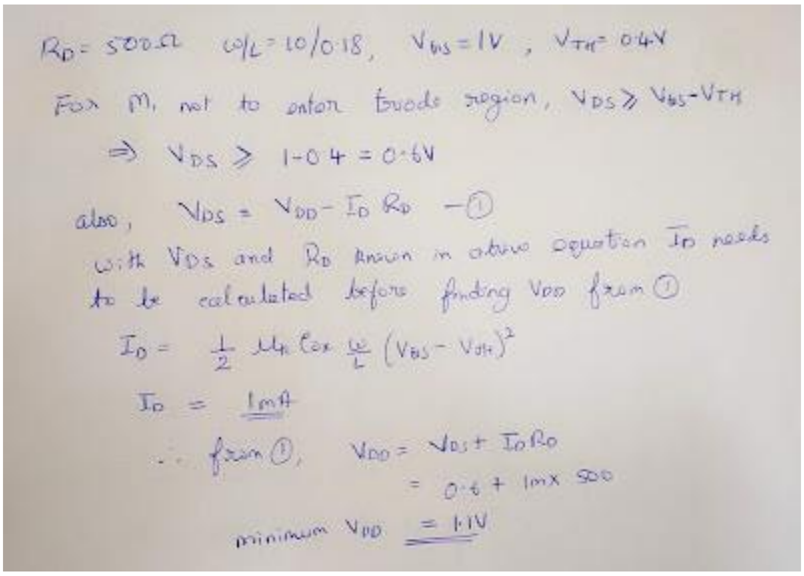
Q1.

Calculation	Set 1	Set 2	Set 3	Marks
$V_{DS}=V_{GS}-V_{TH}$	0.7V	0.6V	0.8V	1
I_D	1.47mA	1mA	3.55mA	1
V_{DD}	1.8025V	1.1V	1.688V	1

Solution of Set 2 question


$R_D = 500\Omega$ $W/L = 10/0.18$, $V_{GS} = 1V$, $V_{TH} = 0.4V$

For M_1 not to enter triode region, $V_{DS} \geq V_{GS} - V_{TH}$

$\Rightarrow V_{DS} \geq 1 - 0.4 = 0.6V$

also, $V_{DS} = V_{DD} - I_D R_D$ —(1)

with V_{DS} and R_D known in above equation I_D needs to be calculated before finding V_{DD} from (1)

$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{TH})^2$

$I_D = 1mA$

∴ from (1), $V_{DD} = V_{DS} + I_D R_D$

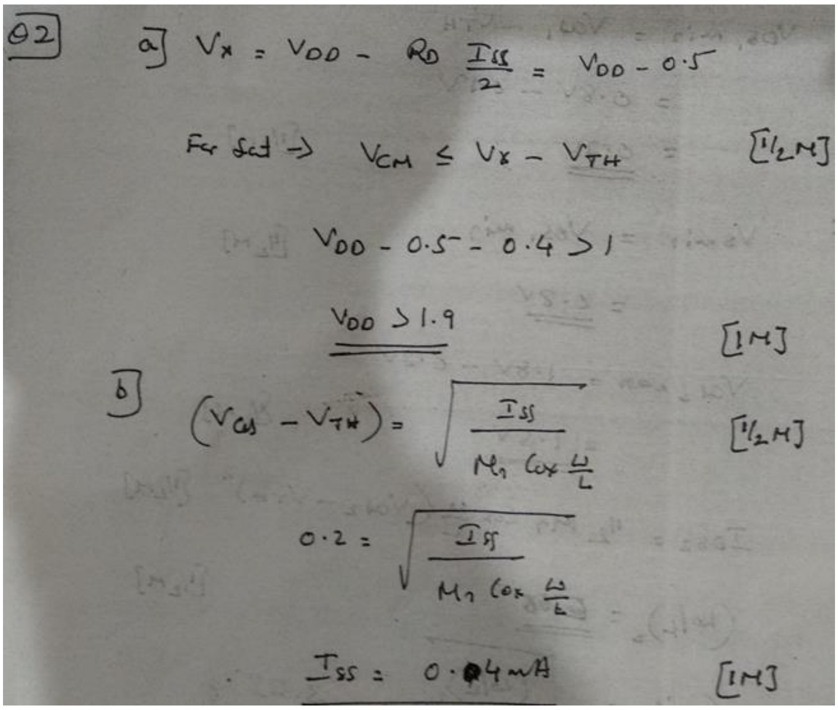
$= 0.6 + 1m \times 500$

minimum V_{DD} $= 1.1V$

Q2.

Calculation	Set 1	Set 2	Set 3	Marks
V_{DD}	2V	1V	1.8V	1.5
I_{ss}	0.44mA	0.04mA	0.036mA	1.5

Solution of Set 2 question


Q2

a] $V_X = V_{DD} - R_D \frac{I_{SS}}{2} = V_{DD} - 0.5$

For Sat → $V_{CM} \leq V_X - V_{TH}$ [1/2 M]

$V_{DD} - 0.5 - 0.4 > 1$

$V_{DD} > 1.9$ [1M]

b] $(V_{GS} - V_{TH}) = \sqrt{\frac{I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$ [1/2 M]

$0.2 = \sqrt{\frac{I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$

$I_{SS} = 0.04 mA$ [1M]

Q3.

Calculation	Set 1	Set 2	Set 3	Marks
R_{out}	$R_D + {}^1/_{gm2} \| r_{03}$	$R_D + {}^1/_{gm2}$	${}^1/_{gm2}$	0.5
A_V	$g_{m1}\left(R_D + {}^1/_{gm2} \| r_{03}\right)$	$g_{m1}\left(R_D + {}^1/_{gm2}\right)$	$\frac{R_1 \| {}^1/_{g_{m1}}}{R_s + R_1 \| {}^1/_{g_{m1}}} \frac{g_{m1}}{g_{m2}}$	1
R_{out}	R_D	$\frac{1}{g_{m2}}$	R_D	0.5
A_V	$\frac{R_D}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$	$\frac{{}^1/_{g_{m2}}}{\frac{1}{g_{m1}} + \frac{1}{g_{m3}}}$	$\frac{R_D}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$	1

Q4.

Calculation	Set 1	Set 2	Set 3	Marks
G_m	0.77 mA/V	1mA/V	1mA/V	1.5
W/L	5.92 (~6)	8.33 (~9)	8.33 (~9)	1.5

Solution of Set 2 question

Q4

$V_{GS} = V_{DD} = 1.8V$ [1/2 M]

$V_{DS} = V_{GS} - V_{TH} = 1.2V$ [1/2 M]

$I_D = (V_{DD} - V_{DS})/R_D = \underline{\underline{0.6 mA}}$ [1/2 M]

$g_m = \frac{2I_D}{V_{GS} - V_{TH}} \Rightarrow \underline{\underline{1 mA/V}}$ [1/2 M]

$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})$ [1/2 M]

$1mA = 100\times10^{-6} \times \frac{W}{L} (1.2V)$

$(W/L) = 8.33 \simeq 9$ [1/2 M]

Q5.

Calculation	Set 1	Set 2	Set 3	Marks
I_D	1mA	1mA	1.67mA	0.5
$V_{DS}=V_{GS}-V_{TH}$	0.85V	0.6V	0.5V	0.5
W/L	27.68	55.55	133.6	1
R_1	21.42kΩ	45kΩ	86.956kΩ	1
R_2	300kΩ	90kΩ	117.66kΩ	1

Solution of Set 2 question

a) $V_{RS} = 200mV$ $\quad I_D R_S = 200mV$

$$I_D = \frac{200m}{200\Omega} = 1mA$$

For M to Remain in saturation

$$V_{DS} \geq V_{GS} - V_{TH}$$

$$V_{DS} = V_{DD} - I_D R_D - V_S$$
$$= 1.8 - 1m \times 1000 - 0.2V$$
$$= 0.6 \quad \Rightarrow V_{GS} - V_{TH} \leq 0.6$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2$$

$\frac{W}{L}$ is minimum when $(V_{GS} - V_{TH})$ is maximum $= 0.6$

$$\therefore I_D = 1m = \frac{1}{2}\, 100\mu\, \frac{W}{L} (0.6)^2$$

$$\frac{W}{L} = 55.55$$

b) $V_{GS} - V_{TH} = 0.6 \Rightarrow V_{GS} = 1 \quad \because V_{TH} = 0.4$

$$V_{GS} = V_G - V_S \Rightarrow V_G = V_{GS} + V_S$$
$$= 1 + 0.2 = 1.2V$$

$$V_G = \frac{V_{DD} R_2}{R_1 + R_2} = 1.2 \qquad \frac{R_2}{R_1 + R_2} = \frac{1.2}{1.8} = 0.66$$

$$\frac{R_2}{R_1} = 2$$

Input impedance $= 30k\Omega = R_1 \| R_2$

$\Rightarrow R_1 = 45k\Omega \quad R_2 = 90k\Omega$

Q6.

Calculation	Set 1	Set 2	Set 3	Marks
V_{GS1}	0.7V	0.8V	0.7V	0.5
$V_{DS1\ min}$	0.3V	0.3V	0.3V	0.5
V_{Smin}	0.3 V	0.3V	0.3V	0.5
V_{GS2max}	1.5V	1.5V	1.5V	0.5
W/L	4.13	5	4.13	1
Voltage gain	3.67	3.33	3.69	1

Solution of Set 2 question

Q6] a] **For M_1** $\Rightarrow$ $I_{D1} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS1} - V_{TH})^2$ [½ M]

$V_{GS1} = \underline{\underline{0.8V}}$

$V_{DS,min} = V_{GS1} - V_{TH}$

$= 0.8V - 0.5V$

$= \underline{\underline{0.3V}}$ [½ M]

For M_2: $V_{S\,min} = V_{DS,min}$ [½ M]

$= \underline{\underline{0.3V}}$

$V_{GS2\,max} = 1.8V - 0.3V$

$= \underline{\underline{1.5V}}$ [½ M]

$I_{DS2} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS2} - V_{TH})^2$ [½ M]

$(W/L)_2 = \underline{\underline{5.08}}$ [½ M]

b] Voltage Gain $= \sqrt{\frac{(W/L)_1}{(W/L)_2}} = \underline{3.33}$

[½ M] [½ M]