1. 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. $V_i = 1.2 + A\sin(\omega t)$
      ii. $V_i = 0.9 + A\sin(\omega t)$
      iii. $V_i = 1.4 + A\sin(\omega t)$
   c. What is the voltage gain in the active region?

b. i) $A_{max} = 0.5V$ ⎫ Want to avoid
   ii) $A_{max} = 0.2V$ ⎬ entering either
   iii) $A_{max} = 0.3V$ ⎭ off or saturation!
   Must look at both input bounds, 0.7V and 1.7V.

a. $V_{o_1} = V_o$ in Off region $= V_{cc} = \underline{5.2V}$

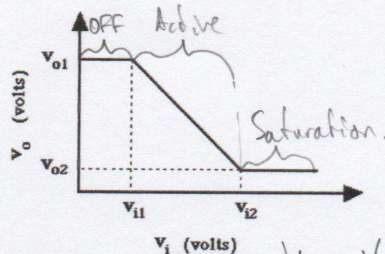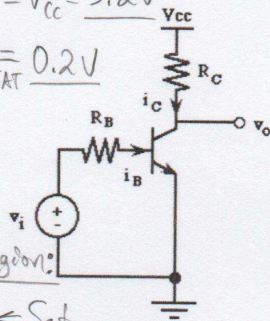$V_{o_2} = V_o$ in Sat. region $= V_{CE,SAT} = \underline{0.2V}$

$V_{i_1} = $ min. V_i for active region
$= V_{BE,ON} = \underline{0.7V}$

$V_{i_2} = $ min. V_i to enter Sat. region:

$i_C = \dfrac{V_{cc} - V_{CE,SAT}}{R_C} = 5mA \leftarrow$ Sat.

$i_B = \dfrac{i_C}{\beta} = 50mA \leftarrow$ Active

$V_{i_2} = V_{BE,ON} + i_B R_B = \underline{1.7V}$

c) $G_{ach} = A_V = \dfrac{V_{o_1} - V_{o_2}}{V_{i_1} - V_{i_2}}$

$= \underline{-5 V/V}$

2. 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) Ohmic: $I_D = kV_{DS}(V_{GS}-V_{TH})$
   Active: $I_D = k(V_{GS}-V_{TH})^2$

c.ii) Intersection in Ohmic Region!

$\begin{cases} I_D = kV_{DS}(V_{GS}-V_{TH}) \\ I_D = \dfrac{V_{DD} - V_{DS}}{R_D} \end{cases}$

→ Solving system for V_{DS} → $\boxed{V_{DS} = 2V}$

$I_D = 40mA$

DV Charactistic of Right Side ($V_{DD} + R_D$)
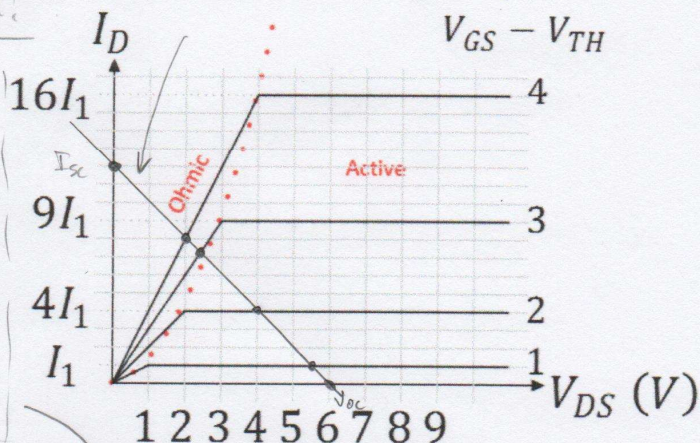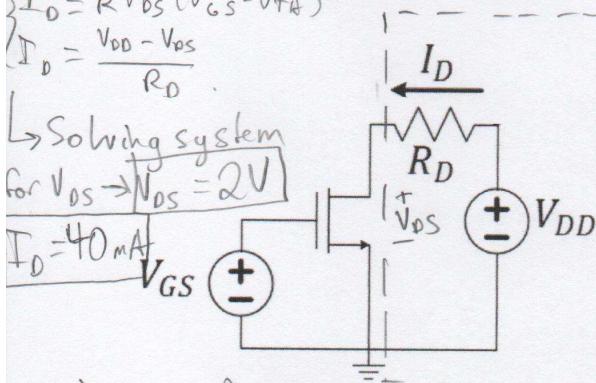
b) $I_1 = k(1)^2$
   $4I_1 = k(2)^2$
   $9I_1 = k(3)^2$ ⎬ All equally work!
   $16I_1 = k(4)^2$

$k = I_1 \rightarrow \boxed{k = 5mA/V^2}$
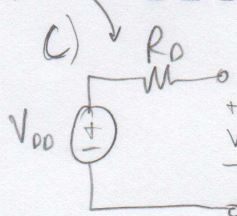
c) • Right side forms a Thev. equivalent.
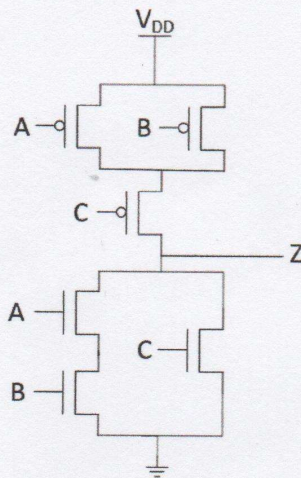 $-V_{OC} = V_{DD} = 6V$
   $-I_{SC} = \dfrac{V_{DD}}{R_D} = 60mA$

• c.i) Intersection in Active region!
   $\boxed{I_D = 4I_1 = 20mA}$
   $V_{DS} = V_{DD} - I_D R_D \rightarrow \boxed{V_{DS} = 4V}$

3. 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

$Z = 0$ if and only if:

· A AND B = 1

or

· C = 1

$Z = 1$ if and only if

· C = 0 AND (A OR B = 0)

4. Suppose we have a square wave signal with $V_{rms} = 8V$ and $P_{avg} = 16W$ attached to some unknown load R. There is also some amount of sinusoidal noise corrupting the system.
   a. What is the value of R?
   b. Suppose the SNR of the system is 64. What is the amplitude of the noise signal?
   c. What would be the new SNR of the system if the amplitude of the noise signal was doubled?

a. $P_{avg} = \frac{V_{rms}^2}{R}$

$R = \frac{V_{rms}^2}{P_{avg}}$

$\boxed{R = 4\,\Omega}$

b) $SNR = \frac{P_{signal}}{P_{noise}}$

$= \frac{\left(\frac{V_{rms,sig}^2}{R}\right)}{\left(\frac{V_{rms,noise}^2}{R}\right)}$

$= \left(\frac{V_{rms,sig}}{V_{rms,noise}}\right)^2$

$SNR = \frac{V_{rms,sig}^2}{\left(\frac{A}{\sqrt{2}}\right)^2}$

$\frac{A^2}{2} = \frac{64}{64}$

$\boxed{A = \sqrt{2}}$

c) A doubles → $V_{rms,noise}^2$ Quadruples

$\boxed{SNR = 16}$ ↳ $\frac{1}{4}$ the SNR

5. Lightning Round! The parts of this question are not related to one another.
   a. An IC has an operating frequency of 2.4 GHz, supply voltage of $V_{DD} = 5V$, and dissipates 10W.
      i. What is the new power dissipation if the supply voltage is increased to 15V?
      ii. Suppose we want the IC to dissipate 15W by changing only the operating frequency. What should this new operating frequency be?

i. $P = naf CV_{DD}^2$ $\boxed{P = 90W}$

· 3 times V_{DD} gives 9 times power

ii) Original power is 10W, thus we want $\frac{3}{2}$ the original power → $\frac{3}{2}$ the original frequency

↳ $\boxed{f = 3.6\,GHz}$

   b. We have a continuous-time signal given by $x(t) = 3\cos(4\pi t) - \sin(8\pi t)$ sampled at $T_s = \frac{1}{8}s$ to form the sampled signal $x[n]$.
      i. List the frequencies present in the above signal (in Hertz).
      ii. Find the values of $x[n]$ at samples $n = 0, 1, 2, 3, 4$.
      iii. What is the sampling frequency of this sampler?

i. $\cos(\omega t) = \cos(2\pi f t)$

$\boxed{f_1 = 2\,Hz}$

$\boxed{f_2 = 4\,Hz}$

ii. $x[0] = x(0) = 3$

$x[1] = x(\frac{1}{8}) = 0$

$x[2] = x(\frac{2}{8}) = -3$

$x[3] = x(\frac{3}{8}) = 0$

$x[4] = x(\frac{4}{8}) = 3$

iii. $f_s = \frac{1}{T_s}$

$\boxed{f_s = 8\,Hz}$