Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Circuits & Electronics
Spring 2007

Quiz #1

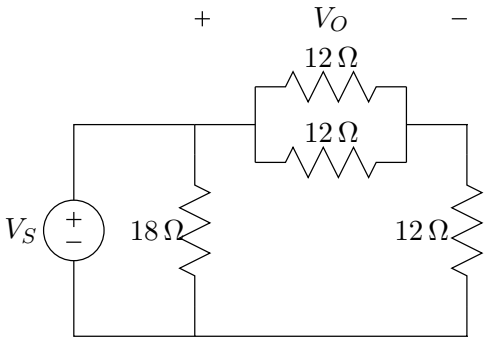
13 March 2007

Name:_____

- There are 26 pages in this quiz, including this cover page. Please check that you have them all.
- Please write your name in the space provided above, and circle the name of your recitation instructor along with the time of your recitation.
- **IMPORTANT:** The problems in this quiz vary in difficulty; moreover, questions of different levels of difficulty are distributed throughout the quiz. If you find yourself spending a long time on a question, consider moving on to later problems in the quiz, and then working on the challenging problems after you have finished all of the easier ones.
- Do your work for each question within the boundaries of that question, or on the back of the preceding page. When finished, enter your answer to each question in the corresponding answer box that follows the question.
- Remember to include the sign and units for all numerical answers.
- This is a closed-book quiz, but you may use a calculator and your double-sided page of notes.
- You have 2 hours to complete this quiz.
- Good luck!

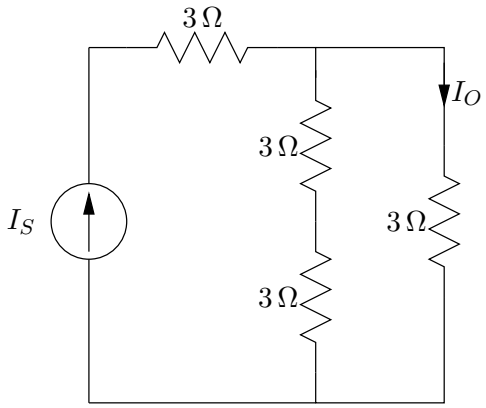
1.	2.	3.	4.	5.	
6.	7.	8.	9.	10.	
11.	12.	13.	14.	15.	
16.	17.	18.	19.	20.	
21.	22.	23.	24.	25.	
				Final Score:	

Problem 1: 4 points



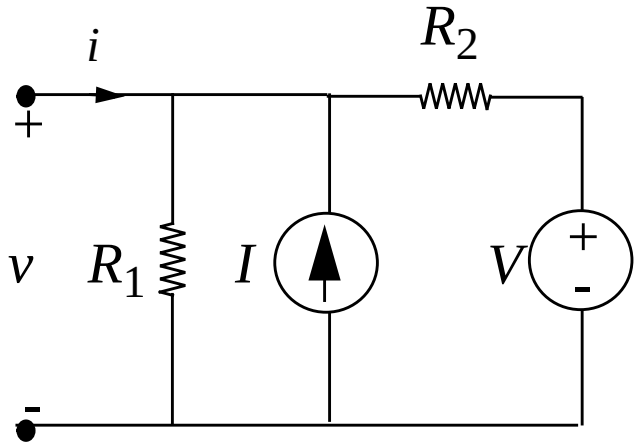
$\frac{V_O}{V_S} =$	1/4	1/3	1/2	2/3	3/4

Problem 2: 4 points

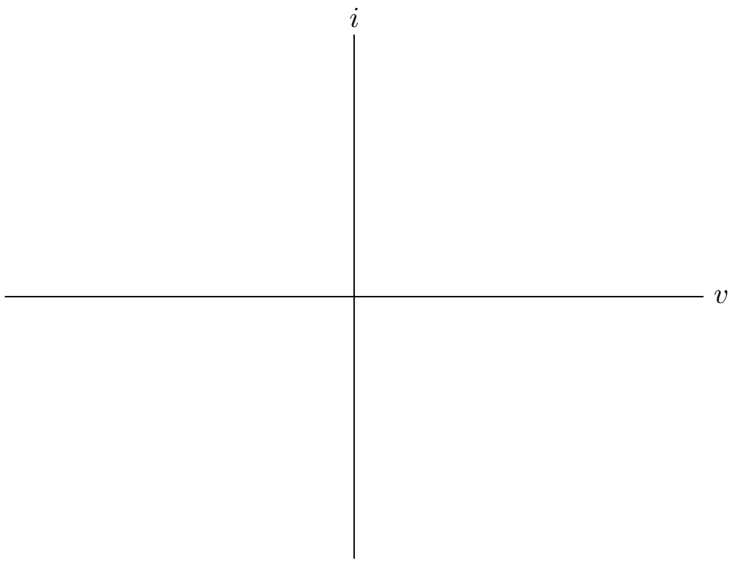


$\frac{I_O}{I_S} =$	1/4	1/3	1/2	2/3	3/4

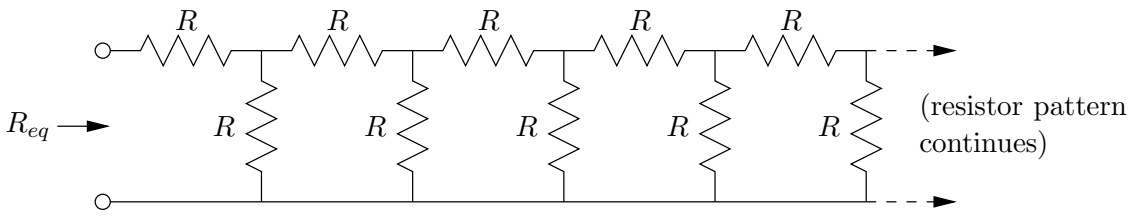
Problem 3: 4 points



Graph the above network's i–v relations as viewed from its port. Clearly label the intercepts and the slope.

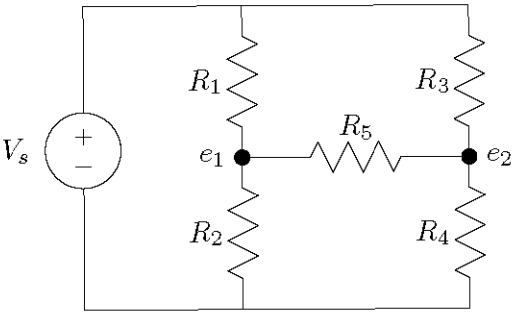


Problem 4: 4 points



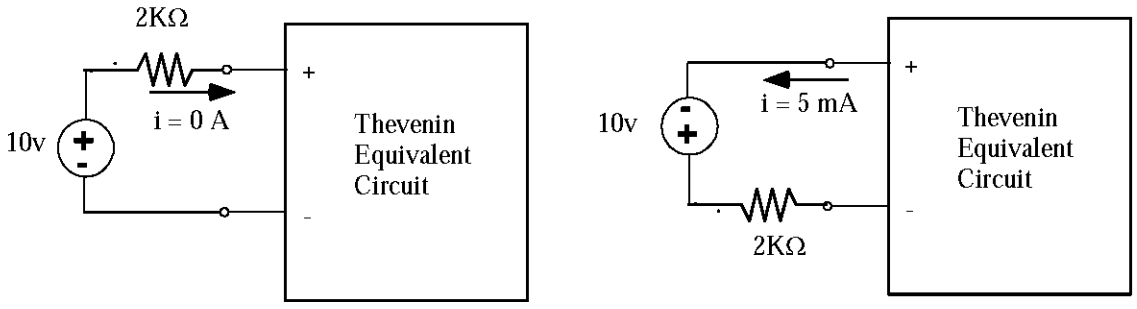
$R_{eq} =$	$R/2$	$R\left(\frac{1+\sqrt{3}}{2}\right)$	$R\left(1+\sqrt{3}\right)$	$R\left(\frac{1+\sqrt{5}}{2}\right)$	$2R$

Problem 5: 4 points



Write the node equations for the nodes e_1 and e_2 in the box below.

Problem 6: 4 points



The current i is measured in two experiments which are performed on a Thevenin equivalent circuit as shown. What is the Thevenin equivalent resistance?

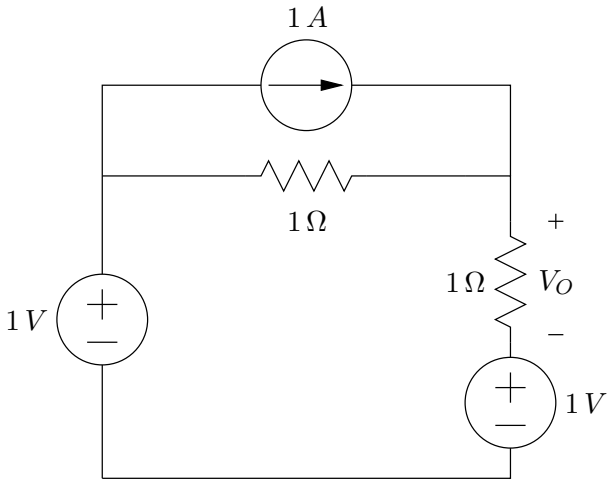
$R_{eq} =$	$0\,\Omega$	$1\,k\Omega$	$2\,k\Omega$	$10\,k\Omega$	$\infty\,\Omega$

Problem 7: 4 points

A battery, which can be modelled by a Thevenin equivalent circuit, has an open circuit voltage of 2 volts. When a $500\,\Omega$ resistor is connected to the battery, the terminal voltage drops to 1 volt. How much power is dissipated in the Thevenin equivalent resistance of the battery under this condition?

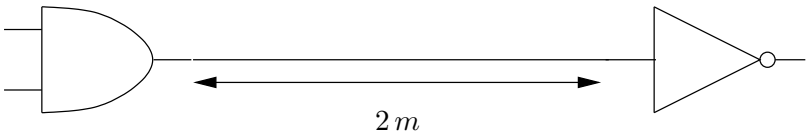
$P_{diss} =$	$0.002\,W$	$0.005\,W$	$0.5\,W$	$2\,W$	$5\,W$

Problem 8: 4 points



$V_o =$	$-3/2\,V$	$-1/2\,V$	$0\,V$	$1/2\,V$	$3/2\,V$

Problem 9: 4 points



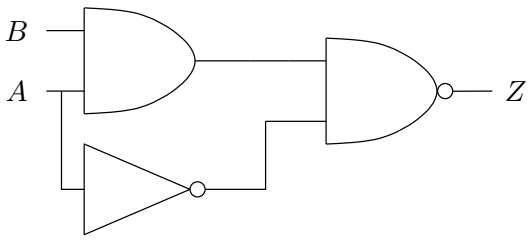
Noise in the 2 meter digital channel shown above is added in at the rate of 0.6 V per meter. To correct for that noise, we introduce buffers into the channel. The purpose of a buffer is to take a signal, to which noise has been added so that it no longer meets the output specifications of the static discipline, and clean it up so that it once again meets the output specifications of the static discipline. These buffers, as well as the gates shown, obey the following static discipline:

$$V_{OL} = 1\,V \qquad V_{OH} = 4\,V$$
$$V_{IL} = 2\,V \qquad V_{IH} = 3\,V$$

What is the minimum number of buffers required to connect between the digital links in order to insure correct operation?

0	1	2	3	4

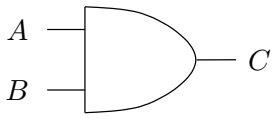
Problem 10: 4 points



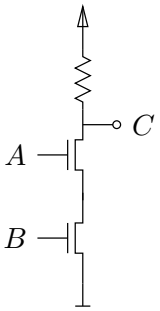
Fill in the truth table for the above digital circuit.

A	B	Z
0	0	
0	1	
1	0	
1	1	

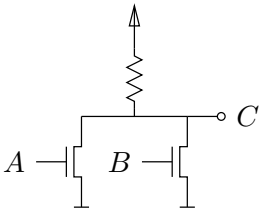
Problem 11: 4 points



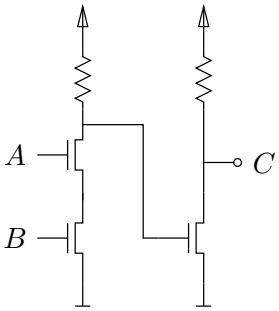
This gate is equivalent to:



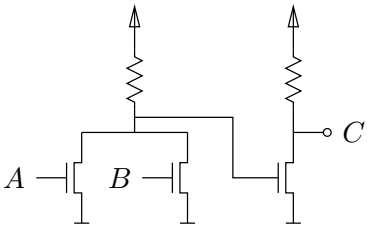
(a) Circuit **A**



(b) Circuit **B**



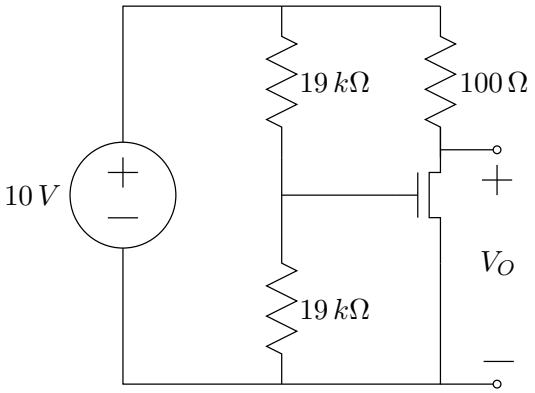
(c) Circuit **C**



(d) Circuit **D**

A	**B**	**C**	**D**	**none of the above**

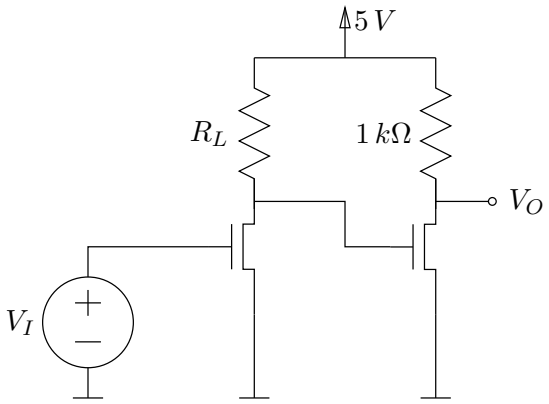
Problem 12: 4 points



Find the power dissipated in R_{ON}, if the MOSFETs are accurately represented by the switch-resistor model, where the threshold voltage $V_T = 2\,V$ and the on-resistance $R_{ON} = 100\,\Omega$.

$P_{diss} =$	$0.25\,W$	$0.5\,W$	$0.75\,W$	$1\,W$	$2\,W$

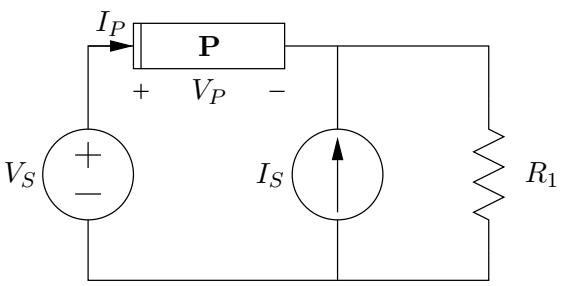
Problem 13: 4 points

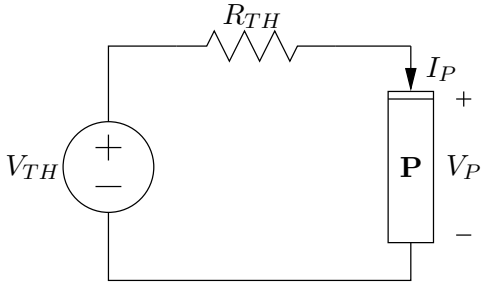


Given that $V_I = 5\,V$ and $V_O = 5\,V$, and that the MOSFETs are accurately represented by the switch-resistor model, where the threshold voltage $V_T = 2\,V$ and the on-resistance $R_{ON} = 100\,\Omega$, find the minimum value of R_L which will allow this buffer to operate correctly.

$R_L =$	$50\,\Omega$	$150\,\Omega$	$500\,\Omega$	$1\,k\Omega$	$2\,k\Omega$

Problem 14: 4 points

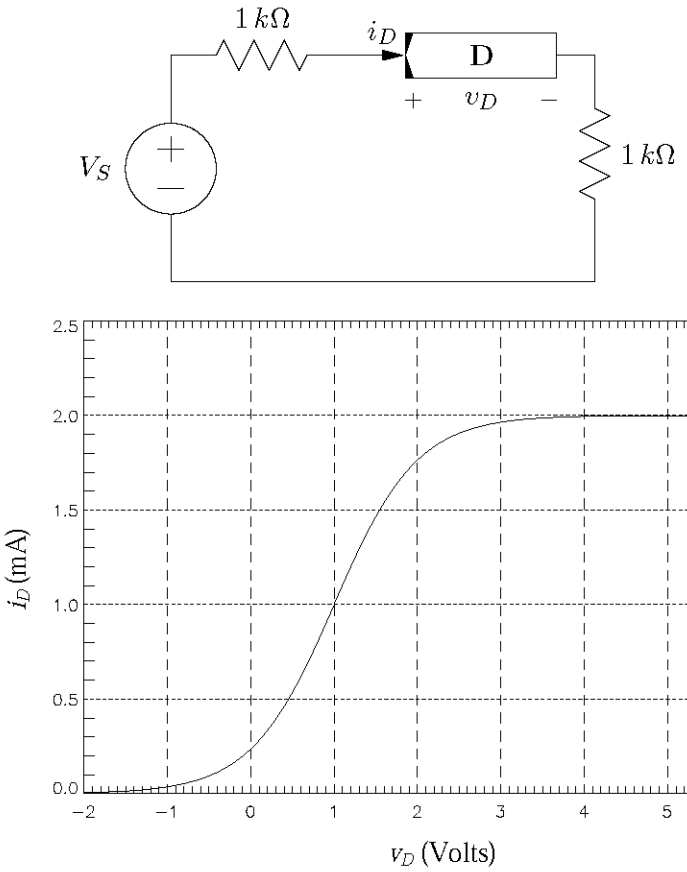




The device **P** in the circuits above is a nonlinear device. The circuit in the left-hand figure above that includes this device can be represented by the equivalent circuit which is illustrated in the right-hand figure. Find expressions for V_{TH} and R_{TH}.

$V_{TH} =$	$R_{TH} =$

Problem 15: 4 points

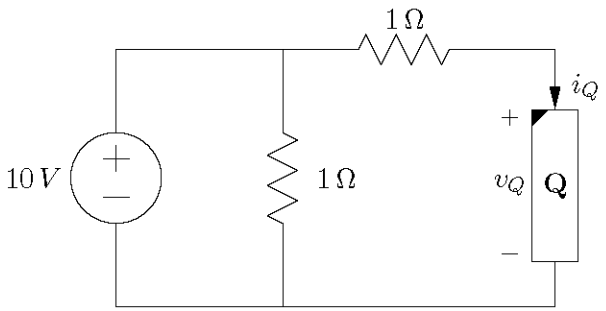


The device D embedded in the circuit shown above has the i–v relation illustrated in the plot located below the circuit schematic.

Circle the value of the voltage source V_S required to bias the device at the operating point $V_D = 1\,V$.

$V_S =$	$-3\,V$	$1\,V$	$2\,V$	$3\,V$	$4\,V$

Problem 16: 4 points



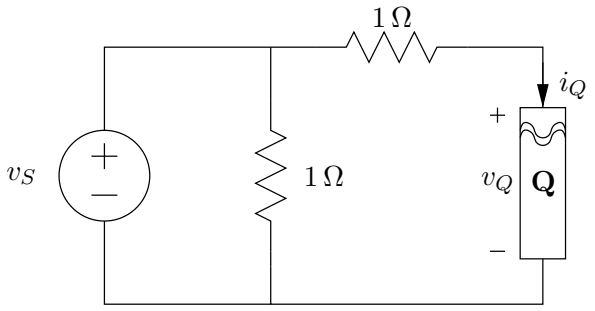
The device Q in the circuit shown above has the i–v relation

$$\begin{array}{lcll} i_Q & = & v_Q^2 + 2v_Q & v_Q > 0 \\ i_Q & = & 0 & v_Q \leq 0 \end{array} \qquad (1)$$

Find the value of v_Q in the circuit.

$v_Q =$	$\frac{-3+\sqrt{11}}{2}\,V$	$1\,V$	$2\,V$	$\frac{-3+\sqrt{29}}{2}\,V$	$10\,V$

Problem 17: 4 points



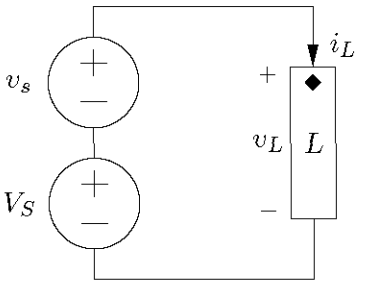
The result of analyzing the above circuit yields the following relationship for the 2-terminal nonlinear device Q:

$$\begin{array}{lcll} v_Q & = & \frac{3}{2}(v_S-1)^2 & v_S \geq 1 \\ v_Q & = & 0 & v_S < 1 \end{array} \qquad (2)$$

Let $v_S = V_S + v_s$; then $v_Q = V_Q + v_q$. Find v_q/v_s if $V_S = 5\,V$.

$\frac{v_q}{v_s} =$	6	12	20	24	48

Problem 18: 4 points



For the above circuit, $i_L = 3v_L^3$. If $V_S = 1\,V$ and $v_s = 0.001\sin(\omega t)$, circle the correct expression for i_l.

$i_l =$

A: $3\,\text{amps}$

B: $(3 \times 10^{-9})\sin^3(\omega t)\,\text{amps}$

C: $(1.11 \times 10^{-4})\sin(\omega t)\,\text{amps}$

D: $(9.0 \times 10^{-3})\sin(\omega t)\,\text{amps}$

E: $(6.0 \times 10^{-3})\sin^2(\omega t)\,\text{amps}$

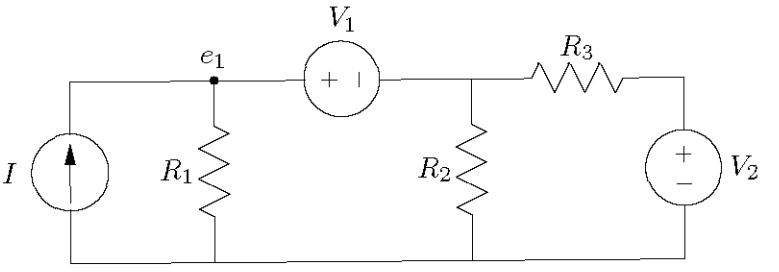
Problem 19: 4 points

A	B	C	$F(A,B,C)$
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

Write a logic expression corresponding to the function $F(A, B, C)$ in the above truth table. You need not simplify your expression.

$F(A, B, C) =$

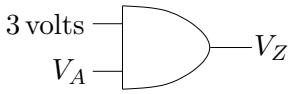
Problem 20: 4 points

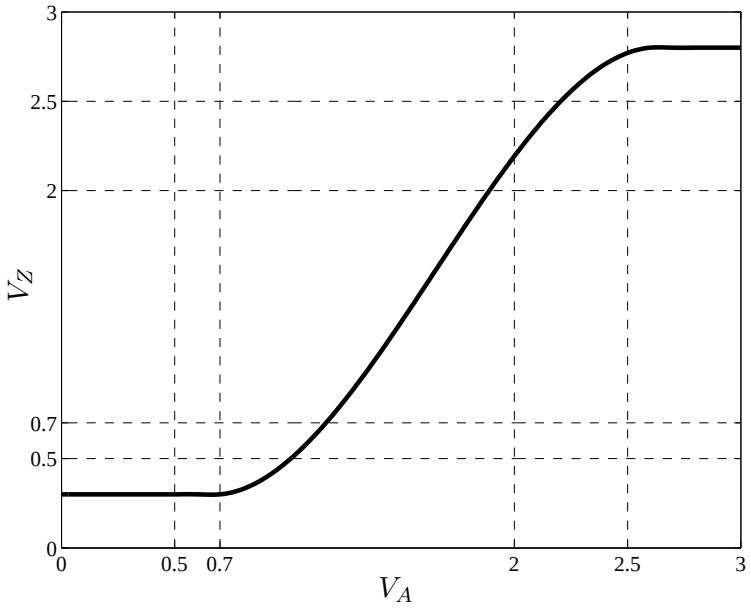


Following the node method, write a single node equation involving the node voltage e_1 in terms of I, V_1, V_2, R_1, R_2 and R_3.

Node equation for e_1:

Problem 21: 4 points





$V_{OL} = 0.5\,V$ $\quad$ $V_{OH} = 2.5\,V$
$V_{IL} = 0.7\,V$ $\quad$ $V_{IH} = 2.0\,V$

The voltage at the output Z of the 2-input AND gate is a function of the voltage at input A, as graphed above. Circle the correct entry in the following list which indicates whether or not the AND gate satisfies the static discipline, and which boundary is broken if the static discipline is violated.

A: Yes, it satisfies the static discipline.

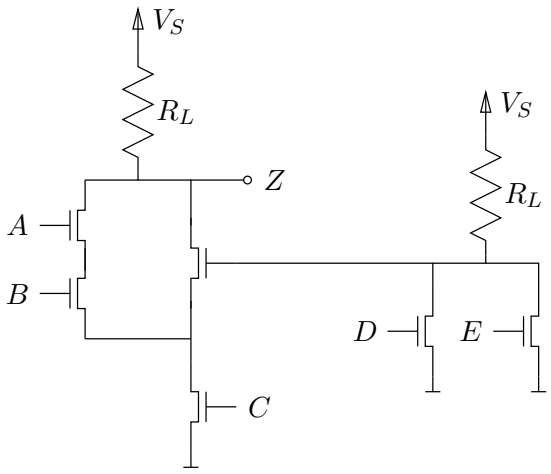
B: No, because the V_{IL} threshold is not met for all valid inputs.

C: No, because the V_{OL} threshold is not met for all valid inputs.

D: No, because the V_{OH} threshold is not met for all valid inputs.

E: No, because the transition through the forbidden region is not instantaneous.

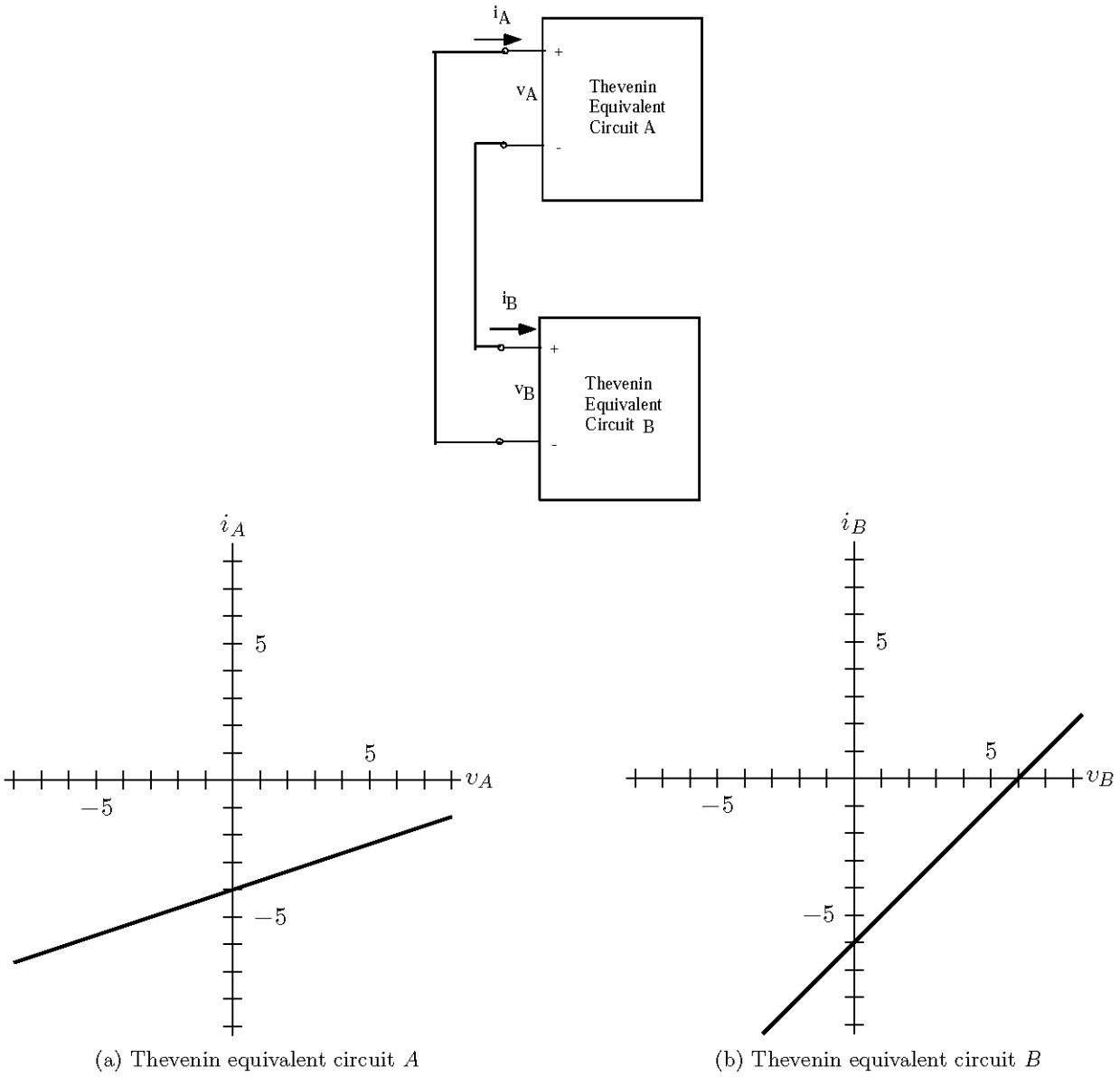
Problem 22: 4 points



Write a boolean expression for Z in terms of A, B, C, D, and E. You need not simplify your expression.

$Z =$

Problem 23: 4 points



(a) Thevenin equivalent circuit A

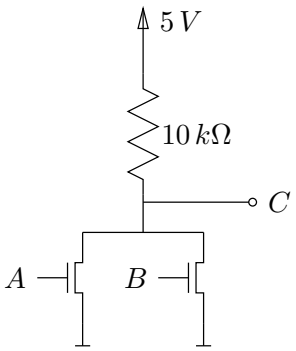
(b) Thevenin equivalent circuit B

The i–v characteristics for each of two Thevenin equivalent circuits are plotted in the graphs corresponding to the labelled network. Using the graphs, *estimate* the current i_A when the circuits are connected as shown. Circle the answer corresponding to the value nearest your estimate. (*Hint: This problem is most easily done graphically.*)

$i_A =$	$4.5\,A$	$1.5\,A$	$-1.5\,A$	$-3\,A$	$-4.5\,A$

Problem 24: 4 points

The NOR gate circuit shown operates in a digital system characterized by a static discipline with the voltage thresholds below.



For both of the MOSFETs,
$R_{ON} = 2\,k\Omega$
$V_T = 2\,V$

$V_{OL} = 1\,V$ $\quad$ $V_{OH} = 4.5\,V$
$V_{IL} = 1.9\,V$ $\quad$ $V_{IH} = 3\,V$

The supply voltage is currently $5\,V$. In order to save power, the designers are thinking of reducing the supply voltage to $4\,V$. Can the designers make this change and still satisfy the static discipline?

A: Yes, they can make this change.

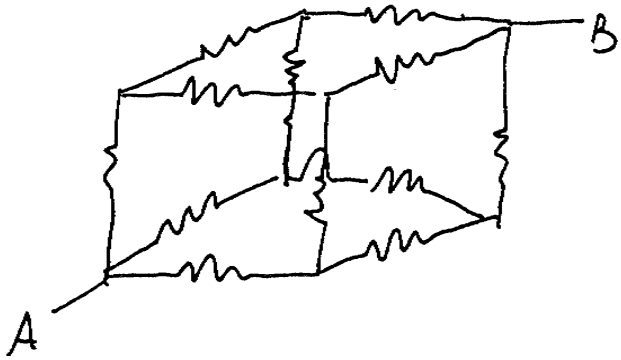
B: No, because the MOSFETS will never turn on.

C: No, because the gate will not meet the V_{OH} part of the static discipline.

D: No, because the gate will not meet the V_{IH} part of the static discipline.

E: No, because the gate will not meet the V_{IL} part of the static discipline.

Problem 25: 4 points
{*Head Scratcher*}



Calculate the equivalent resistance R_{eq} seen between the nodes A and B in the circuit shown above. Assume that all of the resistors have a value of $1\,\Omega$, and that 1 amp flows into node A and out of node B. (*Note: this problem can be solved without writing any node equations.*)

$R_{eq} =$	$1/6\,\Omega$	$1/3\,\Omega$	$1/2\,\Omega$	$5/6\,\Omega$	$1\,\Omega$