CSU0007 Basic Electronics, Homework 5

- Four questions in total. Submit your work via Moodle before 9PM, Dec 19th, 2020 (Saturday).
- Textbook coverage: Section 7.1 to Section 7.6. Note that we use notations V_S and V_{CC} interchangeably.
- For all questions, consider the SCS model of a MOSFET. Clearly state your reasoning to earn full score.

1. (40 points) In this question, we review the fundamental properties of a MOSFET.
    1. (10 points) State the boundary condition between the saturation region and the triode region.
    2. (10 points) In class, we showed that starting from the cut-off region, with the fixed value of V_{DS}, if we gradually increase the value of V_{GS} then then MOSFET will first enter the saturation region and then the triode region. Now, suppose we fix the value of V_{GS} (so that it is larger than V_T) and then gradually increase the value of V_{DS} from 0. In this setting, eventually, will the MOSFET go from which region to which region?
    3. (10 points) Under what condition will a MOSFET go from the saturation region to the cut-off region?
    4. (10 points) In which of the three regions will the MOSFET behave as a *dependent current source* where current i_{DS} is dependent on the value of V_{GS}?
2. (15 points) Consider the MOSFET amplifier, version 1, as we've discussed in class (Figure 7.19 in the textbook), with the following setup: $V_T = 1$V, $V_S = 10$V, $K = 1$mA/V^2, and $R_L = 8$kΩ. Assume that the MOSFET always operates in the saturation region. Compute $\frac{v_O}{v_{IN}}$ for
    1. (5 points) $v_{IN} = 1.5$V
    2. (5 points) $v_{IN} = 1.7$V
    3. (5 points) $v_{IN} = 1.9$V
3. (25 points) Again, consider the MOSFET amplifier, version 1. Do the following analyses:
    1. (15 points) Given a constant V_S, consider the range of v_{IN} for the MOSFET to operate in the saturation region. Would the size of this range increase or decrease if we increase R_L? Why?
    2. (10 points) This type of amplifier has a property (you may call it a feature or a bug) that if both $V_T > 0$ and $V_S > 0$, then the output of the amplifier will never change, no matter what negative value of the input is (as long as the input is negative). Explain why.
4. (20 points) Now, consider the MOSFET amplifier, version 2, as we've discussed in class (Figure 7.46 in the textbook). Using the parameters specified in that figure, compute v_O for
    1. (5 points) $v_{IN} = -0.2$V
    2. (5 points) $v_{IN} = -0.1$V
    3. (5 points) $v_{IN} = 0$V
    4. (5 points) Following the question above, when $v_{IN} = 0$V, what would be the value of *current* flowing out from the voltage supply (i.e., from the leftmost voltage source in that figure in the textbook)?