Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Electronic Circuits
Fall 2003

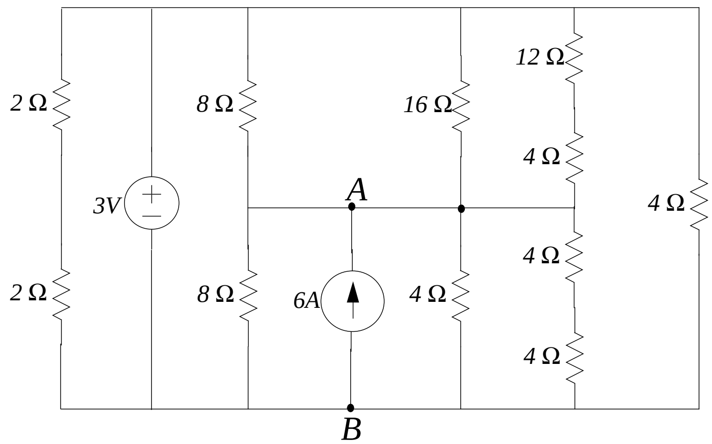
Quiz 1

- Please write your name on each page of the exam in the space provided, and circle the name of your recitation instructor and the time of your recitation at the bottom of this page.
- Please verify that there are 14 pages in your exam.
- To the extent possible, do all of your work on the pages contained within this exam. In particular, try to do your work for each question within the boundaries of the question, or on the back side of the page preceding the question. Extra pages are also available at the end of your exam.
- You may use one double-sided page of notes and a calculator while taking this exam.
- Good luck!

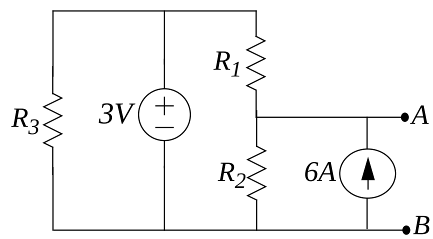
Problem	Points	Score	Grader
1	20		
2	20		
3	15		
4	25		
5	20		
Total	100		

Name: ____________________

Problem 1 – 20 Points



(A) Determine the values of R_1, R_2 and R_3 so that the entire circuit above is equivalent to the simpler circuit shown below for the purpose of creating the Norton equivalent of the above circuit when viewed from its port labeled A-B.



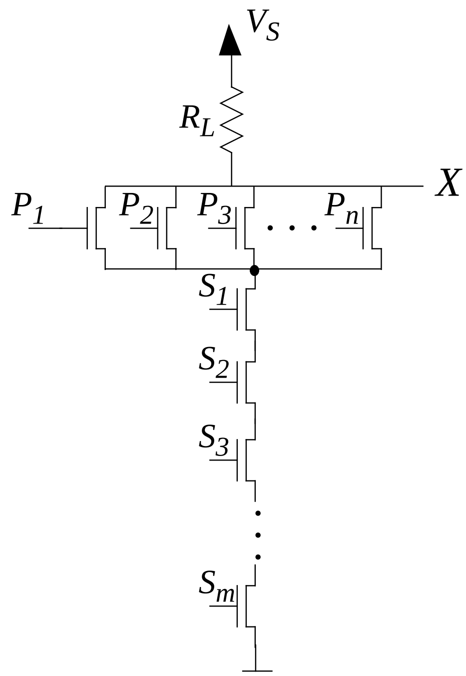
$R_1 =$	$R_2 =$	$R_3 =$

(over)

(B) Assuming $R_1 = R_2 = R_3 = 8\Omega$ in the circuit in Part **(A)**, draw the Norton equivalent of the circuit when viewed from its A-B port. Note that these may not be the values you obtained in Part **(A)**. (Be sure to specify element values, units and polarities.)

Problem 3 – 15 Points

(A) The digital circuit below has logic inputs $P_1, P_2, \ldots P_n, S_1, S_2, \ldots S_m$ and output X. Assuming that the element values are chosen so that the circuit satisfies a static discipline, what is the logic function computed by the circuit?

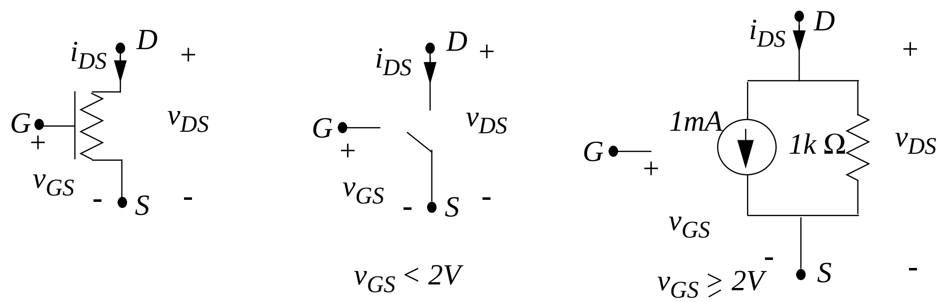


$X =$

(B) For what choice of logic input values is the maximum power consumed by the circuit? Assume that all the MOSFETs have a nonzero value for their ON resistance.

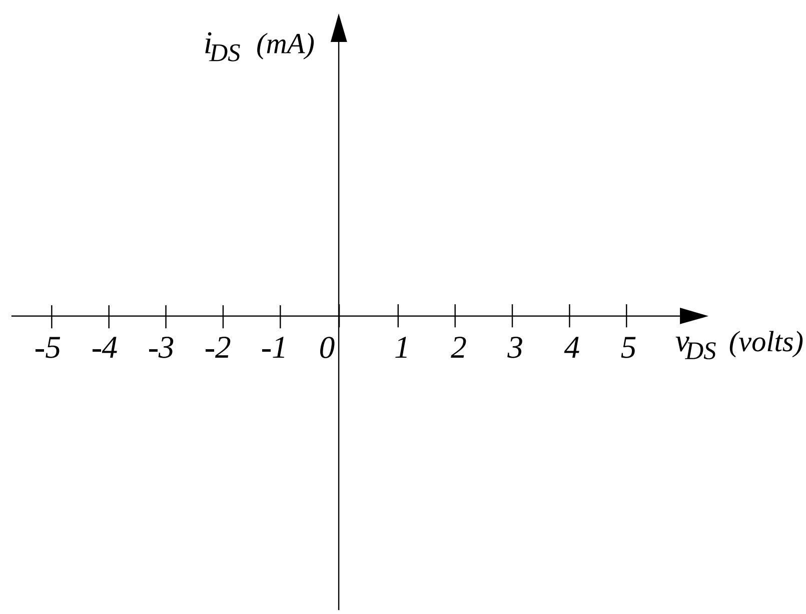
Problem 4 – 25 Points

The semiconductor device team at Yenron Inc. has created a remarkable new device called the LOSFET. The symbol for the device and its equivalent circuit model are shown below.

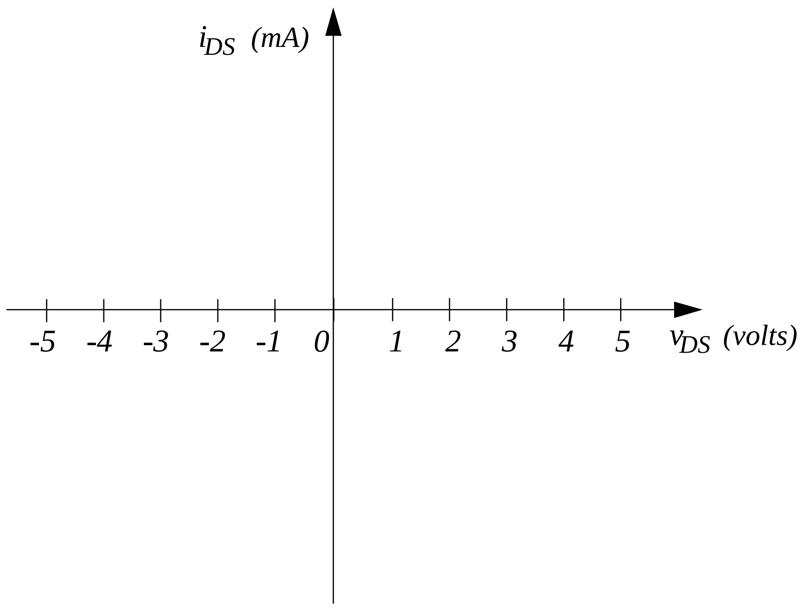


Like the MOSFET studied in 6.002, the LOSFET has three terminals labeled G (gate), D (drain), and S (source). When $v_{GS} < 2V$, the device displays an open circuit between its D and S terminals, and when $v_{GS} \geq 2V$, the device behavior between its D and S terminals can be modeled by a $1mA$ current source in parallel with a $1k\Omega$ resistor. The current into the gate G is always 0.

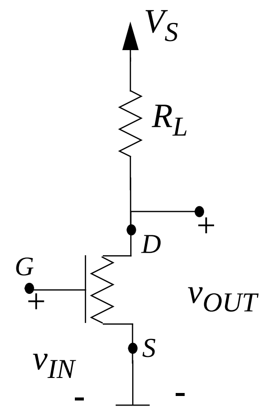
(A) Plot the i_{DS} versus v_{DS} curve for the LOSFET when $v_{GS} < 2V$ in the range $-5V \leq v_{DS} \leq +5V$.



(B) Plot the i_{DS} versus v_{DS} curve for the LOSFET when $v_{GS} \geq 2V$ in the range $-5V \leq v_{DS} \leq +5V$. Clearly mark all relevant intercept values on the two axes.



(C) Yenron engineers use the LOSFET to build the inverter circuit shown below.



Assuming that $V_S = 4V$ and $R_L = 1k\Omega$, determine v_{OUT} for (i) $v_{IN} = 0V$ and (ii) $v_{IN} = 4V$. (Remember that the LOSFET turns ON for $v_{GS} \geq 2V$.)

(i) $v_{IN} = 0V, \quad v_{OUT} =$	(ii) $v_{IN} = 4V, \quad v_{OUT} =$

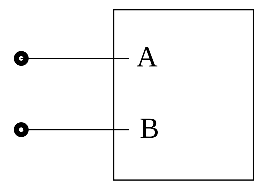
(D) Yenron develops several inverters using the same LOSFET but with various values of V_S and R_L. One of the inverters produces a high output of $v_{OUT} = 5V$ and a low output of $v_{OUT} = 1V$. (Note that although this inverter has the same internal circuit as the inverter described earlier, this inverter has different values of R_L and V_S).

Determine whether this inverter satisfies a static discipline with the following voltage thresholds: $V_{OH} = 3.5V$, $V_{OL} = 0.5V$, $V_{IH} = 2.5V$, and $V_{IL} = 1.9V$. (Simply answer yes if it satisfies the static discipline. If your answer is no, indicate a threshold that is not met by the device.)

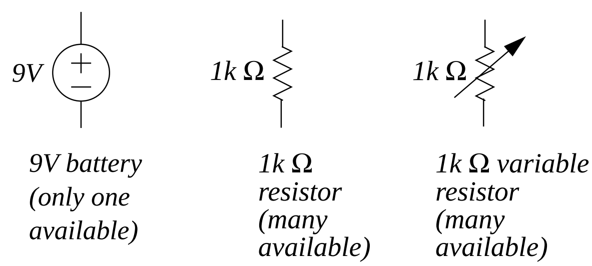
(E) Next, determine whether the inverter in Part **(D)** satisfies a static discipline with the following voltage thresholds: $V_{OH} = 3.0V$, $V_{OL} = 1.5V$, $V_{IH} = 1.9V$, and $V_{IL} = 1.7V$. (Simply answer yes if it satisfies the static discipline. If your answer is no, indicate a threshold that is not met by the device.)

Problem 5 – 20 Points

(A) Yikes, Inc. has developed the new device shown below that requires the application of voltages in the range 0V to 3V at its A-B port.



The Yikes engineers rummage through their supply room but cannot find an appropriate variable voltage source, rather they find **only one** 9V battery and **several** $1k\Omega$ fixed and variable resistors. (A $1k\Omega$ variable resistor can vary between 0Ω and $1k\Omega$). Symbols for these elements are shown below.



You are called in as a 6.002 expert to help the Yikes engineers. The Yikes engineers also tell you that the resistance looking into the A-B port of the device is infinite. Design a circuit that can supply voltages in the exact range 0V to 3V using only the circuit elements in the supply room. Clearly mark the terminals in your circuit which must be connected to the A-B port of the device.

(B) Always looking to help your client, you notice that the device would work even better if voltages in the exact range $-3V$ to $+3V$ were applied at its A-B port. Design a circuit that can supply these voltages using only the elements available in the supply room. (Hint: Try producing two separate voltages, v_1 and v_2, that can be varied independently such that $v_1 - v_2$ produces the desired output voltage.)

(End)