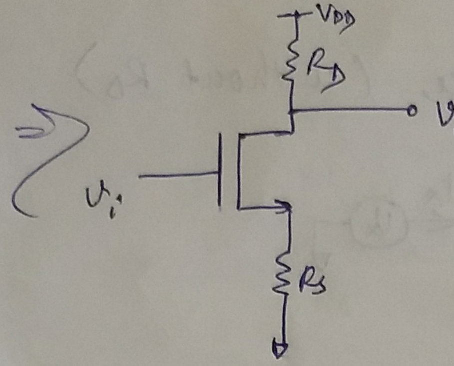
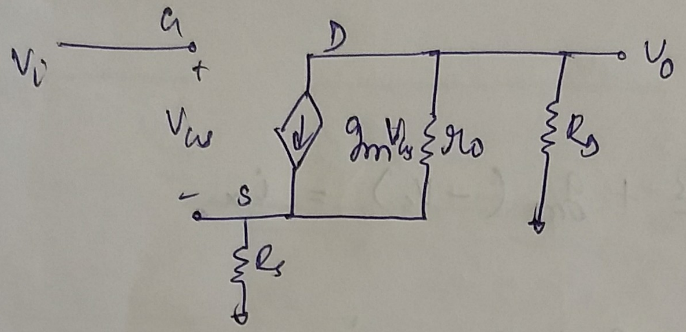
1.

A)



common source configuration



$$g_m (V_i - V_s) + \frac{(V_o - V_s)}{r_o} + \frac{V_o}{R_D} = 0$$

$$\frac{V_s}{R_S} = -\frac{V_o}{R_D} \Rightarrow V_s = -\frac{R_S}{R_D} V_o$$

$$g_m V_i + \left(\frac{R_S}{R_D} g_m + \left(1 + \frac{R_S}{R_D}\right)\frac{1}{r_o} + \frac{1}{R_D}\right) V_o = 0$$

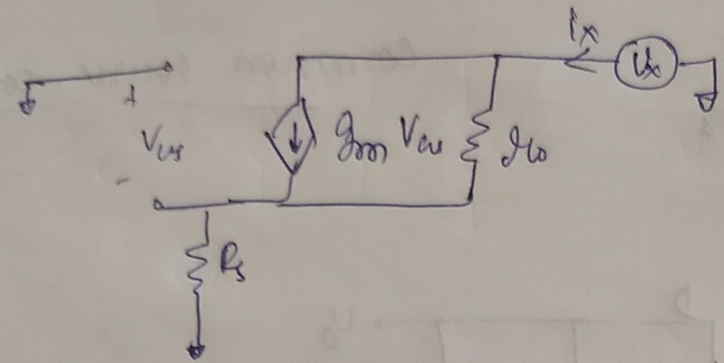
a) $$A_v = \frac{V_o}{V_i} = \frac{-g_m}{\frac{R_S}{R_D} g_m + \left(1 + \frac{R_S}{R_D}\right)\frac{1}{r_o} + \frac{1}{R_D}}$$

$$= \frac{-10^{-3}}{\frac{5\times10^3}{10\times10^3}\times10^{-3} + \left(1 + \frac{5\times10^3}{10\times10^3}\right)\frac{1}{50\times10^3} + \frac{1}{10\times10^3}}$$

$$= -\frac{10^{-3}}{0.5\times10^{-3} + 0.03\times10^{-3} + 0.1\times10^{-3}}$$

$$= 1.587$$

b) To calculate o/p impedance, (without R_D)



$$i_x = \frac{V_s}{R_s}, \quad \frac{V_x - V_s}{r_o} + g_m(-V_s) = i_x$$

$$\frac{V_x}{r_o} - \frac{i_x R_s}{r_o} - g_m i_x R_s = i_x$$

$$\frac{V_x}{r_o} = \left(\frac{R_s}{r_o} + g_m R_s + 1\right) i_x$$

$$R_{out} = R_s + (1 + g_m R_s) r_o$$

including R_D

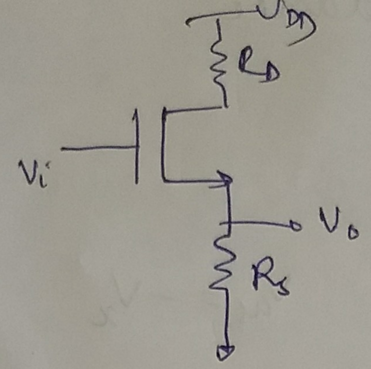
$$R'_{out} = (R_s + (1 + g_m R_s) r_o) \,||\, R_D$$

$$= (5K + (1 + 1m \cdot 5K) 50K) \,||\, 10K$$

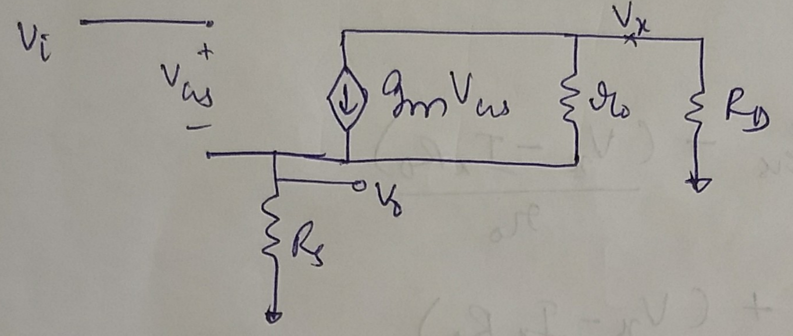
$$= 305K \,||\, 10K$$

$$= 9.6825 K\Omega$$

c) I/p impedance is infinity.



common drain configuration



$V_{gs} = V_i - V_o$

$$V_x = -\frac{V_o}{R_s} \times R_D$$

$$\frac{V_o}{R_s} = g_m (V_i - V_o) + \frac{(V_x - V_o)}{r_o}$$

$$= g_m (V_i - V_o) + \left(-V_o \frac{R_D}{R_s} - V_o\right)\frac{1}{r_o}$$

$$V_o\left(\frac{1}{R_s} + g_m + \left(\frac{R_D}{R_s} + 1\right)\frac{1}{r_o}\right) = g_m V_i$$

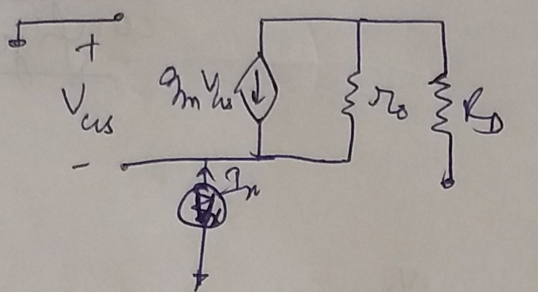
a) $$A_V = \frac{V_o}{V_i} = \frac{g_m}{\frac{1}{R_s} + g_m + \left(\frac{R_D}{R_s}+1\right)\frac{1}{r_o}}$$

$$= \frac{1m}{\frac{1}{5K} + 1m + \left(\frac{10K}{5K} + 1\right)\frac{1}{50K}}$$

$$= \frac{1m}{0.2m + 1m + 0.06m}$$

$$= 0.79365$$

b) Calculation of O/P Impedance.



$V_{gs} = -V_x$

$$I_x = -g_m V_{gs} + \frac{(V_x - I_x R_D)}{r_o}$$

$$= g_m V_x + \frac{(V_x - I_x R_D)}{r_o}$$

$$= \left(g_m + \frac{1}{r_o}\right)V_x - I_x \frac{R_D}{r_o}$$

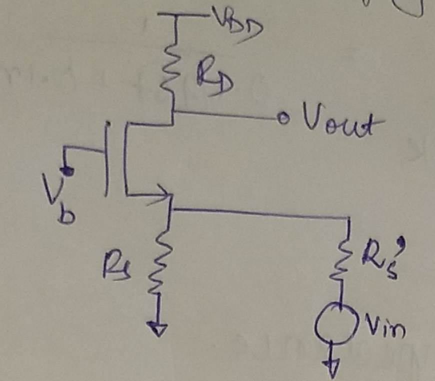
$$\left(1 + \frac{R_D}{r_o}\right) I_x = \left(g_m + \frac{1}{r_o}\right) V_x$$

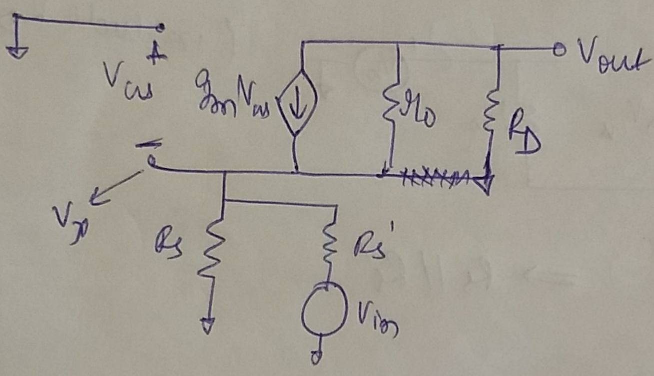
$$R_{out} = \frac{V_x}{I_x} = \frac{r_o + R_D}{1 + g_m r_o} = \frac{50K + 10K}{1 + 1m \cdot 50K} = 1.1765 K\Omega$$

$$R_{out}' = R_{out} \,//\, R_s = 1.1364 K\Omega$$

c) Input impedance is infinity.

B) Common Gate Amplifier.





$$\frac{V_x}{R_S} + \frac{V_x - V_{in}}{R_S'} = -\frac{V_{out}}{R_D} \quad \& \quad -\frac{V_{out}}{R_D} = -g_m V_x + \frac{(V_{out} - V_x)}{r_o}$$

$$V_x\left(\frac{1}{R_S} + \frac{1}{R_S'}\right) - \frac{V_{in}}{R_S'} = -\frac{V_{out}}{R_D} \quad \& \quad \left(g_m + \frac{1}{r_o}\right) V_x = \left(\frac{1}{R_D} + \frac{1}{r_o}\right) V_{out}$$

$$V_x = \frac{(R_D + r_o)}{(1 + g_m r_o) R_D} V_{out}$$

$$\frac{(R_D + r_o)}{(1 + g_m r_o) R_D}\left(\frac{1}{R_S} + \frac{1}{R_S'}\right) V_{out} + \frac{V_{out}}{R_D} = \frac{V_{in}}{R_S'}$$

a) $$A_V = \frac{V_{out}}{V_{in}} = \frac{1/R_S'}{\frac{(R_D + r_o)}{(1 + g_m r_o) R_D}\left(\frac{1}{R_S} + \frac{1}{R_S'}\right) + \frac{1}{R_D}}$$

for $R_S' = 1M\Omega$

$$A_V = \frac{1/10^6}{\frac{60K}{510K}\left(\frac{1}{5K} + \frac{1}{1M}\right) + \frac{1}{10K}} = \frac{10^{-2}}{1.17647 \times \frac{1005K}{5K \times 1M} + 1} = \frac{10^{-2}}{2.365 \times 10^{-1} + 1}$$

$$\cancel{\approx 9.99763 \times 10^{-3}}$$

$$= 8.0873 \times 10^{-3}$$

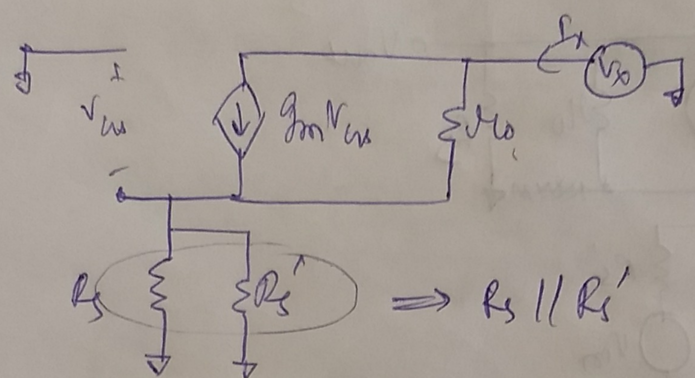
for $R_s' = 1\Omega$

$$A_v = \frac{1}{\frac{60K}{510K}\left(\frac{1}{5K}+1\right)+\frac{1}{10K}} = \frac{1}{0.11767 + 0.1m} = \frac{1}{117.77m}$$

$$= 8.491126$$

b) Calculation of o/p impedance.

(include R_D later)



expression similar to that of common source.

$$R_{out}' = R_D \,||\, \left[\left(R_s||R_s' + (1+g_m(R_s||R_s'))\right) r_o\right]$$

for $R_s' = 1M\Omega$, $R_s || R_s' = 4.975 K\Omega$

$$R_{out}' = 10K\Omega \,||\, \left[4.975K + (1 + 1m \times 4.975K) 50K\right]$$

$$= 10K\Omega \,||\, 303.725K$$

$$= 9.68124 K\Omega$$

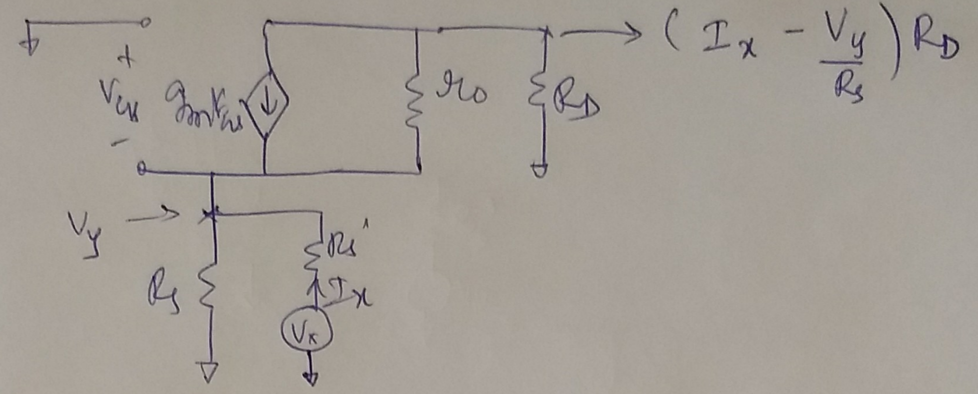
for $R_s' = 1\Omega$, $R_s || R_s' = 5K\Omega || 1 = 0.9998 K\Omega$

$$R_{out}' = 10K\Omega \,||\, \left[0.9998K + (1 + 1m \times 0.9998K) 50K\right]$$

$$= 10K\Omega \,||\, 100.9898K$$

$$= 9.099016 K\Omega$$

c) Calculation of i/p impedance



$$\frac{V_y - V_x}{R_s'} = -I_x \quad , \quad -g_m V_y + \left[\left(I_x - \frac{V_y}{R_s}\right)R_D - V_y\right]\frac{1}{r_o}$$

$$\Rightarrow V_y = V_x - I_x R_s' \qquad\qquad = \frac{V_y}{R_s} - I_x$$

$$I_x\left(\frac{R_D}{r_o} + 1\right) = \left[g_m + \frac{1}{r_o}\left(1 + \frac{R_D}{R_s}\right) + \frac{1}{R_s}\right]V_y$$

$$= \left[g_m + \frac{1}{r_o}\left(1 + \frac{R_D}{R_s}\right) + \frac{1}{R_s}\right](V_x - I_x R_s')$$

$$I_x\left\{\frac{R_D}{r_o} + 1 + R_s'\left[g_m + \frac{1}{r_o}\left(1 + \frac{R_D}{R_s}\right) + \frac{1}{R_s}\right]\right\} = \left(g_m + \frac{1}{r_o}\left(1 + \frac{R_D}{R_s}\right) + \frac{1}{R_s}\right)V_x$$

$$R_{in} = R_s' + \frac{\left(\frac{R_D}{r_o} + 1\right)}{g_m + \frac{1}{r_o}\left(1 + \frac{R_D}{R_s}\right) + \frac{1}{R_s}}$$

for $R_s' = 1M\Omega$

$$R_{in} = 1M\Omega + \frac{\frac{10K}{50K} + 1}{1m + \frac{1}{50K}\left(1 + \frac{10K}{5K}\right) + \frac{1}{5k}} = 1M\Omega + \frac{0.2}{1m + 0.06m + 0.2m}$$

$$= 1M\Omega + 158.7\Omega$$

$$= 1000.1587 k\Omega$$

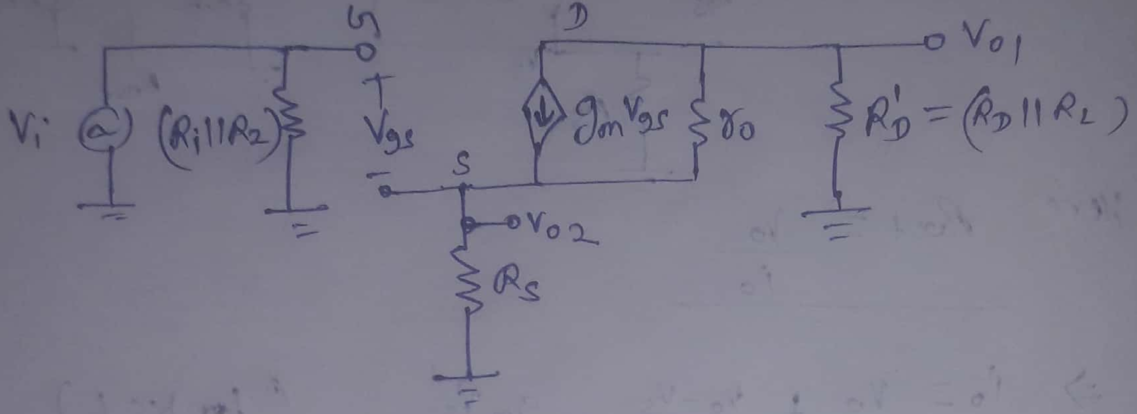
for $R_s' = 1\Omega$

$$R_{in} = 1\Omega + 158.7\Omega$$

$$= 159.7\Omega$$

Q. No. 2(A)

→ Small signal model for the saturation region



(a) KCL at node S,

$$g_m V_{gs} + \frac{V_{o1} - V_{o2}}{r_o} = \frac{V_{o2}}{R_S}$$

$$g_m (V_i - V_{o2}) + \frac{V_{o1} - V_{o2}}{r_o} = \frac{V_{o2}}{R_S} \qquad (\because V_{gs} = V_i - V_{o2})$$

$$g_m V_i = V_{o2}\left(\frac{1}{R_S} + g_m + \frac{1}{r_o}\right) - \frac{V_{o1}}{r_o} \qquad \text{——— (1)}$$

and also

$$\frac{V_{o2}}{R_S} = -\frac{V_{o1}}{R_D'}$$

$$\Rightarrow V_{o2} = -\frac{R_S}{R_D'} V_{o1}$$

putting value of V_{o2} in equation (1)

we get

$$g_m V_i = -\frac{R_S}{R_D'}\left(\frac{1}{R_S} + g_m + \frac{1}{r_o}\right) V_{o1} - \frac{V_{o1}}{r_o}$$

$$g_m V_i = -\left(\frac{1}{R_D'} + \frac{g_m R_S}{R_D} + \frac{R_S}{R_D r_o}\right) V_{o1} - \frac{V_{o1}}{r_o}$$

$$g_m V_i = -\frac{(r_o + g_m R_S r_o + R_S + R_D') V_{o1}}{R_D' r_o}$$

$\Rightarrow \quad g_m R_D' r_o V_i = -(r_o + R_S + R_D' + g_m R_S r_o) V_{o1}$

$$\Rightarrow \boxed{\frac{V_{o1}}{V_i} = \frac{-g_m R_D' r_o}{r_o + R_D' + R_S(1+g_m r_o)}} \quad \text{— (2)}$$

gain for CS amplifier.

and after putting value of V_{o1} in equation (2)

we get

$$-\frac{R_D' \cdot V_{o2}}{R_S \; V_i} = \frac{-g_m R_D' r_o}{r_o + R_D + R_S(1+g_m r_o)}$$

$$\Rightarrow \boxed{\frac{V_{o2}}{V_i} = \frac{g_m r_o R_S}{r_o + R_D' + R_S(1+g_m r_o)}} \quad \text{— (3)}$$

gain for CD amplifier.

as value are given as

$R_1 = R_2 = R_L = 10\,k\Omega$, $g_m = 1\,mS$, $r_o = 50\,k\Omega$

$R_s = 5K$, $R_D = 10\,k\Omega \Rightarrow R_D' = R_D \| R_L = 5\,k\Omega$

after putting values in equation (2) and (3)

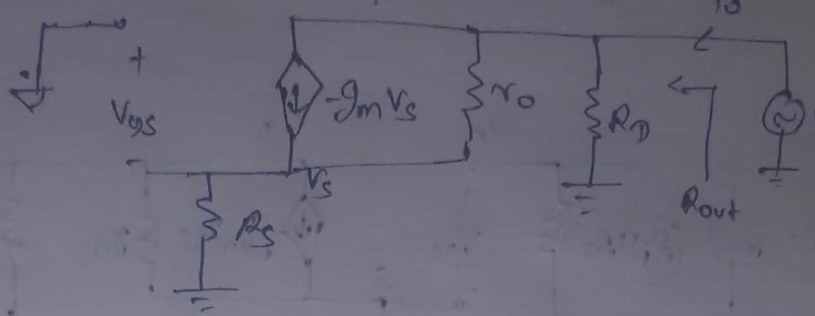
$$\boxed{\frac{V_{o1}}{V_i} = -0.806}$$

$$\boxed{\frac{V_{o2}}{V_i} = 0.806}$$

(b)

(b) output impedance calculation by shorting source. (3)

→ for CS



Here $R_{out} = \dfrac{V_o}{i_o}$

$$\Rightarrow \quad i_o = \frac{V_o}{R_D} + \frac{V_o - V_s}{r_o} - g_m V_s \qquad (\text{by KCL})$$

$$i_o = V_o\left(\frac{1}{R_D} + \frac{1}{r_o}\right) - V_s\left(g_m + \frac{1}{r_o}\right)$$

$$V_o\left(\frac{r_o + R_D}{r_o R_D}\right) = i_o + V_s\frac{(r_o g_m + 1)}{r_o} \quad \text{--- (1)}$$

and

$$\frac{V_s}{R_s} = -g_m V_s + \frac{V_o - V_s}{r_o}$$

$$V_s\left(\frac{1}{R_s} + g_m + \frac{1}{r_o}\right) = \frac{V_o}{r_o}$$

$$V_s = \frac{V_o}{r_o}\left(\frac{R_s r_o}{r_o + g_m r_o R_s + R_s}\right) = \frac{R_s V_o}{r_o + R_s + g_m r_o R_s}$$

from equation (1)

$$V_o\left(\frac{r_o + R_D}{r_o R_D}\right) = i_o + \frac{(r_o g_m + 1) R_s V_o}{r_o (r_o + R_s + g_m r_o R_s)}$$

$$V_o\left(\frac{r_o + R_D}{r_o R_D} - \frac{R_s(1 + r_o g_m)}{r_o(r_o + R_s(1 + g_m r_o))}\right) = i_o$$

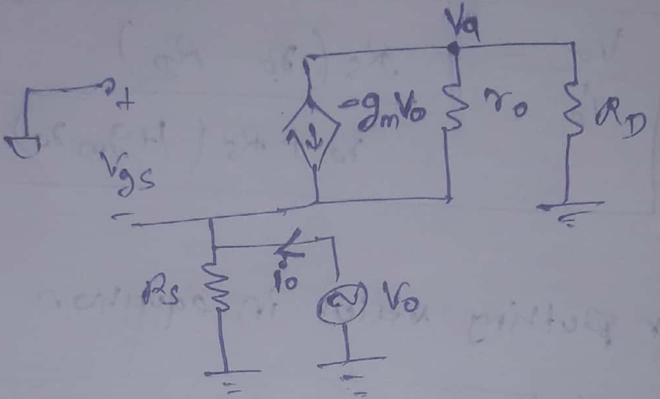
after solving

(4)

$$V_o\left(\frac{R_D + r_o + R_s(1+g_m r_o)}{R_D[r_o + R_s(1+g_m r_o)]}\right) = i_o$$

$$\boxed{R_{out} = \frac{V_o}{i_o} = \frac{R_D(r_o + R_s(1+g_m r_o))}{r_o + R_D + R_s(1+g_m r_o)}} \rightarrow (4) \rightarrow \text{for CS}$$

$\Rightarrow$ Similar for CD amplifier



$$R_{out} = \frac{V_o}{i_o}$$

$\Rightarrow$ $i_o = \dfrac{V_o}{R_s} + g_m V_o + \dfrac{V_o - V_a}{r_o}$ (by KCL) —— (1)

and $\dfrac{V_a}{R_D} = \dfrac{V_a - V_o}{r_o} - g_m V_o$

$$V_a\left(\frac{1}{R_D} - \frac{1}{r_o}\right) = -V_o\left(g_m + \frac{1}{r_o}\right)$$

$$V_a\left(\frac{r_o - R_D}{r_o R_D}\right) = -V_o\frac{(1+g_m r_o)}{r_o}$$

$$V_a = \frac{(1+g_m r_o)\,V_o \cdot R_D}{(R_D - r_o)\cdot}$$

Putting value of Va in equation (1)

(5)

$$i_o = v_o\left(\frac{1}{R_S} + g_m + \frac{1}{r_o}\right) - \frac{1}{r_o}\frac{(1+g_m r_o) R_D V_o}{(R_D - r_o)}$$

$$i_o = V_o\left[\frac{r_o + g_m r_o R_S + R_S}{r_o R_S} + \frac{(1+g_m r_o) R_D}{r_o(r_o - R_D)}\right]$$

$$i_o = V_o\left[\frac{r_o + R_S(1+g_m r_o) - R_D}{R_S(r_o - R_D)}\right]$$

$$R_{out} = \boxed{\frac{V_o}{i_o} = \frac{R_S(r_o - R_D)}{r_o + R_S(1+g_m r_o) - R_D}} \quad \text{— (5)} \rightarrow \text{for CD}$$

after putting value in equation (4) & (5)

we get

$$\boxed{R_{out} = 9.68\ k\Omega \quad \text{for CS}}$$

and

$$\boxed{R_{out} = 0.677\ k\Omega \quad \text{for CD ampr}}$$

(c) input impedance

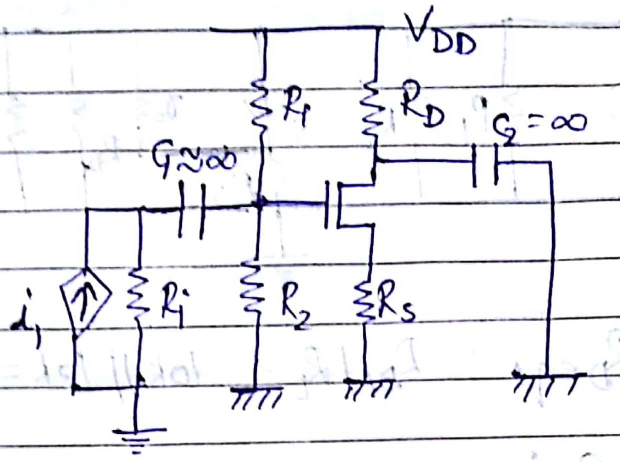
$$R_{in} = R_1 \| R_2 = 5\ k\Omega$$

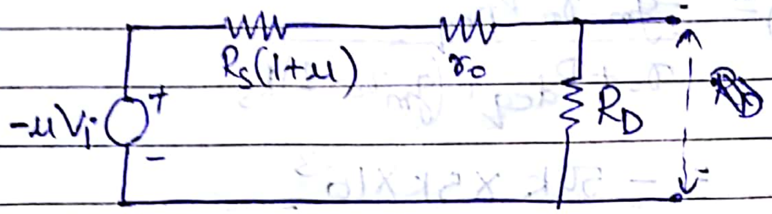
Date :

2. (B) $R_i = 1\,M\Omega$

$R_{eq} = R_1 \,||\, R_2 \,||\, R_i$

In a common source eq. circuit is

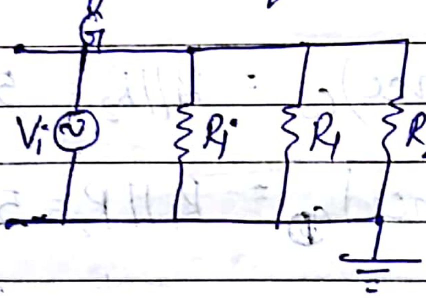




for short circuit gain.

Output current $= \dfrac{\mu V_i}{R_s (1+\mu) + r_o}$

Small signal equivalent of input,



Input Current $= \dfrac{V_i}{R_{eq}}$

$\therefore A_i$ (Current Gain) $= \dfrac{\mu R_{eq}}{R_s(1+\mu) + r_o}$

$\mu = g_m r_o = 50$

$\dfrac{50\, R_{eq}}{R_s(51) + 50} = 10 \rightarrow R_s = \dfrac{5R_{eq} - 50}{51}$

Scanned by CamScanner

$\therefore$ Output Impedence $= R_d \,||\, r_o + R_s(1+\mu)$
$= R_d \,||\, 5R_{eq}$
for Output Impedence to be max.
R_d should be as high as possible

$\therefore$ Output impedence $= 5R_{eq}$

CD config,
Current Gain $= \dfrac{\mu R_{eq}}{r_o + R_D} = 10$

$r_o + R_{eq} = \dfrac{\mu R_{eq}}{10} = 5R_{eq}$

O/P Imp. $= R_s \,||\, \dfrac{r_o + R_D}{1+\mu}$

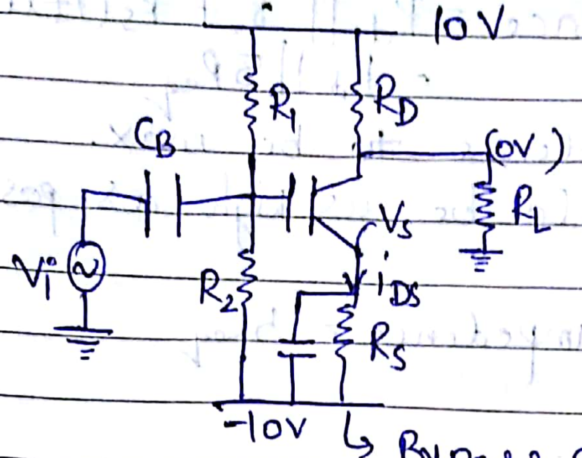
If R_s is high, we cannot use C-G config.
As Current Gain < 1.
$\Rightarrow$ CS config. O/P Impedence $= \dfrac{5R_{eq}}{51}$

$R_s = \dfrac{5R_{eq} - 50}{51}$ and R_D is as high as poss.

eg: $\boxed{R_d = 250\, R_{eq}}$

If we dont consider DC biasing
$R_{eq} = R_i = 1000\,k\Omega$
$R_s = \dfrac{5000 - 50}{51} = 97\,k\Omega$
$R_D = 250\, R_{eq} = 250\,M\Omega$
O/P Imp. $= 5R_{eq} = 5M\Omega$
If we consider DC biasing,
$R_s = \dfrac{5R_{eq} - 50}{51}$ $R_D = 250\, R_{eq}$.

Q. (c)



Given: $k' = 1\,mA/V^2$ $\quad V_{GG} = 0$

$V_T = 0.5V$ $\quad V_{SS} = -10V$

$V_{DD} = 10V$ $\quad \lambda = 0.01\,V^{-1}$

$V_{GG} = 0$ $\qquad \dfrac{10}{R_1} = \dfrac{0-(-10)}{R_2} \Rightarrow R_1 = R_2$

In DC current I_{DS}:

$10 = i R_D$

$10 + V_S = i R_S$

$i = \dfrac{10^{-3}}{2}(-V_S - 0.5)^2$

$$\text{Gain} = \frac{\mu(R_D||R_L)}{r_o + (R_D||R_L) + R_S(1+\mu)}$$

$$\mu = g_m r_o = \sqrt{2ik'} \cdot \frac{1}{\lambda i} = \frac{1}{\lambda}\sqrt{\frac{2k'}{i}} = \frac{1}{\lambda}\sqrt{\frac{k'R_D}{5}}$$

$$\text{Gain} = \frac{\frac{1}{\lambda}\sqrt{\frac{k'R_D}{5}}\,(R_D||R_L)}{r_o + (R_D||R_L) + R_S\left(1 + \frac{1}{\lambda}\sqrt{\frac{k'R_D}{5}}\right)}$$

for Gain to be max. $R_S \approx 0$

$r_o = \dfrac{100}{i}$ $\qquad R_D = \dfrac{10}{i}$ $\Rightarrow r_o || R_D = \dfrac{9.1}{i}$

$$\text{Gain} = \sqrt{2ik'}\left(\frac{9.1}{i} || R_L\right)$$

$$\text{Gain} = \frac{\sqrt{2k'}\,(9.1\,R_L)}{R_L\sqrt{i} + \frac{9.1}{\sqrt{i}}}$$

$\therefore$ for max. Gain, $\frac{9.1}{\sqrt{i}} = R_L\sqrt{i} \Rightarrow i = \frac{9.1}{R_L}$

$$\text{Gain} = \sqrt{\frac{9.1\,k'}{2}} \times \sqrt{R_L}$$

$$i = \frac{9.1}{R_L} = \frac{k'}{2}(-V_S - V_T)^2$$

$$-V_S > V_T = 0.5 \Rightarrow V_S < 0.5$$

$$\frac{9.1}{R_L} = \frac{k'}{2}(0.5)^2$$

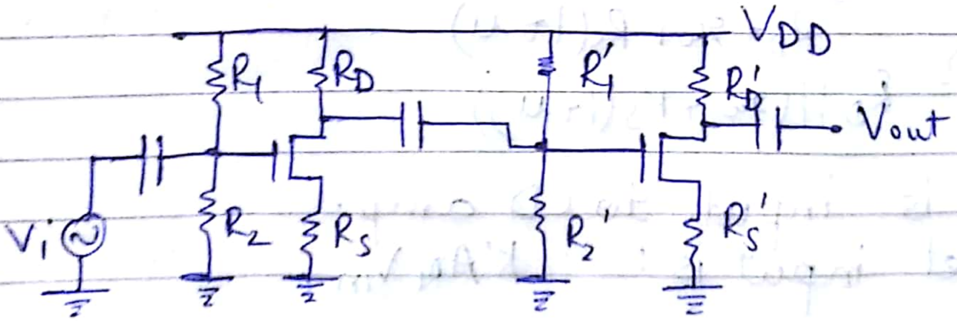
$$\boxed{R_L \approx 72\,k\Omega}$$

Gain $= 18.2$

$R_S = \frac{9}{i} = 72\,k$, $R_D = \frac{10}{i} = 80\,k$

$R_1 = R_2 = 100k$, $R_L = 72\,k\Omega$

③ ⓐ CS-CS Amp.



$$A_{v_1} = \frac{-g_m r_o R_D}{R_D + r_o + R_S(1+\mu)}$$

$$Z_{out}^{(1)} = R_D \| (r_o + R_S(1+\mu))$$

At Gate of second,

$$\frac{A_{r_1} \cdot (R_1' \| R_2')}{(R_1' \| R_2') + Z_{out}^{(1)}} = k A_{r_1}$$

$$V_{out} = k A_{r_1} \cdot A_{r_2}$$

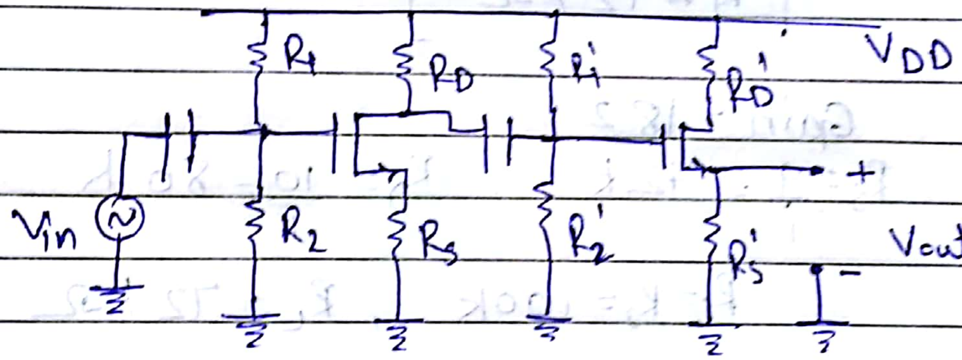
$$A_{V_2} = \frac{-g_m' r_o' R_D'}{R_D' + r_o' + R_s'(1+\mu')}$$

$$\text{Gain} = k A_{r_1} A_{V_2}$$

$$Z_{in} = R_1 \| R_2$$

$$Z_{out} = R_D' \| (r_o' + R_s'(1+\mu))$$

(b) CS-CD Amp.



$$A_{r_1} = \frac{-\mu R_D}{R_D + r_o + R_s(1+\mu)}$$

$$Z_{out}^{(1)} = R_D \| (r_o + R_s(1+\mu))$$

∴ It is input to CD amp.

Net input is: $k' A_{r_1} V_{in}$

$$k' = \frac{(R_1' \| R_2')}{Z_{out}' + (R_1' \| R_2')}$$

Scanned by CamScanner

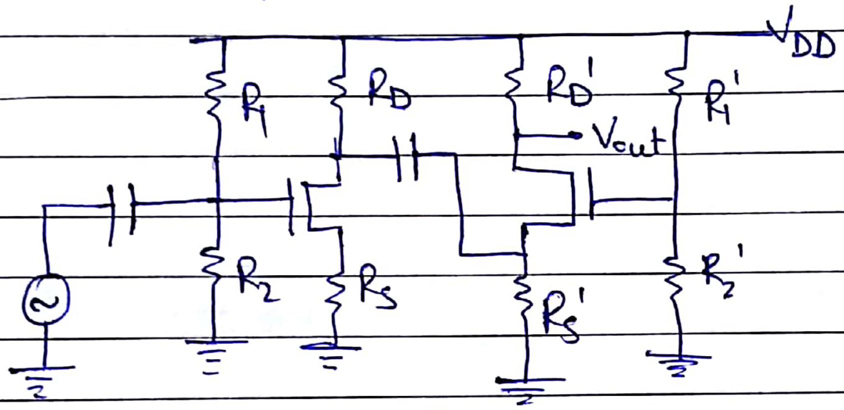
$$\frac{\text{Output}}{k' A_{v_1} v_{in}} = \frac{+\mu R_S}{R_D + r_o + R_S(1+\mu)} = A_{v_2}$$

$$\text{Gain} = \frac{V_o}{V_{in}} = k' A_{v_1} \cdot A_{V_2}$$

$$Z_{in} = (R_1 \| R_2)$$

$$Z_{out} = R_S' \,\Big\|\, \frac{R_D + r_o}{1+\mu}$$

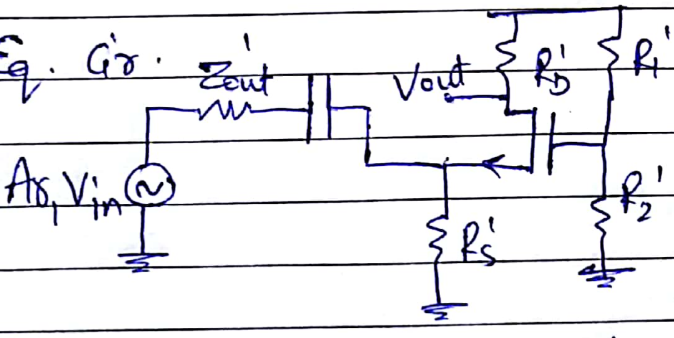
(c) CS-CG Amp.



$$A_{v_1} = \text{Gain} = \frac{-\mu R_D}{R_D + r_o + R_S(1+\mu)}$$

$$Z_{out}{}' = R_D \| (r_o + R_S(1+\mu))$$

Eq. Cr.



$R_i = Z_{out}'$

$v_{in} = A_{v_1} v_{in}$

$$A_{V_2} = \frac{v_{out}}{A_{v_1} v_{in}} = \frac{-(1+\mu')R_S'}{R_i + R_S'} \cdot \frac{R_D'}{R_D' + (1+\mu')(R_i \| R_S') + r_o'}$$

$$A_v = A_{v_1} \cdot A_{V_2}$$

$$Z_{out} = R_D \| (r_o + (1+\mu)(R_i \| R_S))$$

$$Z_{in} = R_1 \| R_2$$