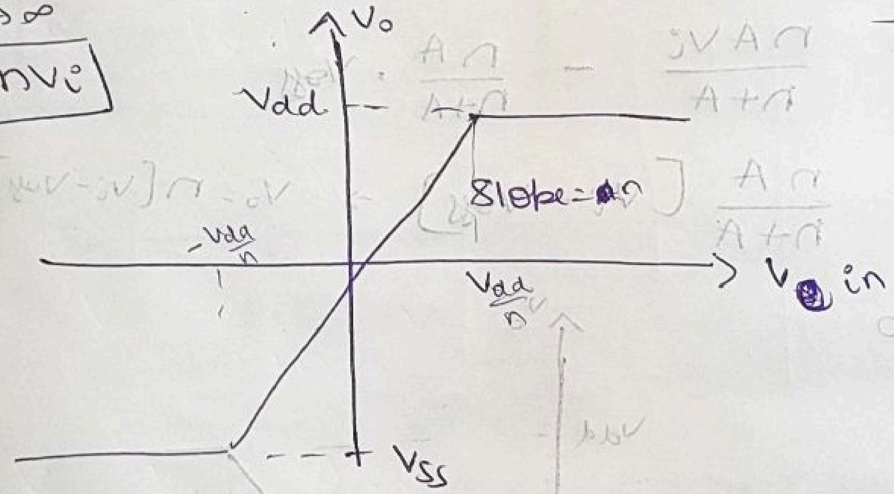
$\Rightarrow V_o = AV_e$

$\Rightarrow V_o = A\left[V_i - \frac{V_o}{n}\right]$

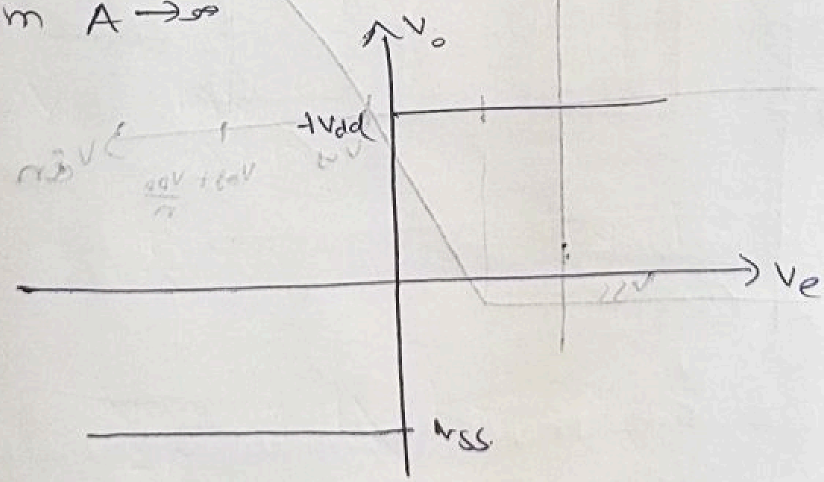
$\Rightarrow V_o = \left(\frac{An}{A+n}\right)V_i$ [till the saturation limit]

as $A \to \infty$

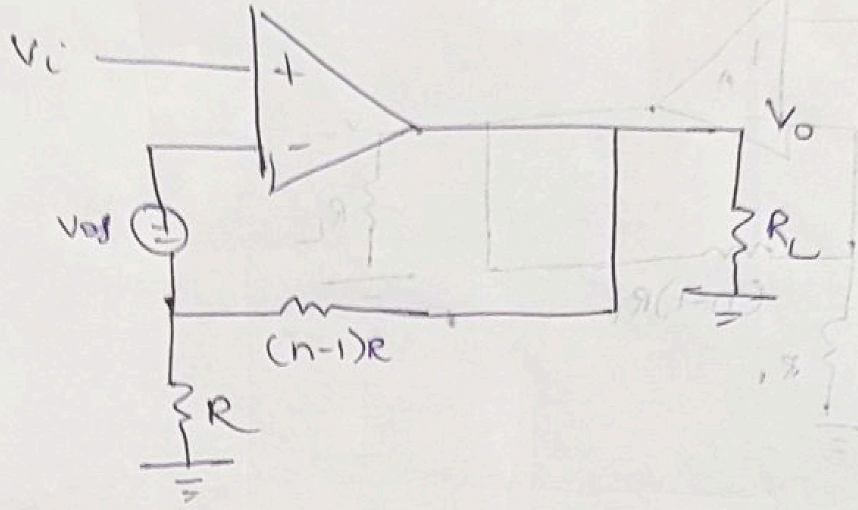
$\boxed{V_o = nV_i}$



lim $A \to \infty$



For a non ideal opamp with offset



$\Rightarrow V_o = A(V_e - V_{off})$ (given)

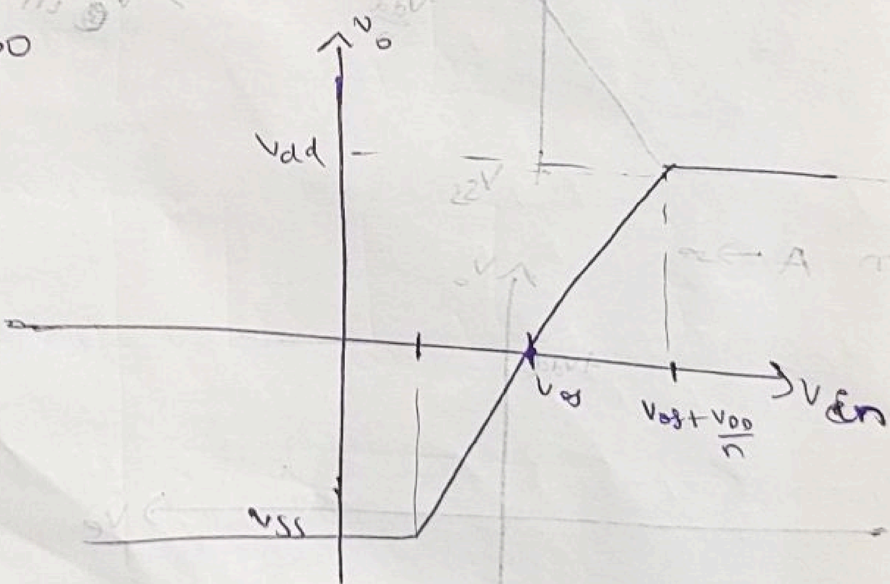
$V_o = A\left(V_{in} - \frac{V_o}{n} - V_{off}\right)$

$\Rightarrow V_o\left(1 + \frac{A}{n}\right) = AV_i - AV_{off}$

$\Rightarrow V_o = \frac{nAV_i}{n+A} - \frac{nA}{n+A} \cdot V_{off}$

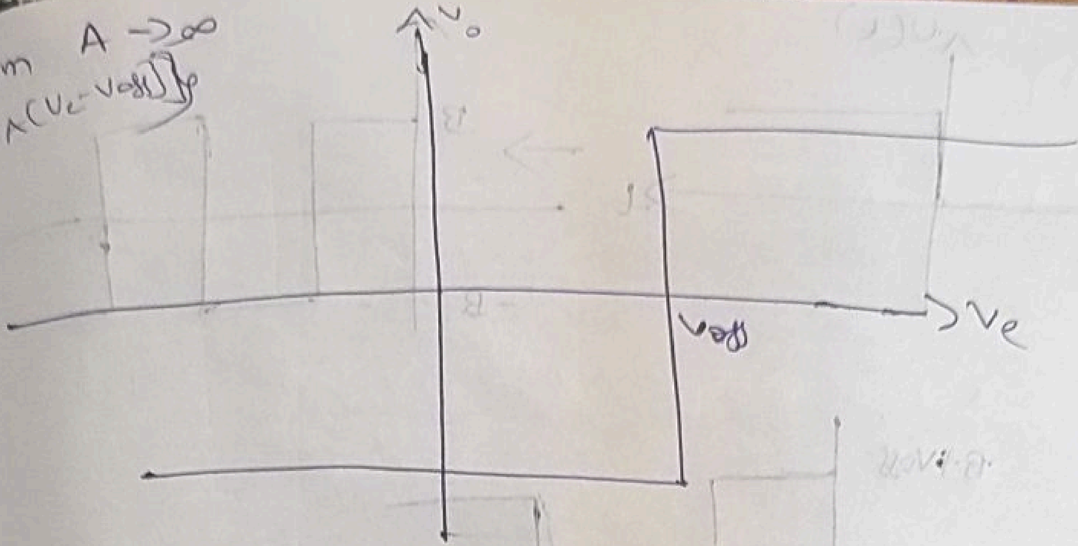
$\Rightarrow V_o = \frac{nA}{n+A}\left[V_i - V_{off}\right] \Rightarrow V_o = n\left[V_i - V_{off}\right]$

$V_{off} > 0$



$\lim_{A \to \infty}$

$\left[V_0 = A(V_e - V_{off})\right]$

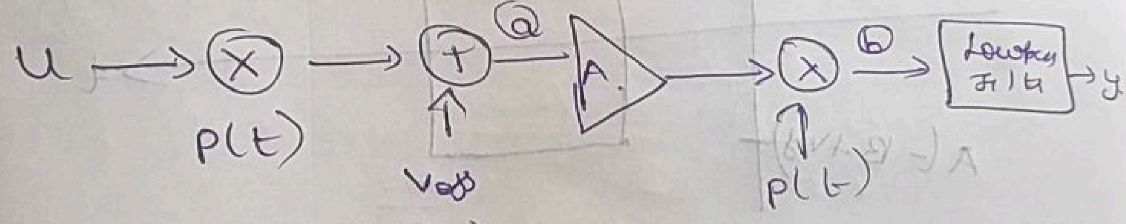


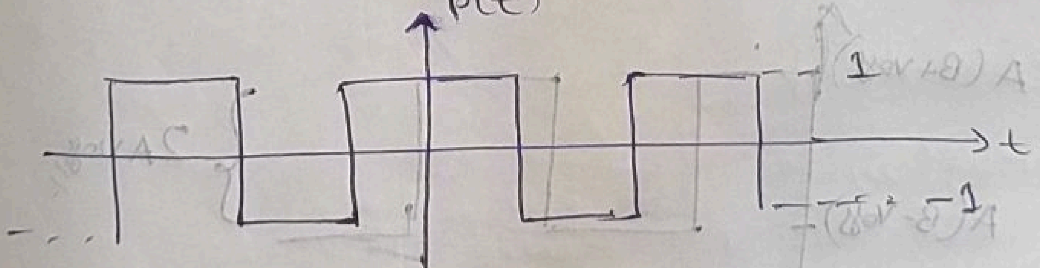
$$V_0\big|_{non\text{-}ideal} = V_0\big|_{ideal} - \underbrace{\left(\frac{n A}{n + A}\right) V_{off}}_{\text{output DC offset}}$$

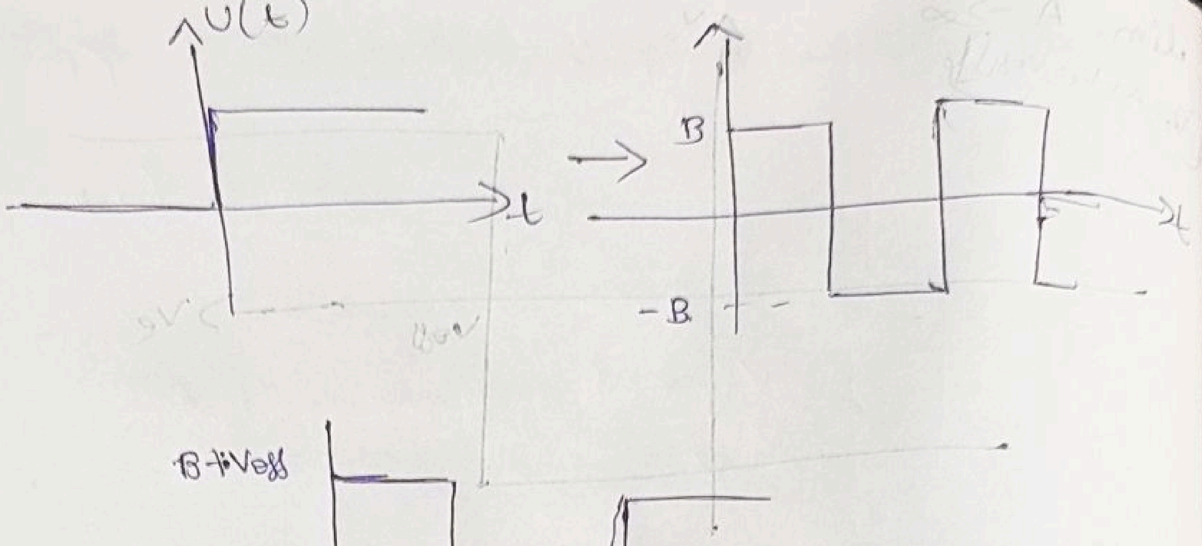
when $A \to \infty$.

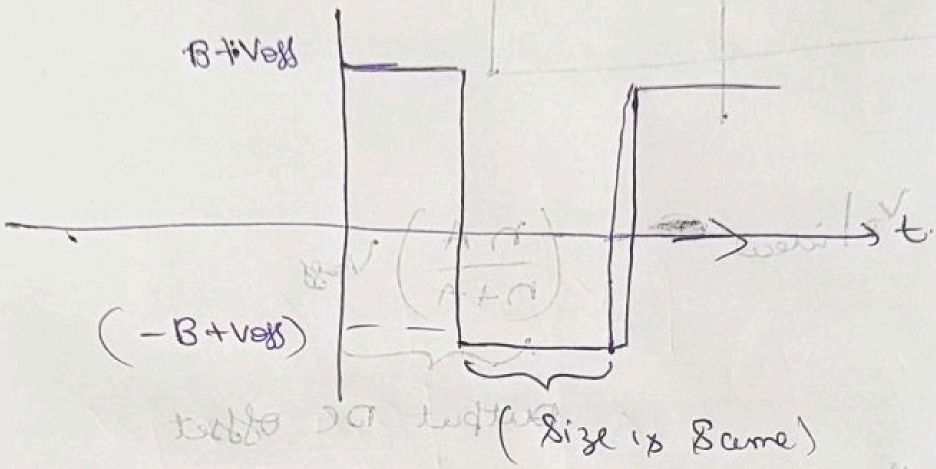
$$\boxed{DC_{offset} = -A V_{off}}$$

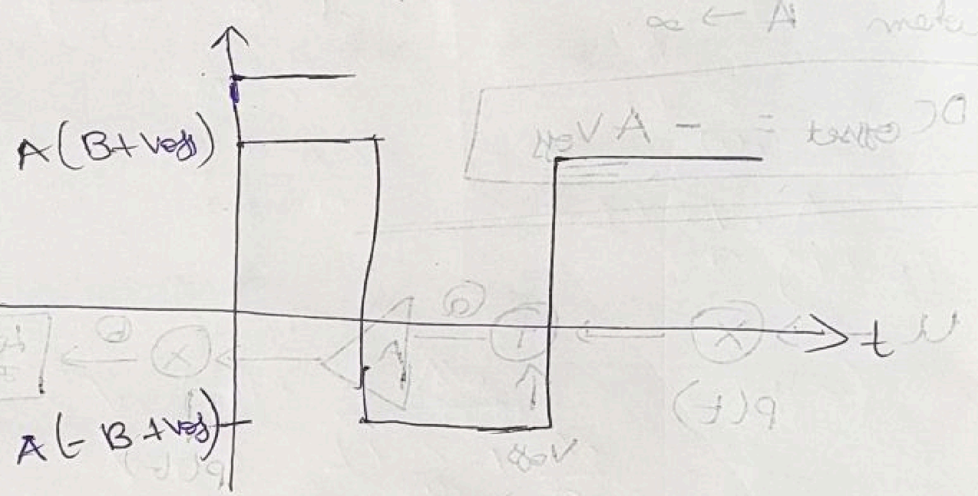
(14.)

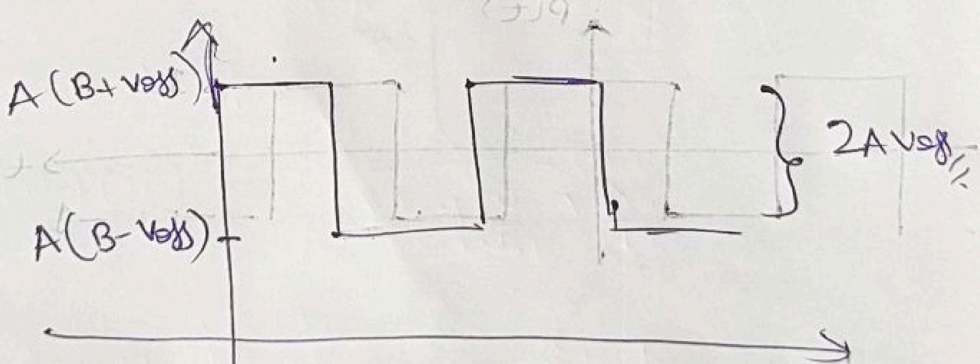






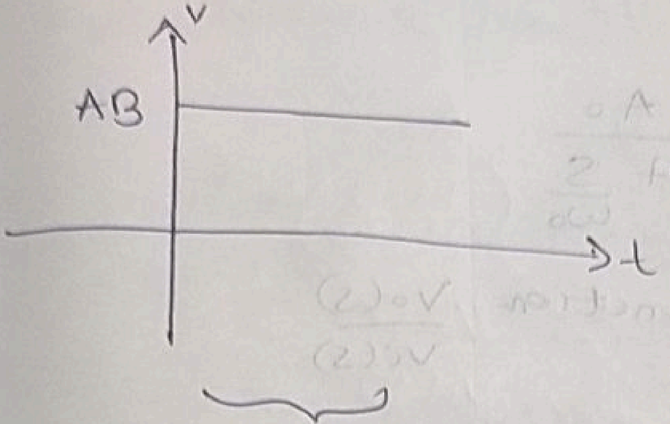






Now we must pass it through low pass filter//

~~This~~ The above graph can be expressed as



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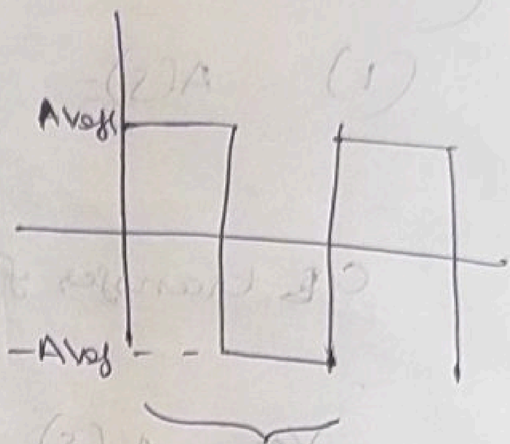


No frequency.

This has frequency

∴ output will be only from the DC part

$$\therefore \quad y = AB$$

So the output is purely dc amplified with a gain A.

$$\therefore \quad \boxed{\frac{y}{u} = A}$$

(19.)

(1) $A(S) = \dfrac{A_0}{1 + \dfrac{S}{\omega_0}}$

CL transfer function $= \dfrac{V_0(S)}{V_i(S)}$

$$\frac{V_0}{V_e} = A(S)$$

$$V_0 = A(S)\left[V_i - \frac{V_0}{n}\right]$$

$$V_0\left[1 + \frac{A(S)}{n}\right] = V_i\, A(S)$$

$$\frac{V_0}{V_{in}} = \frac{A(S)}{1 + \frac{A(S)}{n}} = \frac{\frac{A_0}{1 + \frac{S}{\omega_0}}}{1 + \frac{1}{n} \cdot \frac{A_0}{\left(1 + \frac{S}{\omega_0}\right)}}$$

$$\frac{V_0}{V_{in}} = \frac{A_0}{1 + \frac{S}{\omega_0} + \frac{A_0}{n}} = H(S)$$

Close loop -

$$H(j(\omega)) = \frac{A_0}{1 + \frac{j\omega}{\omega_0} + \frac{A_0}{n}}$$

$$|H(j\omega)| = \frac{A_0}{\sqrt{\left(1 + \frac{A_0}{n}\right)^2 + \left(\frac{\omega}{\omega_0}\right)^2}}$$

we need to find the 3dB frequency

Max value of $|H(j\omega)| = \dfrac{A_0}{\left(1+\frac{A_0}{n}\right)}$

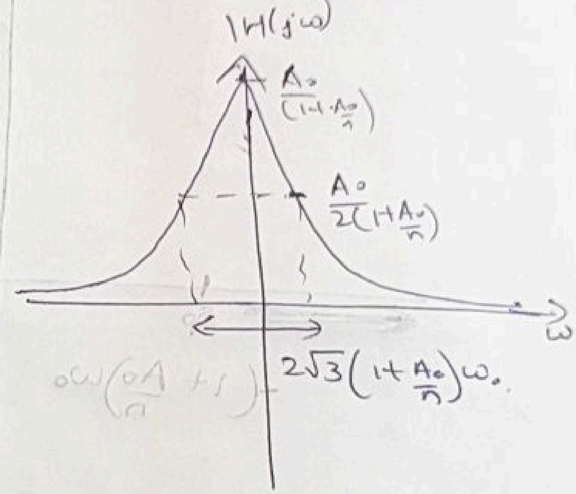
$$\therefore \frac{A_0}{2\left(1+\frac{A_0}{n}\right)} = \frac{A_0}{\sqrt{\left(1+\frac{A_0}{n}\right)^2+\left(\frac{\omega}{\omega_0}\right)^2}}$$

$$\Rightarrow 4\left(1+\frac{A_0}{n}\right)^2 = \left(1+\frac{A_0}{n}\right)^2+\left(\frac{\omega}{\omega_0}\right)^2$$

$$\Rightarrow \left(\frac{\omega}{\omega_0}\right)^2 = 3\left(1+\frac{A_0}{n}\right)^2$$

$$\Rightarrow \frac{\omega}{\omega_0} = \pm\sqrt{3}\left(1+\frac{A_0}{n}\right)$$

$$\Rightarrow \omega = \pm\sqrt{3}\left(1+\frac{A_0}{n}\right)\omega_0$$



$\therefore$ 3dB bandwidth

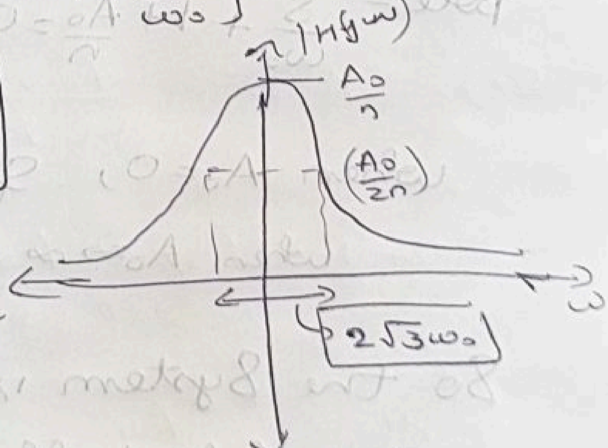
$$= 2\sqrt{3}\left(1+\frac{A_0}{n}\right)\omega_0$$

Close loop gain $\Rightarrow$ $\dfrac{(A(S))}{n}$

$$= \frac{1}{n}\left[\frac{A_0}{1+\frac{S}{\omega_0}}\right]$$

$$H(j\omega) = \frac{1}{n}\left[\frac{A_0}{1+j\frac{\omega}{\omega_0}}\right]$$

$$\Rightarrow |H(j\omega)| = \frac{1}{n}\frac{A_0}{\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}}$$



3dB bandwidth

$$\Rightarrow \frac{\cancel{A_0}}{2\cancel{n}} = \frac{1}{\cancel{n}}\frac{\cancel{A_0}}{\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}}$$

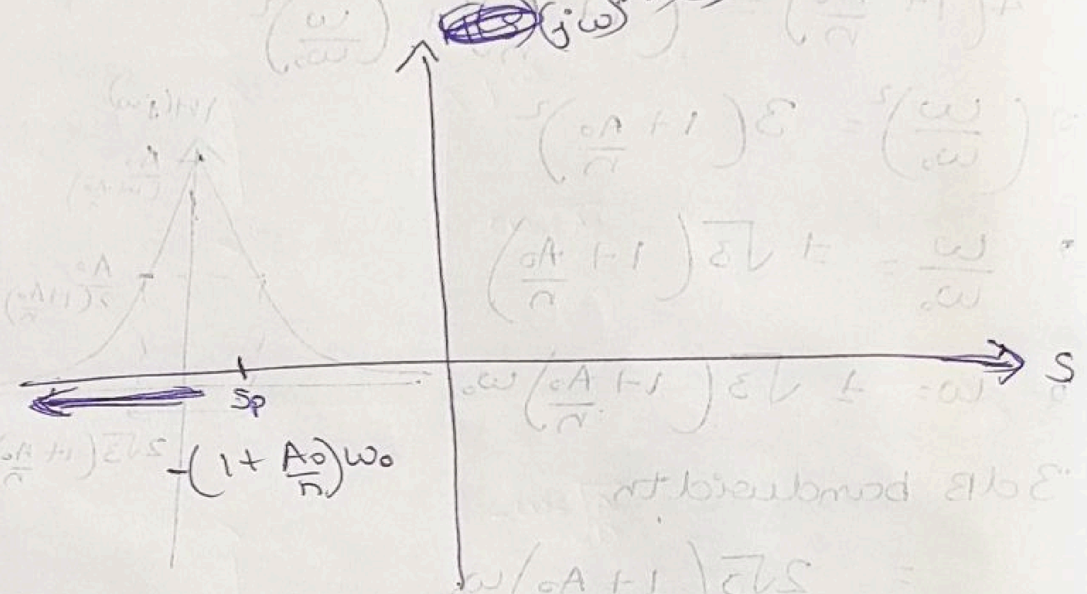
$$\Rightarrow 1+\left(\frac{\omega}{\omega_0}\right)^2 = 4. \qquad \Rightarrow \left(\frac{\omega}{\omega_0}\right)^2 = 3$$

$$\Rightarrow \omega = \pm\sqrt{3}\,\omega_0.$$

$\therefore$ 3dB bandwidth $= 2\sqrt{3}\,\omega_o$

(b.) $A(s) = \dfrac{A_o}{\left(1+\dfrac{s}{\omega_o}\right)^2}$

we need to Find $\rightarrow \dfrac{V_o(s)}{V_i(s)}$



$H(s) = \dfrac{A_o}{1+\dfrac{s}{\omega_o}+\dfrac{A_o}{n}}$

pole: $\dfrac{s}{\omega_o} + 1 + \dfrac{A_o}{n} = 0 \rightarrow s = -\left(1+\dfrac{A_o}{n}\right)\omega_o$

when $A_o = 0$, $S_p = -\omega_o$

when $A_o \Rightarrow \infty$ $S_p = -\infty$

So the system is stable as pole is on the left half of the plane

(b) $A(s) = \dfrac{A_o}{\left(1+\dfrac{s}{\omega_o}\right)^2}$

$$\Rightarrow \frac{V_o}{V_{in}} = \frac{A(s)}{1+\frac{A(s)}{n}} = \frac{\dfrac{A_o}{\left(1+\frac{s}{\omega_o}\right)^2}}{1+\dfrac{A_o}{\left(1+\frac{s}{\omega_o}\right)^2}\times\dfrac{1}{n}}$$

$$\Rightarrow \frac{V_o}{V_{in}} = \frac{A_o}{\left(1+\frac{s}{\omega_o}\right)^2+\frac{A_o}{n}}$$

$$= \frac{A_o}{\frac{s^2}{\omega_o^2}+\frac{2s}{\omega_o}+1+\frac{A_o}{n}}$$

$$= \frac{\dfrac{A_o}{\left(1+\frac{A_o}{n}\right)}}{\dfrac{s^2}{\omega_o^2\cdot\left(1+\frac{A_o}{n}\right)}+\dfrac{2s}{\omega_o\left(\frac{A_o}{n}+1\right)}+1}$$

$$\Rightarrow \frac{V_o}{V_{in}} = \frac{G}{\frac{s^2}{\omega_p^2}+\frac{2s}{\omega_p Q_p}+1}$$

$\omega_p = \omega_o\left(1+\frac{A_o}{n}\right)^{1/2}$ and $\left(Q_p = \frac{A_o}{n}+1\right)$

$$\Rightarrow H(s) = \frac{A_o}{\frac{s^2}{\omega_o^2}+\frac{2s}{\omega_o}+1+\frac{A_o}{n}}$$

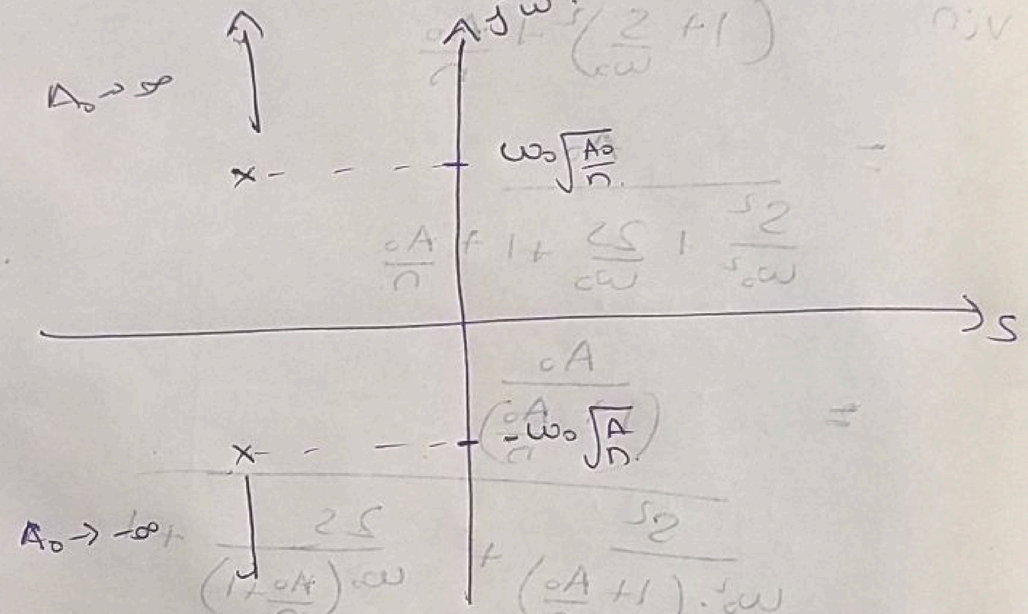
$$\frac{s^2}{\omega_o^2}+\frac{2s}{\omega_o}+1+\frac{A_o}{n} = 0$$

$\Rightarrow$

$$S = \frac{-\frac{2}{\omega_0} \pm \sqrt{\frac{4}{\omega_0^2} - \frac{4}{\omega_0^2}\left(1+\frac{A_0}{n}\right)}}{\frac{2}{\omega_0^2}}$$

$$S = -\omega_0 \pm \omega_0 \sqrt{1 - \left(1+\frac{A_0}{n}\right)}$$

$$\therefore S = -\omega_0 \pm i\omega \sqrt{\frac{A_0}{n}}$$



It is stable as for $\omega_0 > 0$, poles are strictly on the left half plane.

(c.) $$H(s) = \frac{A(s)}{1 + \frac{A(s)}{n}}$$

and $$A(s) = \frac{A_0}{\left(1+\frac{s}{\omega_0}\right)^3}$$

$$\Rightarrow H(s) = \frac{A_0}{\left(1+\frac{s}{\omega_0}\right)^3 + \frac{A_0}{n}}$$

$$n(S) = \frac{A_0}{\frac{S^3}{\omega_0^3} + 1 + \frac{3S}{\omega_0}\left(1 + \frac{S}{\omega_0}\right) + \frac{A_0}{n}}$$

$$= \frac{A_0}{\frac{S^3}{\omega_0^3} + \frac{3S^2}{\omega_0^2} + \frac{3S}{\omega_0} + 1 + \frac{A_0}{n}}$$

$\Rightarrow$ Roots:-

$$\frac{S^3}{\omega_0^3} + \frac{3S^2}{\omega_0^2} + \frac{3S}{\omega_0} + 1 + \frac{A_0}{n} = 0$$

$\Rightarrow$ $S_1 = \omega_0^3 - (A_0\omega_0^3 + n\omega_0^3)^{\frac{1}{3}} - \omega_0.$

$$S_2 = -\omega_0 - \frac{\sqrt{3}}{2}\left[\omega_0^3 - \left(\frac{A_0\omega_0^3 + n\omega_0^3}{n}\right)\right]^{\frac{1}{3}} i - \frac{1}{2}\left(\omega_0^3 - \left(\frac{A_0\omega_0^3 + n\omega_0^3}{n}\right)\right]^{\frac{1}{3}}.$$

$$S_3 = -\omega_0 + \frac{\sqrt{3}}{2}\left[\omega_0^3 - \left(\frac{A_0\omega_0^3 + n\omega_0^3}{n}\right)\right]^{\frac{1}{3}} i - \frac{1}{2}\left[\omega_0^3 - \left(\frac{A_0\omega_0^3 + n\omega_0^3}{n}\right)\right]^{\frac{1}{3}}$$