(1)

(a) $V_z = V_{z0} + I_z r_z$

$\Rightarrow 5.75 = V_{z0} + 5 \times 0.05$

$\Rightarrow V_{z0} = 5.5\,V$

(b) $V_s = \min = 9V$

$I_z = I_{zK} = 0.3mA$

$V_z = V_{z0} + I_z r_z \approx 5.6V$

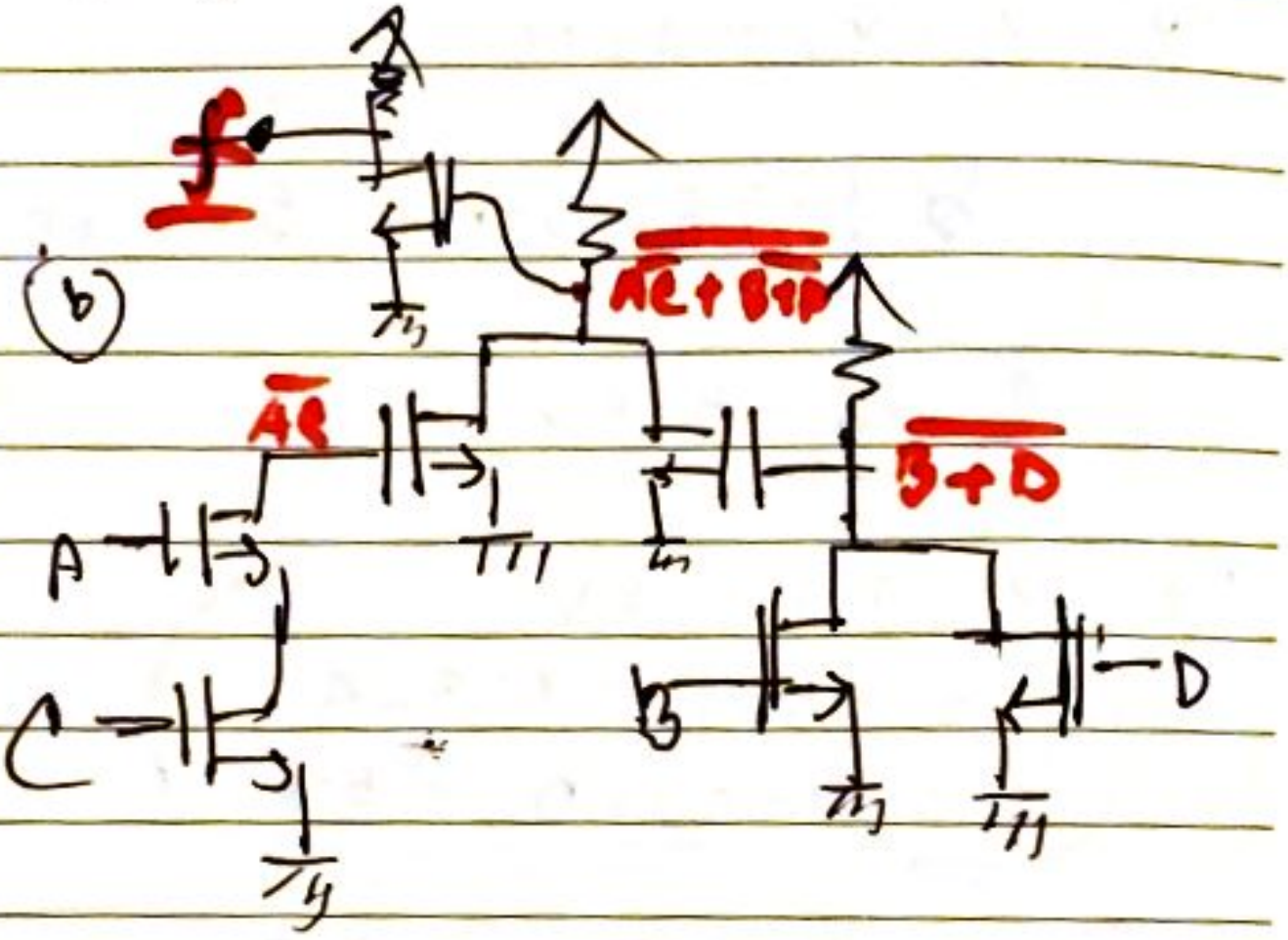
(c) $I_s = \frac{V_{in} - V_z}{R_s} = \frac{9 - 5.5}{0.5} = 7\,mA$

$I_s = I_z + I_L$

$\Rightarrow I_L = 6.7mA$

(d) $R_L = \frac{V_z}{I_L} = \frac{5.5}{6.7} \approx 0.8\,k\Omega$

(3) (a) $f = \overline{AB(C + \overline{D}E)}$



$$I_B = \frac{I_C}{\beta} \Rightarrow \alpha I_E$$

③ ACTIVE

KVL → $0 - (-15) = 20 I_B + V_{BE} + 2 I_E$

$$\Rightarrow 15 = 20 \times \frac{\alpha}{\beta} I_E + 0.2 + 2 I_E$$

$$\Rightarrow I_E = 1.98 \text{ mA}$$

$$I_C = \alpha I_E = 1.96 \text{ mA}$$

$$I_B = I_E - I_C = 0.02 \text{ mA}$$

KVL ⇒ $15 - (-15) = 5 I_C + V_{CE} + 2 I_E$

$$\Rightarrow V_{CE} = 6.34 \text{ V}$$

verification

$$V_{CE} > 0.2 \text{ V}$$

(4) Saturation

let $I_D = x$

$V_G = 5V$

$\frac{10 - V_D}{5} = x \Rightarrow V_D = 10 - 5x$

$\frac{V_S - 0}{3} = x \Rightarrow V_S = 3x$

$\therefore V_{DS} = V_D - V_S = 10 - 8x$

$V_{GS} = 5 - 3x$

$x = \frac{1}{2} \times 2 \times (5 - 3x - 1)^2$

$\Rightarrow x = 4^2 - 24x + 9x^2$

$\Rightarrow 9x^2 - 25x + 16 = 0$

$\Rightarrow x = 1, 1.778$

Smaller

$\therefore I_D = 1mA$

$V_{DS} = 2V$

$V_{GS} = 2V$

$\therefore V_{OV} = 1V$

Verification

$V_{DS} > V_{OV}$ ✓

$V_{GS} > V_t$ ✓

1

(a) $V_{ZO} = 5.5V$ [see set 1]

(b) Set - 1

$I_Z = 0.3\,mA$

$V_Z = 5.5V$

$V_{in} = 9V$

(a) $I_L = \frac{V_Z}{R_L} = \frac{5.5}{10} = 0.55\,mA$

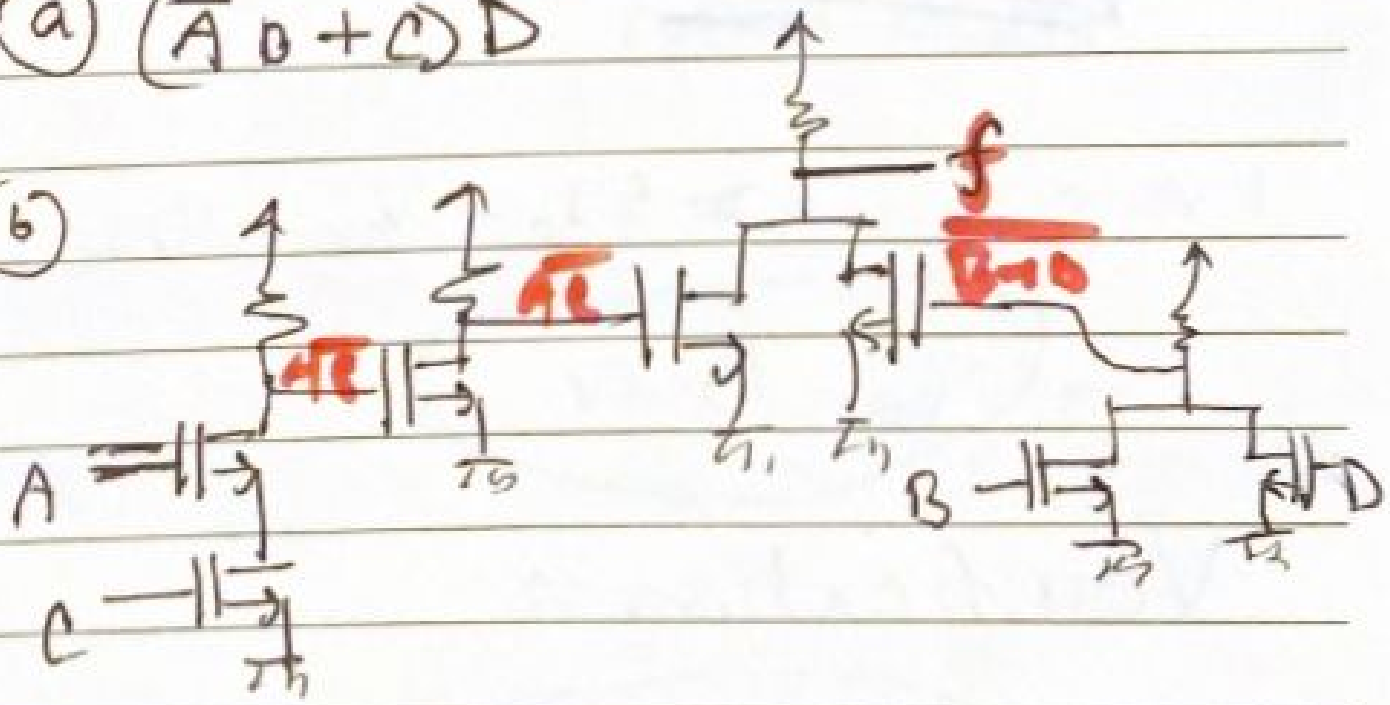
$I_S = I_L + I_Z = 0.85\,mA$

(a) $R_S = \frac{V_{in} - V_Z}{I_S} = \frac{9 - 5.5}{0.85} = 4.375\,k\Omega$

2

(a) $\overline{A}D + CD$

(b)



$$I_B = \frac{I_C}{\beta} \Rightarrow \alpha I_E$$

(3) ACTIVE

KVL $\rightarrow$ $0 - (-15) = 20 I_B + V_{BE} + 2 I_E$

$$\Rightarrow 15 = 20 \times \frac{\alpha}{\beta} I_E + 0.7 + 2 I_E$$

$$\Rightarrow \boxed{I_E = 1.98 \text{ mA}}$$

$$\boxed{I_C = \alpha I_E = 1.96 \text{ mA}}$$

$$\boxed{I_B = I_E - I_C = 0.02 \text{ mA}}$$

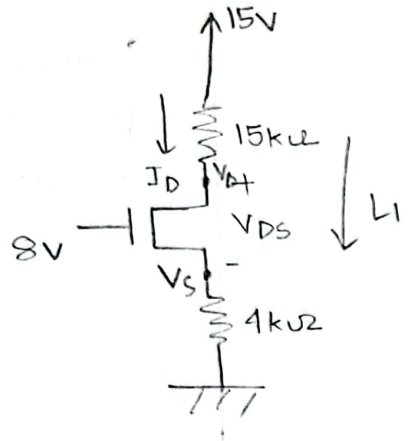
KVL $\Rightarrow$ $15 - (-15) = 5 I_D + V_{DE} + 2 I_E$

$$\Rightarrow \boxed{V_{DE} = 6.34 \text{ V}}$$

Verification

$V_{DE} > 0.2 \text{ V}$

Answer to the Q.No.-4



Given

$V_T = 1V$

$K_n' = 4mA/V^2$

Assuming our circuit is in saturation region-

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

$$= \frac{4}{2}(8 - V_S - 1)^2$$

$$= 2(7 - V_S)^2$$

$$= 2(49 - 14V_S + V_S^2)$$

$$I_D = 98 - 28V_S + 2V_S^2 \quad \text{— i)}$$

Here-

$V_{GS} = V_G - V_S$

$= 8 - V_S$

$$I_D = \frac{V_S - 0}{4}$$

$$(98 - 28V_S + 2V_S^2)\,4 = V_S$$

$$392 - 112V_S + 8V_S^2 - V_S = 0$$

$$8V_S^2 - 113V_S + 392 = 0$$

$V_S = 8$

$\boxed{V_S = 6.125}$ [we will take smaller value]

$$\therefore I_D = \frac{6.125}{4} = 1.53125\,mA$$

Now to verify.

$$V_{DS} = V_D - V_S$$

$$I_D = \frac{15 - V_D}{15}$$

$$1.53125 = \frac{15 - V_D}{15}$$

$$\therefore V_D = -7.96875\,V$$

$$\therefore V_{DS} = V_D - V_S$$

$$= -7.96875 - 6.125$$

$$= -14.094\,V$$

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

$$-14.094 \not\geq 1.875 - 1$$

$$-14.094 \not> 0.875$$

So our circuit is not in ~~acti~~ saturation region.

Now let's assume the circuit is in triode region.

$$I_D = K_n' [(V_{GS} - V_T) V_{DS} - \tfrac{1}{2} V_{DS}^2]$$

$$= 4 [(8 - V_S - 1) V_{DS} - \tfrac{1}{2} V_{DS}^2] \quad \text{---} 1)$$

$V_{GS} = 8 - V_S$

Applying KVL along L_1 -

$$15 = I_D 15 + V_{DS} + I_D 4$$

$$15 = 19 I_D + V_{DS}$$

~~$V_{DS} = 15 - 19 I_D$~~

~~$\frac{15 - V_{DS}}{I_D} = 19$~~

$$\frac{15 + V_{DS}}{19} = I_D$$

$$V_{DS} = 15 - 19 I_D$$

Substituting the value I_D in eqn i)

$$\frac{15-V_{DS}}{19} = 4\left[\left(7-V_S\right)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

Putting the value of I_D & V_{DS} in eqn i)

$$I_D = 4\left[(7-V_S)(15-19I_D) - \frac{1}{2}(15-19I_D)^2\right]$$

Now-

$$I_D = \frac{V_S}{4}$$

$$\therefore V_S = 4I_D$$

$$I_D = 4\left[(7-4I_D)(15-19I_D) - \frac{1}{2}(15-19I_D)^2\right]$$

$$I_D = 4(15-19I_D)\left[7-4I_D - \frac{1}{2}(15-19I_D)\right]$$

$$= 2(60-76I_D)(7-4I_D-7.5+9.5I_D)$$

$$I_D = (60-76I_D)(-0.5+5.5I_D)$$

$$I_D = -30+330I_D+38I_D-418I_D^2$$

$$-418I_D^2+367I_D-30=0$$

$$\boxed{I_D = 0.787\,mA}$$

$$\boxed{I_D = 0.091}$$

$$\therefore V_{DS} = 15-19.I_D$$
$$= 15-19.0.091$$
$$= 13.271$$

$$\boxed{\therefore V_S = 0.364}$$

For $I_D = 0.091$

$V_{GS} \geq V_T$

$7.636 \geq 1$

$V_{DS} < V_{GS}-V_T$

$13.271 \not< 6.636$

Now for $I_D = 0.787$

$V_S = 4I_D$

$= 3.148V$

$V_{GS} \geq V_T$

$8 - 3.148 \geq 1$

$4.852 \geq 1$

$V_{DS} = 15 - 19.0.787$

$\therefore V_{DS} = 0.047$

$V_{DS} < V_{GS} - V_T$

$0.047 < 3.852$

So our MOSFET is in triode region.