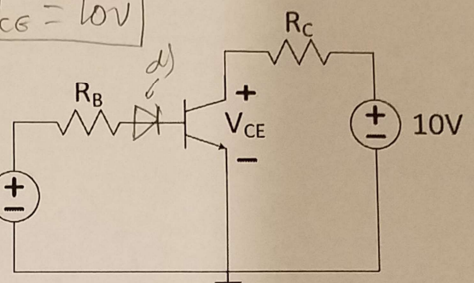
HKN ECE 110 Exam 3 Review Worksheet

1. For the following circuit, $V_{BE,ON} = 0.4V$, $V_{CE,SAT} = 0.2V$, $R_B = 20k\Omega$, $R_C = 2k\Omega$ and $\beta = 100$. Find V_{CE} for the following input voltages.

   a. $V_{in} = 0.3V$
   b. $V_{in} = 1.0V$
   c. $V_{in} = 1.4V$
   d. Repeat a-c if there is now a diode with $V_{on} = 0.7V$ placed between R_B and the BJT



a) $V_{in} < V_{BE,ON} \rightarrow I_B = I_C = 0 \rightarrow V_{CE} = 10V$

b) $I_B = \frac{V_{in} - V_{BE,ON}}{R_B} = 30mA$, $I_C = \beta I_B = 3mA$, $V_{CE} = 10 - I_C R_C = 4V$

c) $I_B = \frac{V_{in} - V_{BE,ON}}{R_B} = 50mA$, $I_C = \beta I_B = 5mA$, $V_{CE} = 10 - I_C R_C = 0V$, $V_{CE} = 0.2V$

Not possible! → Must be in saturation

d) Need $0.4V + 0.7V = 1.1V$ to activate BJT

$V_{in} = 0.3 \rightarrow$ Off $\rightarrow V_{CE} = 10V$

$V_{in} = 1.0V \rightarrow$ Off $\rightarrow V_{CE} = 10V$

$V_{in} = 1.4 \rightarrow I_B = \frac{1.4 - 1.1}{20k\Omega} = 15mA$, $I_C = \beta I_B = 1.5mA$

$V_{CE} = 10 - I_C R_C$

$V_{CE} = 7V$

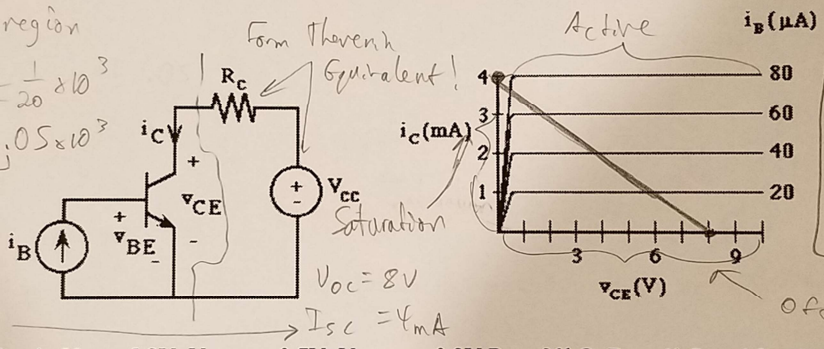
2. For the following circuit: $V_{CC} = 8V$, $R_C = 2k\Omega$, and $V_{CE,SAT} = 0.2V$

   a. Label the three regions of the i_c vs. V_{CE} curves. Hint: what are the regions of operation for a BJT?
   b. What is β of the transistor?
   c. Which of the values of i_B (20, 40, 60, 80μA) force the transistor into saturation?

b) $\beta = \frac{I_C}{I_B}$ in active region

ex: $\beta = \frac{4 \times 10^{-3}}{80 \times 10^{-6}} = \frac{1}{20} \times 10^3 = .05 \times 10^3$

$\beta = 50$



c) 20, 40, 60 mA → Active

80 mA → Saturation

c) Thev. Equiv. of V_{cc} & R_c:

$V_{oc} = V_{cc}$; $I_{sc} = \frac{V_{cc}}{R_c}$

$V_{oc} = 8V$

$I_{sc} = 4mA$

3. For the following circuit, $V_{CC} = 5.2V$, $V_{BE,ON} = 0.7V$, $V_{CE,SAT} = 0.2V$ $R_B = 20k\Omega$, $R_C = 1k\Omega$ and $\beta = 100$.

   a. Determine the values of V_{o1}, V_{o2}, V_{i1}, and V_{i2}.
   b. What is the maximum value of A that keeps the BJT in the active region when:
      i. $V_i = 1.2 + Asin(\omega t)$
      ii. $V_i = 0.9 + Asin(\omega t)$
      iii. $V_i = 1.4 + Asin(\omega t)$
   c. What is the voltage gain in the active region?

b) i) $A = 0.5$

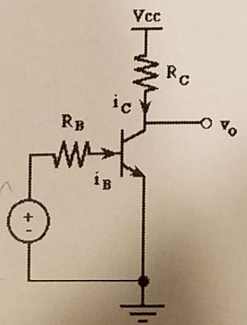
ii) $A = 0.2$ ← Check bottom limit of V_{i1}!

iii) $A = 0.3$

a) $V_{o1} = V_{cc} = 5.2V$

$V_{o2} = V_{CE,SAT} = 0.2V$

$V_{i1} = V_{BE,ON} = 0.7V$



$V_{i2} = V_i$ @ edge of saturation

$I_C = \frac{V_{cc} - V_{CE,SAT}}{R_C} = \frac{5.2 - 0.2}{1k}$

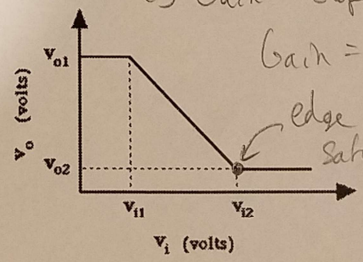
$I_C = 5mA$

$I_B = \frac{I_C}{\beta} = 50mA$

$V_i = I_B R_B + V_{BE,ON}$

$V_i = (50 \times 10^{-6})(20 \times 10^3) + (0.7)$

$= 1 + 0.7 \rightarrow V_{i2} = 1.7V$



c) Gain = Slope in active region

$\text{Gain} = \frac{V_{o1} - V_{o2}}{V_{i1} - V_{i2}} = \frac{5.2 - 0.2}{0.7 - 1.7} = \frac{5}{-1}$

Gain = −5 V/V

4. For the following circuit, $V_{DD} = 6V$, $R_D = 100\Omega$ and $I_1 = 5mA$.
   a. List the equations for I_D in the Ohmic and Active regions.
   b. Using the equations from part (a), determine the value of k.
   c. Find the values of I_D and V_{DS} when:
      i. $V_{GS} = 4V$ and $V_{TH} = 2V$
      ii. $V_{GS} = 5V$ and $V_{TH} = 1V$

a) $I_{D,Ohmic} = k(V_{GS} - V_{TH})V_{DS}$

$I_{D,Active} = k(V_{GS} - V_{TH})^2$

b) $I_1 = k(1)^2 \rightarrow \boxed{k = I_1 = 5mA/V^2}$ ← equivalent

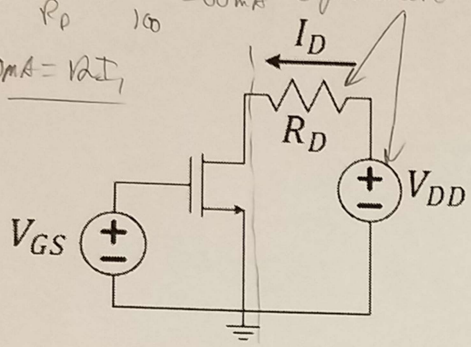
or

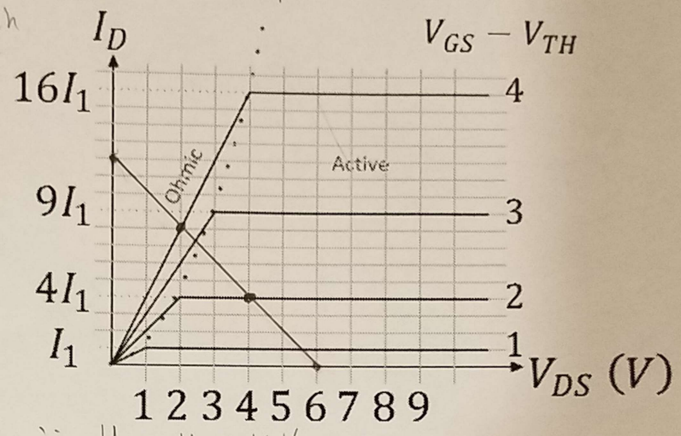
$4I_1 = k(2)^2 \rightarrow k = I_1 = 5mA/V^2$

c) $V_{oc} = V_{DD} = 6V$

$I_{sc} = \frac{V_{DD}}{R_D} = \frac{6}{100} = 60mA$ Form Thevenin Equivalent

$I_{sc} = 60mA = 12I_1$





c) i. $V_{GS} - V_{TH} = 2V$

Intersection in Active Region

$\therefore I_D = k(V_{GS} - V_{TH})^2 = (5mA/V^2)(2V)^2$

$\boxed{I_D = 20mA}$ $\boxed{V_{DS} = 4V}$ ←

$V_{DS} = V_{DD} - I_D R_D = 6 - (20mA)(100)$

ii. $V_{GS} - V_{TH} = 4V$

Intersection in Ohmic Region

$I_D = k(V_{GS} - V_{TH})V_{DS}$

$I_D = (20 \times 10^{-3})V_{DS}$

KVL: $V_{DD} - I_D R_D - V_{DS} > 0$

$I_D = \frac{V_{DD} - V_{DS}}{R_D} = 20 \times 10^{-3} V_{DS}$

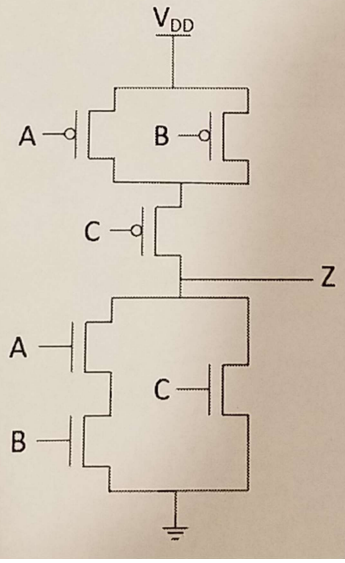
$V_{DD} = 2V_{DS} + V_{DS}$

$V_{DD} = 3V_{DS}$

$\boxed{V_{DS} = 2V}$ ↓

$\boxed{I_D = 40mA}$

5. Fill in the truth table for the following cMOS circuit where A, B and C are inputs and Z is the output.



A	B	C	Z
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0