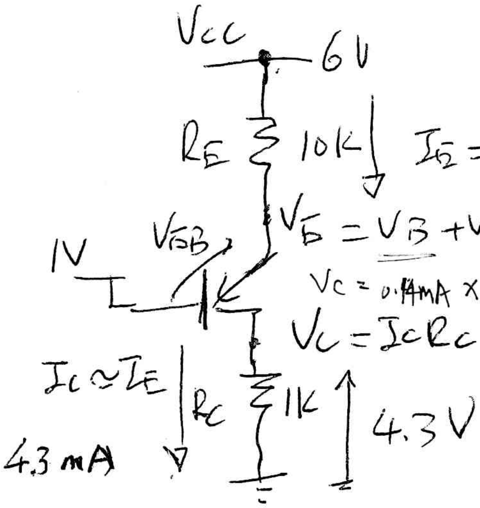
EE2002 Tutorial 5

1(a) V_C, V_E, I_B, I_C, I_E ? $V_{EB} = 0.7V$



$I_E = \frac{V_{CC} - V_E}{R_E} = 0.43mA$

$V_E = \underline{V_B} + V_{EB} = 1.7V$

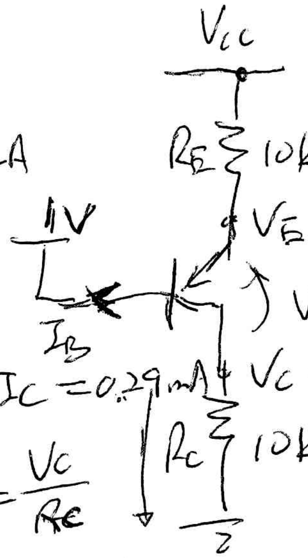
$V_C = 0.14mA \times 1000 = 0.14V$

$V_C = I_C R_C$

Active Region Assumption

$\because V_C > V_B$, forward biasing ~~in~~ CB junction

Assumption is not correct



$I_E = \frac{V_{CC} - V_E}{R_E} = 0.43mA$

$V_E = 1.7V$

$V_{CE}(sat) \simeq 0.3V$

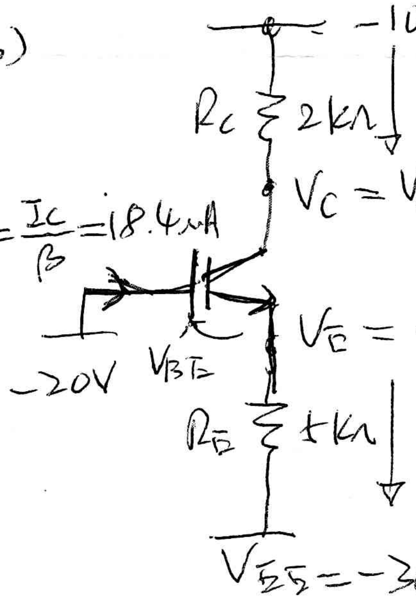
$I_B = I_E - I_C = 0.29mA$

$V_C = 1.7V - 0.3V = 1.4V$

$I_C = \frac{V_C}{R_C} = 0.14mA$

Saturation Region

1(b)



$I_C = \alpha I_E = \left(\frac{\beta}{\beta+1}\right) I_E = 1.84mA$

$V_C = V_{CC} - I_C \cdot R_C = -13.68V$

$I_B = \frac{I_C}{\beta} = 18.4mA$

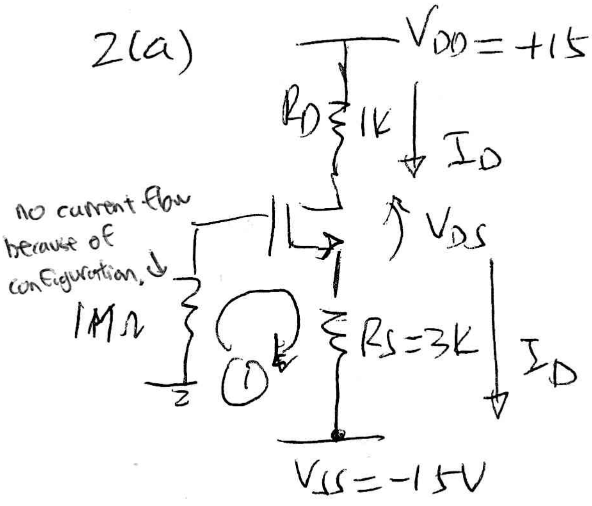
$V_E = -20V - 0.7V = -20.7V$

$I_E = \frac{V_E - V_{EE}}{R_E} = 1.86mA$

Active Region

$V_{BE} = 0.7V$, $\beta = 100$, $\because V_C > V_B$, Q is in active region

2(a)



$V_{GS}+I_D\cdot R_S-15=0$

$\Rightarrow V_{GS}=15-3I_D$ ——(1)

Assume Saturation Region, we have

$I_D=\frac{K_n}{2}(V_{GS}-V_{TN})^2=\frac{0.5}{2}(V_{GS}-1)^2$ ——(2)

(1) into (2), it gives

$K_n=0.5mA/V^2$

$V_{TN}=1V$

$I_D^2-9.78I_D+21.78=0$

$\therefore I_D=6.35mA$ or $3.43mA$.

For $I_D=6.35mA$, $V_{GS}=15-3\times6.35=-4.05V<V_{TN}$

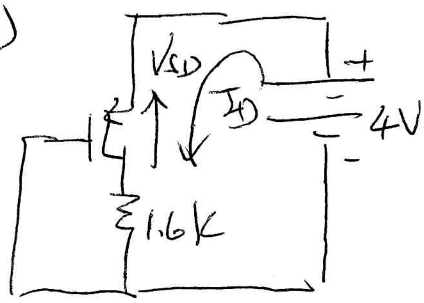
$\therefore I_D=6.35mA$ is rejected

For $I_D=3.43mA$, $V_{GS}=4.71V>V_{TN}$

$\therefore V_{DS}=V_{DD}-I_D\cdot R_D-I_D\cdot R_S-V_{SS} \Rightarrow V_{DS}=16.28V>V_{GS}-V_{TN}$

$\therefore$ The **operating** point is $V_{DS}=16.28V$, $I_D=3.43mA$ #

2(b)



Assume saturation mode

$I_D=\frac{|K_p|}{2}[(V_{SG})-|V_{TP}|)^2=1.125mA$

$\therefore V_{SD}=4V-I_D\cdot R_S$

$=2.2V$

$K_p=-0.25mA/V^2$

$V_{TP}=-1V$

$V_{SD}=2.2V<(V_{SG}-|V_{TP}|)$

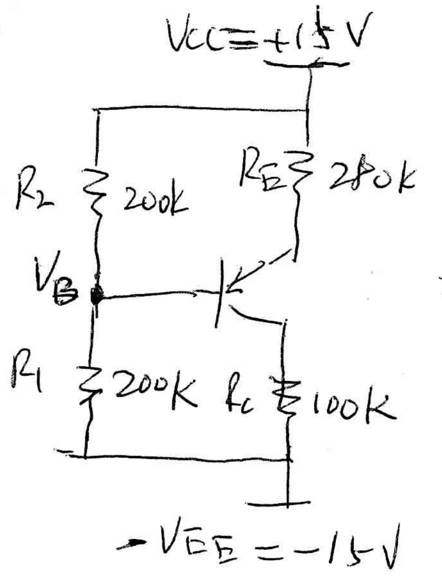
$<(4-1)V$

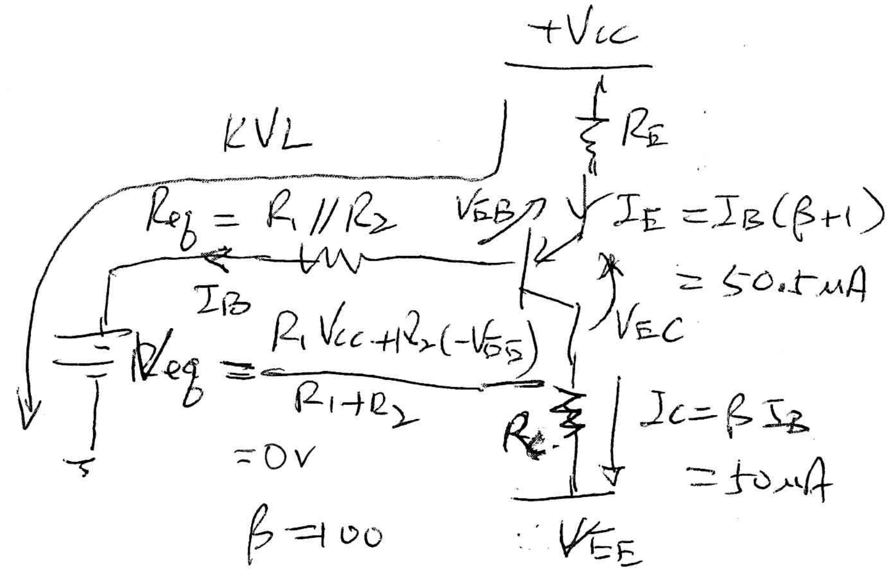
$<3V$

$\therefore$ PMOS is not in saturation region,

it is in triode/ohmic/linear region. #

3





DC Equivalent Circuit (Capacitor Open Circuit)   Alternative Equivalent Circuit

By KVL, $V_{eq} = V_{cc} - (1+\beta) I_B \cdot R_E - V_{EB} - I_B \cdot R_{eq}$

$\Rightarrow I_B = 0.5\ \mu A$

$V_{EC} = V_{cc} - I_E \cdot R_E - I_c \cdot R_C - (-V_{EE}) = 10.86V$

$\therefore$ Q point is $I_B = 50\ \mu A$ and $V_{EC} = 10.86V$ #

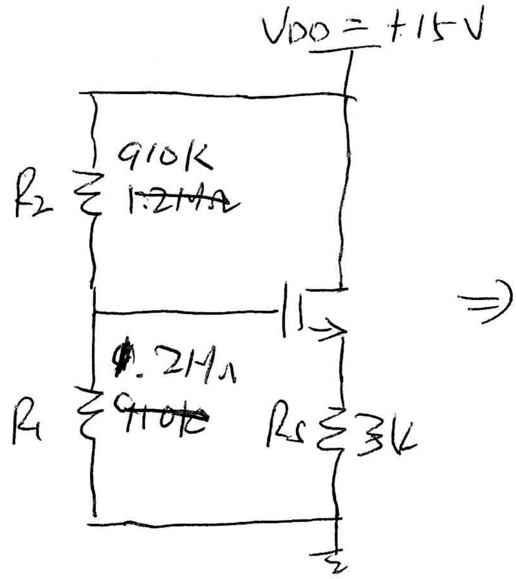
Given: $V_B = V_{eq}^{\,0} + I_B \cdot R_{eq} = 0.05V$

Component Power	Value	Source Power	Value
$P_{R1} = \dfrac{[V_B - (-V_{EE})]^2}{R1}$	1.13mW	$V_{cc} \times (I_E + I_{R2})$	
$P_{R2} = \dfrac{(V_{cc} - V_B)^2}{R2}$	1.12mW	$\lvert V_{EE} \rvert (I_C + I_{R1})$	
$P_{RC} = I_c^2 \cdot R_C$	0.25mW		
$P_{RE} = I_E^2 R_E$	0.71mW		
$P_{BJT} = I_C \cdot \lvert V_{CE} \rvert + I_B \cdot \lvert V_{BE} \rvert$	0.54mW		

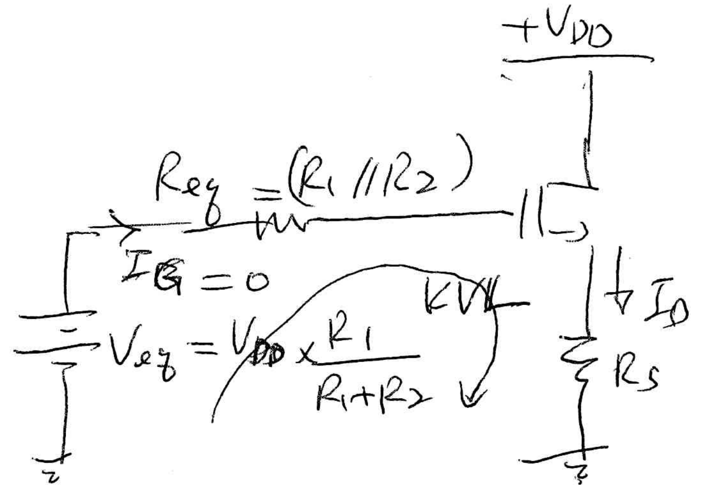
Total Power = 3.76mW

Total Power = 3.75mW

4



$\Rightarrow$



$K_n = 1\,mA/V^2$

By KVL, $V_{eq} = V_{GS} + I_D \cdot R_S$

$\therefore V_{GS} = 8.53 - 3000\, I_D$ —— (1)

Assume saturation mode

$I_D = \frac{K_n}{2}(V_{GS} - V_{TN})^2 = \frac{0.001}{2}(V_{GS}-1)^2$ —— (2)

(1) into (2) gives

$4500\, I_D^2 - 23.59\, I_D + 0.02835 = 0$

$\therefore I_D = 1.87\,mA$ or $3.38\,mA$

For $I_D = 3.38\,mA$, $V_{GS} = 8.53 - 3000 \times 3.38 \times 10^{-3}$
$= 1.61V\ (< V_{TN})$ (rejected)

For $I_D = 1.87\,mA$, $V_{GS} = 2.92V > V_{TN}$

and $V_{DS} = V_{DD} - I_D \cdot R_S = 9.39V$

$\therefore$ Q point is $I_D = 1.87\,mA$ and $V_{DS} = 9.39V$ ∎