(1)(i) $I_D = \frac{I_{DSS}}{2} = 1.5mA$

$I_D = K(V_{GS} - V_T)^2$

$1.5m = 2\times10^{-3}(V_{GS} - 2)^2$

$\therefore V_{GS} = 1.134V$

$V_{GS} = 2.866V$

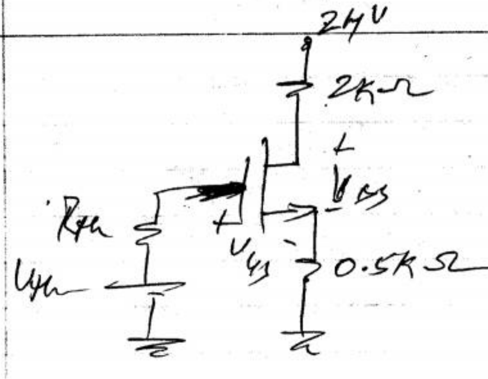
For it to turn on $\Rightarrow V_{GS} > V_T$ so $V_{GS} = 2.866V$

KVL to DS loop

$24 - I_D(2K) - V_{DS} - I_D(0.5K) = 0$

$\therefore V_{DS} = 20.25V$

KVL to G-S loop



$V_{th} - V_{GS} - I_D(0.5K) = 0$

$V_{th} = 3.616V$

Assuming $R_{th} = 1M\Omega$

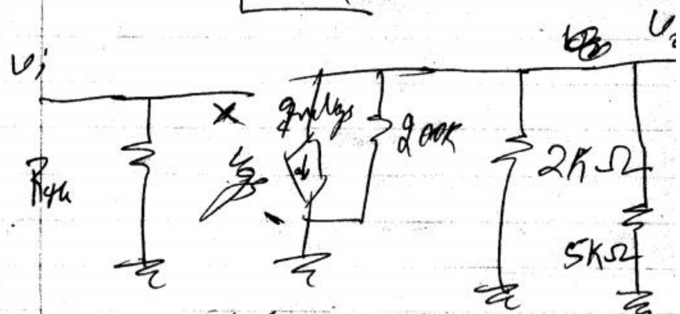
$V_{th} = \frac{R_2}{R_1+R_2}(24)$ $\quad R_{th} = \frac{R_1R_2}{R_1+R_2}$

$\therefore \frac{R_2}{R_1+R_2} = 0.151$ $\quad \therefore 1M = R_1(0.151)$

$\therefore R_1 = 6.62M\Omega$

$\therefore R_2 = 1.18M\Omega$

(ii)



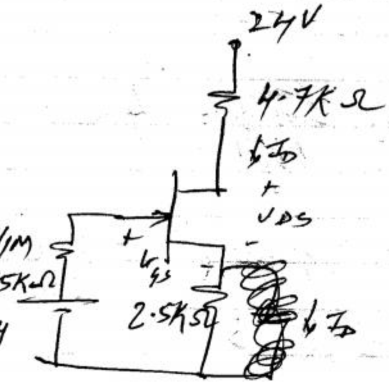
$g_m = 2k(V_{GS} - V_T)$

$= 3.46\ mS$

$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs}(200K \| 2K \| 5K)}{V_{gs}}$

$= -4.91$

(2)



$R_{th} = 7M \| 1M = 875K\Omega$

$V_{th} = \frac{1M}{1M + 7M} \times 24 = 3V$

KVL to G-S loop

$3V - V_{GS} - I_D(2.5\ k) = 0$

$\therefore V_{GS} = 3 - 2.5K(I_D) \rightarrow (1)$

By Schockley's eqn –

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 8m\left(1 - \frac{[3 - 2.5K(I_D)]}{-4}\right)^2$

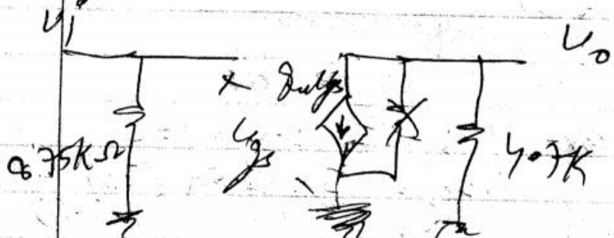
$\therefore I_D = 2mA$. Sub in (1)

$V_{GS} = -2V$

$g_{mo} = \frac{2 I_{DSS}}{|V_P|} = 4\,mS$

$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 2\,mS$



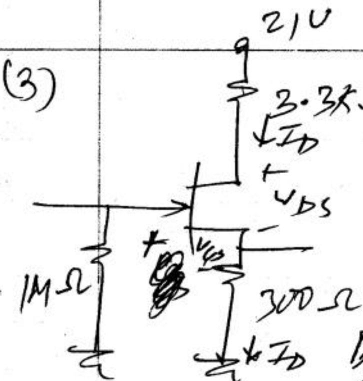
$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs} (4.7K)}{V_{gs}}$

$= -9.4$

$R_i = 8.75K\Omega$

$R_o = 4.7K\,\Omega$

(3)



KVL to GS loop

$-V_{GS} - 300(I_D) = 0$

$V_{GS} = -300 I_D \rightarrow (1)$

By Schokley's equ-

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 8mA\left(1 - \frac{-300 I_D}{-4}\right)^2$

$\therefore I_D = 3.96 mA$

Subs in (1)

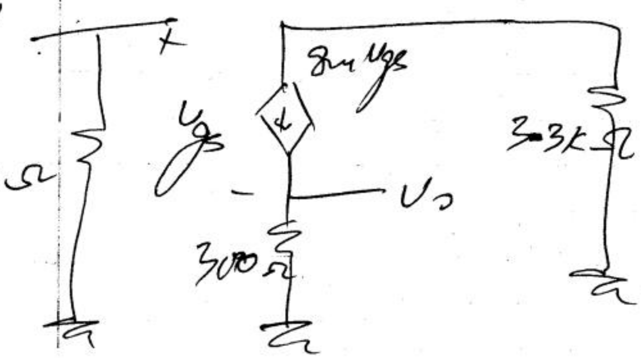
$V_{GS} = -1.19V$

$g_{m0} = \frac{2 I_{DSS}}{|V_P|} = 4mS$

$g_m = g_{m0}\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 4mS\left(1 - \frac{1.19}{4}\right)$

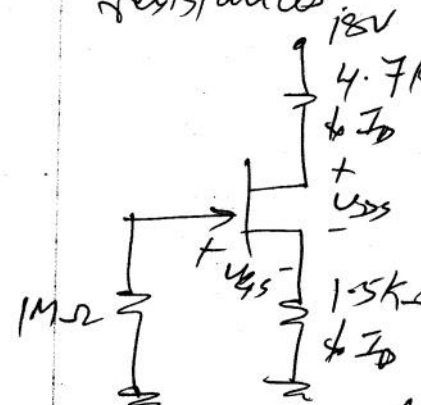
$= 2.81 mS$



$A_v = \frac{V_o}{V_i} = \frac{300(g_m V_{gs})}{V_{gs} + g_m V_{gs}(300)} = 0.457$

$R_i = 1M\Omega$ $R_o = 300\Omega // 1/g_m = 162.78\,\Omega$

(4) Type of biasing: Self bias with source swamping resistances.



$V_P = -4V$

$I_{DSS} = 8mA$

$g_{mo} = 5000\ \mu S$

KVL to GS loop.

$-V_{GS} - 1.5K I_D = 0$

$V_{GS} = -1.5K I_D$ —(1)

By Shockley's eqn

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$\therefore I_D = 8mA\left(1 - \frac{-1.5K I_D}{-4}\right)^2$

$\therefore I_D = 1.51mA$

Sub in (1)

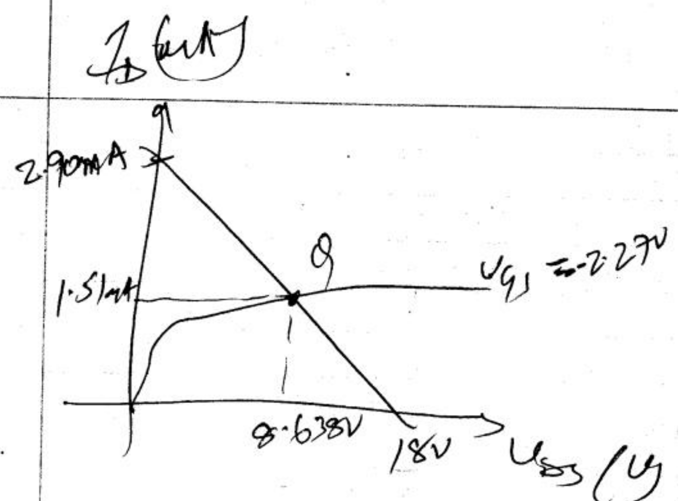
$V_{GS} = -2.27V$

KVL to DS loop.

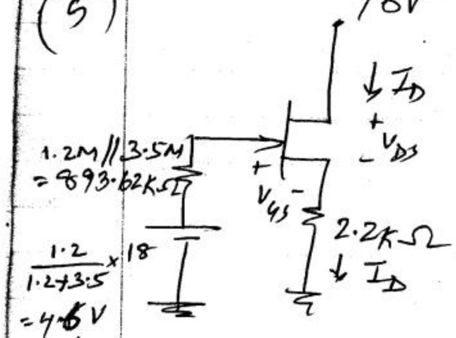
$18 - 4.7K I_D - 1.5K I_D - V_{DS} = 0$

$\therefore V_{DS} = 8.638V$

$Q = (8.638V, 1.5mA)$



(5)



Applying KVL to G-S loop

$$4.6 - V_{GS} - 2.2K(I_D) = 0$$

$$V_{GS} = 4.6 - 2.2K(I_D) \quad \text{—(1)}$$

By Schockley's eqn

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$$

$$I_D = 7m\left(1 - \frac{4.6 - 2.2k(I_D)}{-4}\right)^2$$

$$\therefore I_D = 2.47\ mA.$$

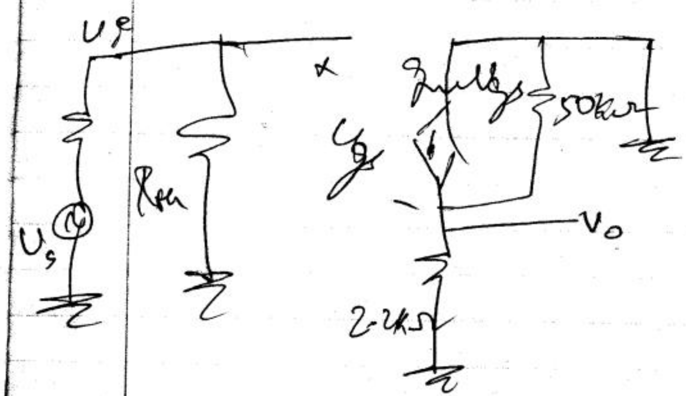
Subs in (1)

$V_{GS} = -1.49V$

$g_{mo} = 5000\ \mu S$

$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 3.14\ mS$



$A_v = \frac{V_o}{V_i} = \frac{g_m V_{gs}(2.2k \| 50k)}{V_{gs} + g_m V_{gs}(2.2k \| 50k)}$

$= 0.87$

$R_i = 893.6k\Omega$

$R_o = 50k \| 2.2k \| 1/g_m$

$= 276.66\ \Omega$

① 1

$I_{Don} = K(V_{GSon} - V_T)^2$

$200\,mA = K(4 - 2)^2$

$K = 50\,mA/V^2$

$g_m = 2K(V_{GS} - V_T)$

$23m = 2 \times 50m(V_{GS} - 2)$

$\therefore V_{GS} = 2.23V$

$g_m = 2\sqrt{K_n I_D}$

$\therefore I_D = 2.645\,mA$

~~KVL to DS loop~~

~~24 − 3.3K I_D − V_DS~~

KVL to G-S loop

$V_{th} - V_{GS} - I_D R_S = 0$

$\frac{8.2K}{8.2K + 47K} \times 24 - 2.23 - (2.645mA) R_S = 0$

$\therefore R_S = 504.81\,\Omega$

KVL to DS loop –

$24 - I_D(3.3K) - V_{DS} - (2.645mA)(R_S) = 0$

$\therefore V_{DS} = 13.94\,V$

$g_m = 23mS$

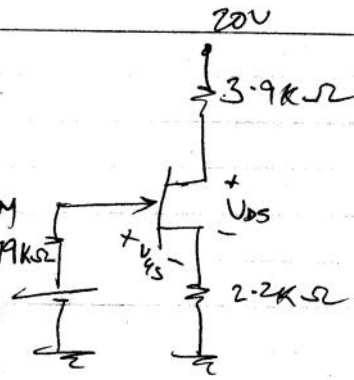
$A_V = \frac{V_o}{V_i} = \frac{-g_m V_{gs}(3.3K\Omega)}{V_{gs}}$ (3.3K)

$= -37.95$

$\frac{V_o}{25mV}$

$\therefore V_o = -0.95V$

(7)



$6.8M // 1M = 871.79k\Omega$

$\frac{1M}{1M+6.8M} \times 20 = 2.56V$

KVL to GS loop

$2.56 - V_{GS} - I_D(2.2K) = 0$

$V_{GS} = 2.56 - 2.2K(I_D)$ → (1)

By Schokley's equ

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 10mA\left(1 - \frac{2.56 - 2.2kI_D}{-4.5}\right)^2$

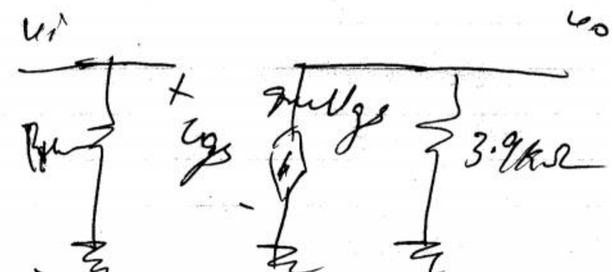
$\therefore I_D = 2.24\,mA$ Sub in (1)

$V_{GS} = -2.37V$

$g_{mo} = \frac{2I_{DSS}}{|V_P|} = 4.44\,mS$

$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

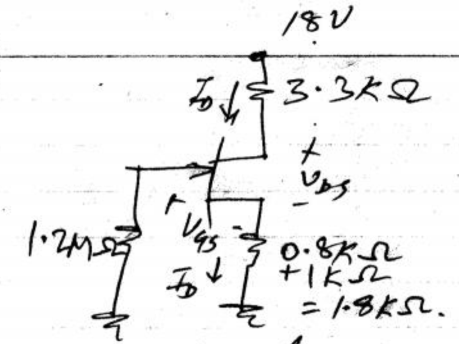
$= 2.10\,mS$



$R_i = R_{th} = 871.79k\Omega$ $R_o = 3.9k\Omega$

$A_v = \frac{V_o}{V_i} = \frac{-g_m \cancel{V_{gs}}(3.9K)}{\cancel{V_{gs}}} = 8.19$

(8)



KVL to GS loop

$-V_{GS} - I_D(1.8K\Omega) = 0$

$\therefore V_{GS} = -I_D(1.8K\Omega)$ → (1)

By Schokley's Eqn.

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 8mA\left(1 - \frac{(-1.8K\,I_D)}{-4}\right)^2$

$I_D = \underline{1.32\,mA}$

Sub in (1)

$V_{GS} = \underline{-2.38V}$

KVL to DS loop

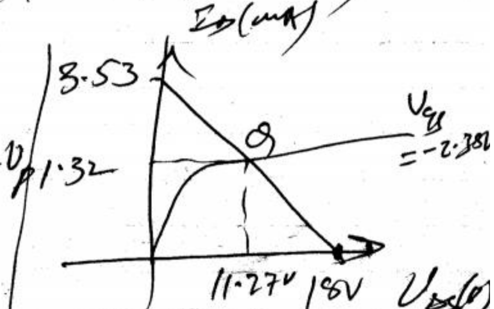
$18 - 3.3K(I_D) - V_{DS} - 1.8K\,I_D = 0$

$V_{DS} = \underline{11.27V}$

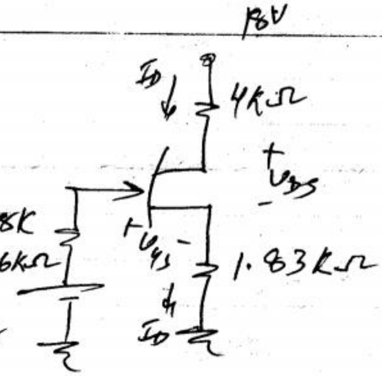
$Q = (11.27V, 1.32mA)$

$\therefore V_{DS} > V_{GS} - V_P$

∴ Region of operation is saturation



(9)



2.1M||88K = 84.46kΩ

$\frac{88K}{2.1M+88K} \times 18 = 0.72V$

KVL to GS loop

$0.72 - V_{GS} - 1.83k(I_D) = 0$

$V_{GS} = 0.72 - 1.83k I_D$ —— ①

By Schockley's eqn

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 8mA\left(1 - \frac{0.72 - 1.83k I_D}{-4}\right)^2$

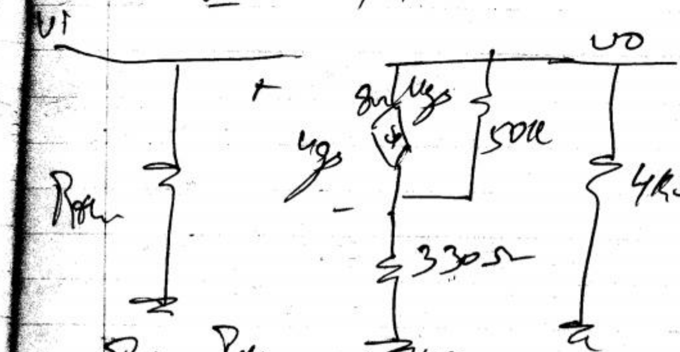
$\therefore I_D = 1.6mA$

Sub in ① $V_{GS} = -2.21V$

$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 5000 \times 10^{-6}\left(1 - \frac{2.21}{4}\right)$

$= 2.24mS$



$R_i = R_{th} = 84.46k\Omega$

$R_o \approx 4k\Omega$

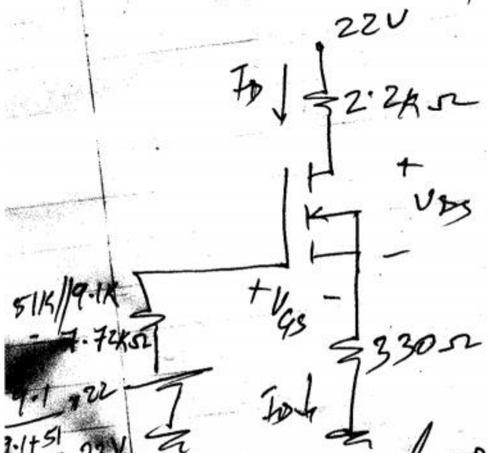
$A_v = \frac{-g_m R_D}{1 + g_m R_S + (R_S + R_D)/r_d}$

$= -4.91$

(10) $I_{D_{on}} = k_n(V_{GS_{on}} - V_T)^2$

$200 = K_n(4-2)^2$

$\therefore K_n = 50 mA/V^2$



KVL to GS loop

$3.33 - V_{GS} - 330 I_D = 0$

$V_{GS} = 3.33 - 330 I_D$ —(1)

1.73mA

$I_D = k_n(V_{GS} - V_{TN})^2$

$I_D = 50m(3.33 - 330 I_D - 2)^2$

$I_D = \cancel{4.03 mA}$ 3.257mA

Sub in (1)

$V_{GS} = \cancel{2V}$ 2.255V

KVL to DS loop

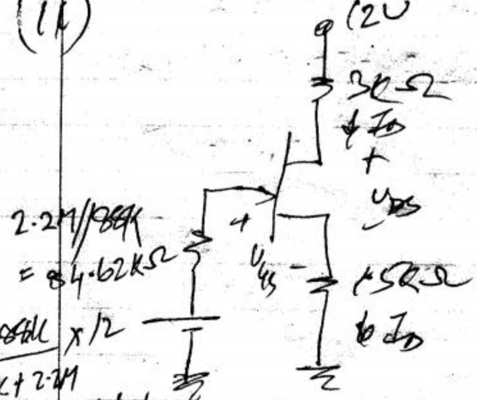
$22 - 2.2k I_D - V_{DS} - 330 I_D = 0$

$\therefore V_{DS} = \cancel{11.8 V}$ 13.76V

$V_D = 22 - 2.2k(I_D)$

$= \cancel{13.12} V$ 14.835V

(11)



$\frac{88K \times 12}{88K + 2.2M} = 0.46V$

Applying KVL to GS loop

$0.46 - V_{GS} - I_D(1.5K) = 0$

$\therefore V_{GS} = 0.46 - 1.5k I_D$ ...(1)

By Shockley's eqn

$I_D = I_{DSS}(1 - V_{GS}/V_P)^2$

$I_D = 8mA\left(1 - \frac{0.46 - 1.5k I_D}{-4}\right)^2$

$I_D = 1.73mA$

* KVL to DS loop

$12 - 3k(I_D) - V_{DS} - 1.5k I_D = 0$

$V_{DS} = 4.22V$ $Q = (4.22V, 1.72mA)$

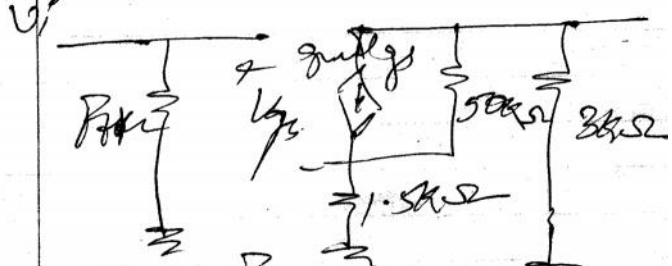
Subs in (1)

$V_{GS} = -2.14V$

$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 5000 \times 10^{-6}\left(1 - \frac{2.14}{4}\right)$

$= 2.33 mS$



$R_i = R_{th} = 84.62k\Omega$

$A_V = \frac{V_o}{V_i} = \frac{-g_m V_{gs} R_D}{V_{gs} + g_m V_{gs} R_s + \frac{(R_D + R_s)}{r_d}}$

$A_v = -1.52$

$R_i = 84.62\ k\Omega$

(12) (i) No reason why V_{GSQ} & I_{DQ} are given. If they were not given then we ~~fed~~ get $I_{DQ} = 1.39mA$ & $V_{GSQ} = +5.41V$

Assuming its not room temp.

∴ Taking what is given

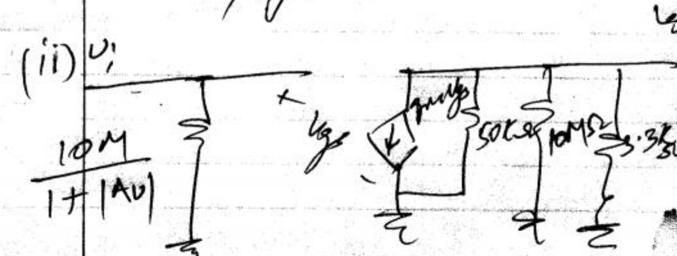
$g_m = 2K(V_{GS} - V_T)$

$= 2\times 0.24mA\,(6.4-3)$

$= 1.63mS$

$r_d = 1/y_{os} = 50{,}000\ \Omega$

(ii)



$$A_v = \frac{V_o}{V_i} = -\frac{g_m V_{gs}(50K \parallel 10M \parallel 3.3K)}{V_{gs}}$$

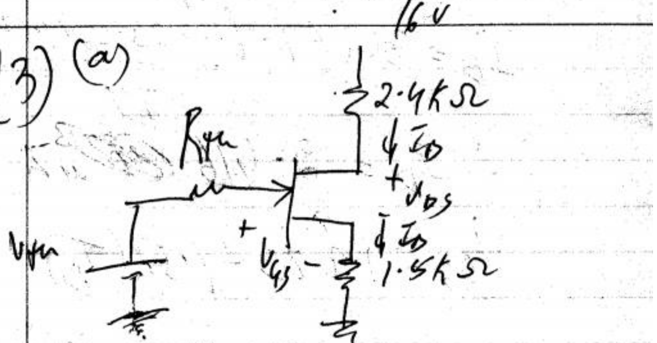
$$A_v = -5.04$$

$$Z_i = \frac{10M}{1+|A_v|} = 1.66\,M\Omega$$

$$Z_o = 3.09\,K\Omega$$

[2]

(13) (a)



$$V_{th} = \frac{270K}{270K + 2.1M} \times 16$$

$$= 1.823V$$

$$R_{th} = 2.1M \parallel 270K = 239.241K\Omega$$

(i) KVL to G-S loop

$$1.823 - V_{GS} - I_D(1.5K) = 0$$

$$\therefore V_{GS} = 1.823 - I_D(1.5K\Omega)$$

By Schokley's eqn

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 8m\left(1 + \frac{(1.823 - I_D(1.5k))}{+4}\right)^2$

$\therefore I_D = 2.416 \text{ mA}$

$V_{GS} = 1.823 + 1.5k(I_D)$

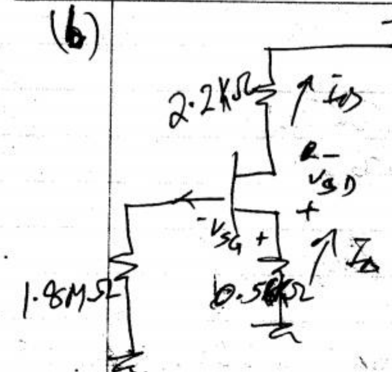
$= -1.801V$

KVL to DS loop

$16 - 2.4k I_D - V_{DS} - 1.5k I_D = 0$

$\therefore V_{DS} = 6.578V$

(b)



KVL to G-S loop

$-I_D(0.56k) - V_{SG} = 0$

$V_{SG} = (-0.56k)I_D$

By Schokley's Eqn

$I_D = I_{DSS}\left(1 + \frac{V_{SG}}{V_P}\right)^2$

$I_D = 9m\left(1 - \frac{0.56k\, I_D}{4.5}\right)^2$

∴ $I_D = 3.225$ mA

∴ $V_{GS} = -0.56K I_D$

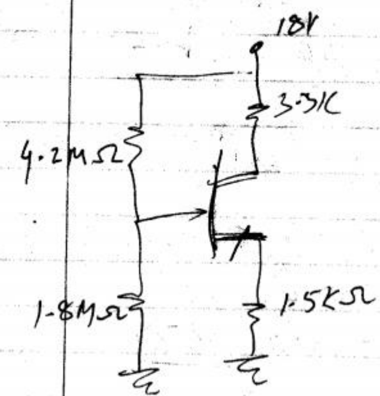
$= -1.806$ V

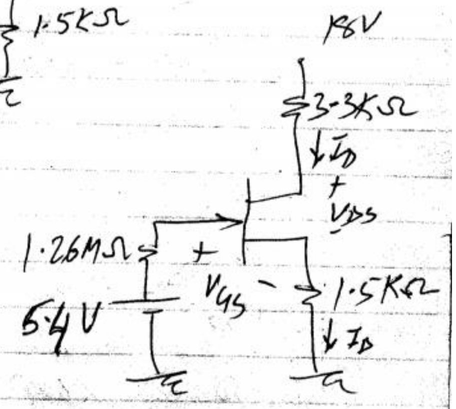
KVL to DS loop

$-0.56K I_D + V_{SD} - 2.2K I_D + 16 = 0$

∴ $V_{SD} = -7.099$ V

(14) Biasing used Voltage divider with swamping source resistance.





KVL to GS loop

$5.4 - V_{GS} - 1.5K(I_D) = 0$

$\therefore V_{GS} = 5.4 - 1.5K(I_D)$ — ①

By Schokley's Eqn –

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$

$I_D = 8mA\left(1 - \frac{(5.4 - 1.5kI_D)}{-4}\right)^2$

$\therefore I_D = 4.31 mA$

Sub in ①

$V_{GS} = -1.065 V$

KVL to DS loop –

$18 - 3.3K(I_D) - V_{DS} - 1.5K(I_D) = 0$

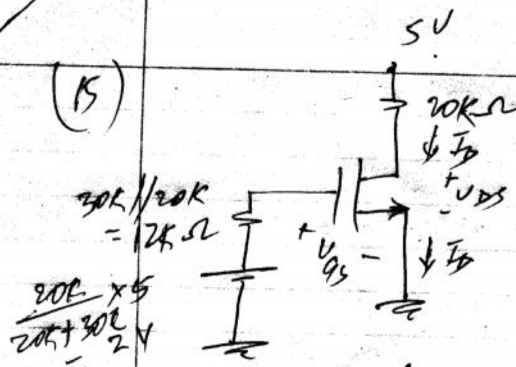
$\therefore V_{DS} = -2.688 V$

$\because V_{DS} \not> V_{GS} - V_T$ ∴ Not saturation

$V_{DS} < 0$ ∴ In Cut-off region.

$Q = (-2.688 V, 4.31 mA)$

(15)



KVL to GS loop

$V_{GS} = 2V$

$I_D = k_n (V_{GS} - V_T)^2$

$= 0.1mA$

KVL to DS loop

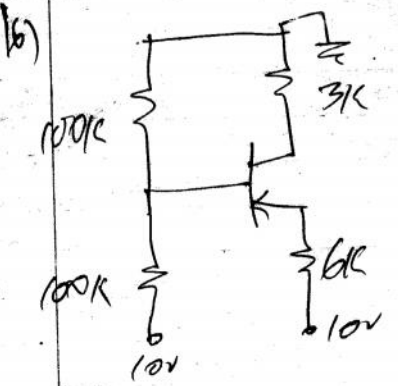
$5 - V_{DS} - 20K I_D = 0$

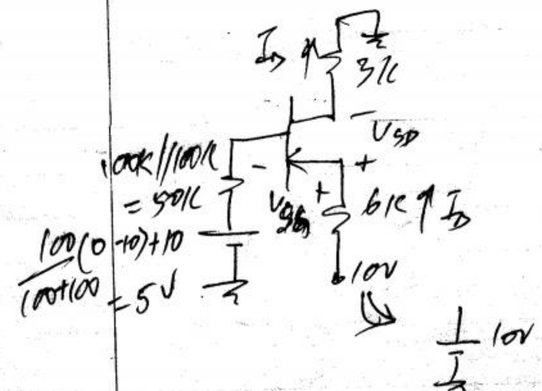
$V_{DS} = 3V$. $\boxed{Q(3V, 0.1mA)}$

$\because V_{DS} > V_{GS} - V_T$

so Region of operation is saturation

(16)





KVL to GS loop

$5 + V_{SG} + 6K(I_D) - 10 = 0$

$V_{SG} = 5 - 6K(I_D)$ → ①

$I_D = K_p(V_{SG} + V_{TP})^2$

$I_D = 75\mu(5 - 6KI_D - 0.8)^2$

$\therefore I_D = 0.34\ mA$

Sub in ① $V_{SG} = 2.96$

$V_D = \cancel{\ldots} + 3K I_D$

$= 1.02V$

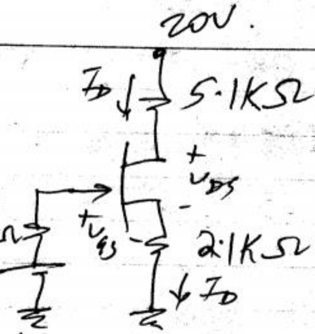
$V_G = 5V$ ..

$V_S = I_D 3K + V_{SD}$

$0V = 10 - 6K I_D$

$= 7.96V$

(17)



$7M \parallel 1.2M = 1.02M\Omega$

$\frac{1.2}{1.2+7} \times 20 = 2.93V$

KVL to GS loop

$2.93 - V_{GS} - 2.1K\ I_D = 0$

$\therefore V_{GS} = 2.93 - 2.1KI_D$ → ①

By Shokley's eqn -

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 10m\left(1 - \frac{2.93 - 2.1KI_D}{-3.5}\right)^2$

$I_D = 2.27\ mA$

Sub in (1)

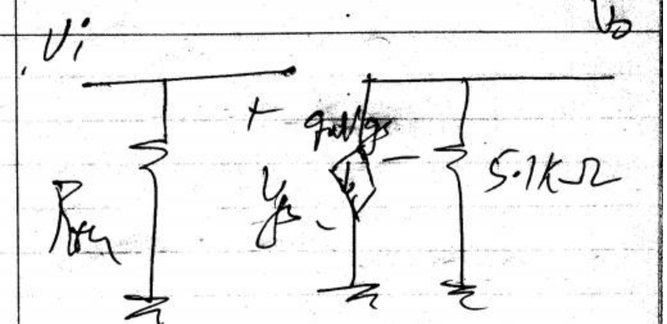
$V_{GS} = -1.84V$

$g_{m0} = \frac{2I_{DSS}}{|V_P|} = 5.71 mS$

$g_m = g_{m0}\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 5.71m\left(1 - \frac{(-1.84)}{(-3.5)}\right)$

$= 2.71 mS$



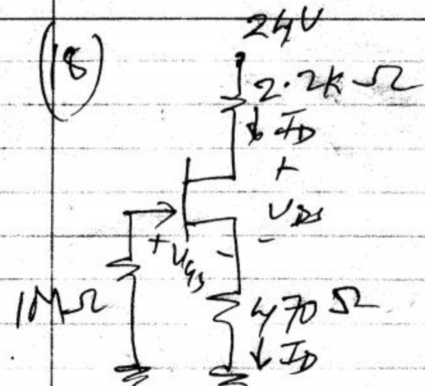
$R_i = R_G = 1.02 M\Omega$

$R_o = 5.1 K\Omega$

$A_v = \frac{V_o}{V_i} = \frac{-g_m V_{gs}(5.1)K}{V_{gs}}$

$= -13.82$

(18)



KVL to GS loop

$-V_{GS} - 470 I_D = 0$

$V_{GS} = -470 I_D$ → (1)

By Shockley's eqn

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = 10mA\left(1 - \frac{470 I_D}{3.5}\right)^2$

$I_D = 3.22mA$

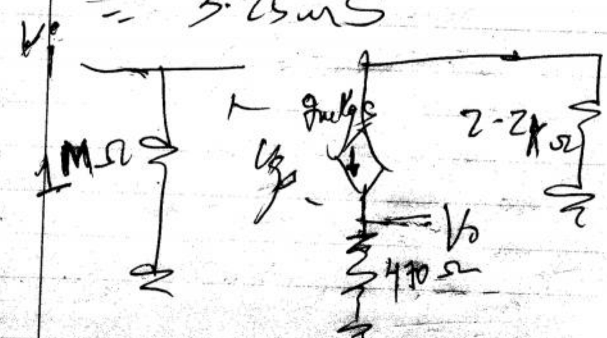
sub in (1)

$V_{GS} = -1.51V$

$g_{m0} = \frac{2 I_{DSS}}{|V_P|} = 5.71mS$

$g_m = g_{m0}\left(1 - \frac{V_{GS}}{V_P}\right)$

$= 3.25mS$



$R_i = 124\ \Omega$

$R_o = 470\ \Omega \,//\, 1/g_m$

$= 185.95\ \Omega$

$A_v = \dfrac{v_o}{v_i} = \dfrac{g_m V_{gs}(470)}{V_{gs} + g_m V_{gs}(470)}$

$= 0.604$

(19) $I_D = 160\ \mu A$

$I_D = K_n(V_{GS} - V_{TN})^2$

$\therefore V_{GS} = 2V$

$V_{GS} = V_G - V_S$

But $V_G = 0$

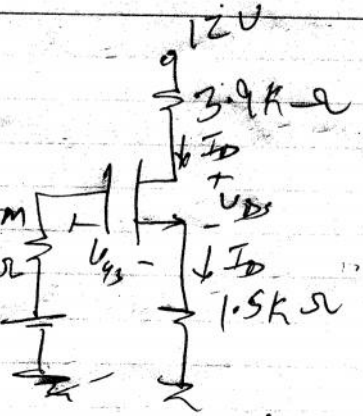
$\therefore V_S = -2V$

$V_{DS} = V_D - V_S$

$\therefore V_D = 3 - 2 = 1V$

$I_D = \dfrac{5 - V_D}{R_D}$ $\quad \therefore R_D = 25\ k\Omega$

(20)



$2.2M \| 1.8M = 990k\Omega$

$\frac{1.8}{1.8+2.2} \times 12 = 5.4V$

KVL to GS loop

$5.4 - V_{GS} - 1.5K\, I_D = 0$

$V_{GS} = 5.4 - 1.5K\, I_D \rightarrow (1)$

$I_D = K_n (V_{GS} - V_T)^2$

$I_D = 0.5m(5.4 - 1.5K I_D - 2)^2$

$\therefore I_D = 1.22mA$

ηαυλακhi® Navlakhi®

Sub in ①

$V_{GS} = 3.57V$

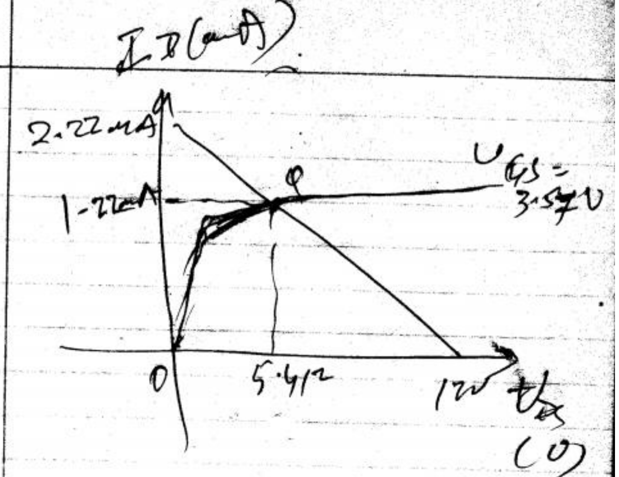
KVL to DS loop

$12 - 3.9K\, I_D - V_{DS} - 1.5K\, I_D = 0$

$\therefore V_{DS} = 5.412$

$\because V_{DS} > V_{GS} - V_T$

$\therefore$ Region of operation is saturation.



$Q \equiv (5.412V, 1.22mA)$