(503-030)

Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Circuits and Electronics
Spring 2003

Handout S03-025 - Quiz # 1

Wednesday March 5, 2003

WITH SOLUTIONS

Name: _____

Recitation Instructor (circle one):

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Recitation Hour (circle one):

9 10 11 12 1 2

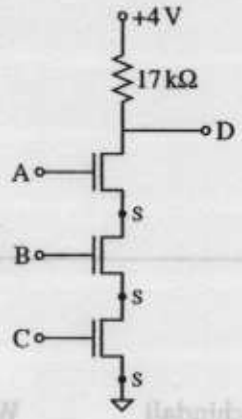
ALL PROBLEMS CARRY THE SAME WEIGHT

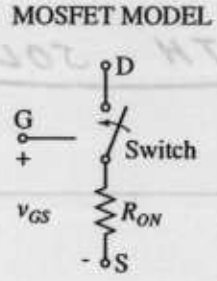
Problem	Points	Score	Grader
1	25		
2	25		
3	25		
4	25		
Total	100		

Name:_____

PROBLEM 1

Assume the convention that a high voltage level denotes a Boolean 1, and a low voltage level denotes a Boolean 0.





For $v_{GS} < V_T$ Switch is open

For $v_{GS} > V_T$ Switch is closed

V_T = 1.0V

R_{ON} = 1kΩ

(A) What is the logical function of this circuit? Express your answer as a boolean function or as a truth table.

THIS IS A THREE-INPUT NAND GATE $D = \overline{ABC}$

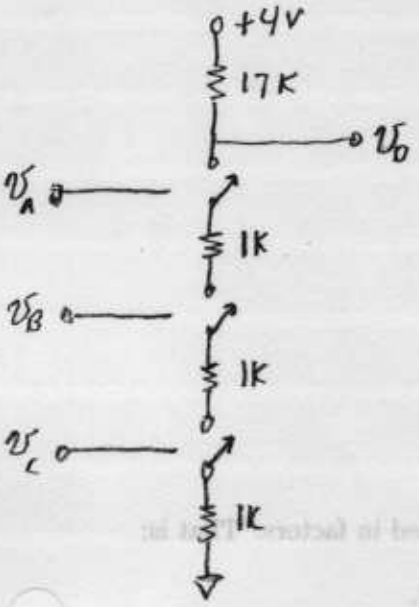
TRUTH TABLE:

A	B	C	D
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Name: _____

(B) What minimum value of 1-state voltage at the inputs will ensure proper operation of the circuit?

THE CIRCUIT WITH THE SR MODEL INSERTED IS:



WITH ALL INPUTS HIGH (ALL SWITCHES CLOSED) THE CURRENT DOWN THE FETS IS $i_0 = \frac{4}{17+(3\times 1)}$ = 0.2 mA

THUS THERE IS A 0.2 VOLT DROP ACROSS EACH FET ($V_{DS} = 0.2V$)

THE SOURCE TERMINAL OF THE TOP FET IS $0.2\times 2 = 0.4V$ ABOVE GROUND. THE MINIMUM ONE-STATE INPUT VOLTAGE IS SET BY THE TOP FET AND IS $0.4V + V_T$ = 1.4 VOLTS

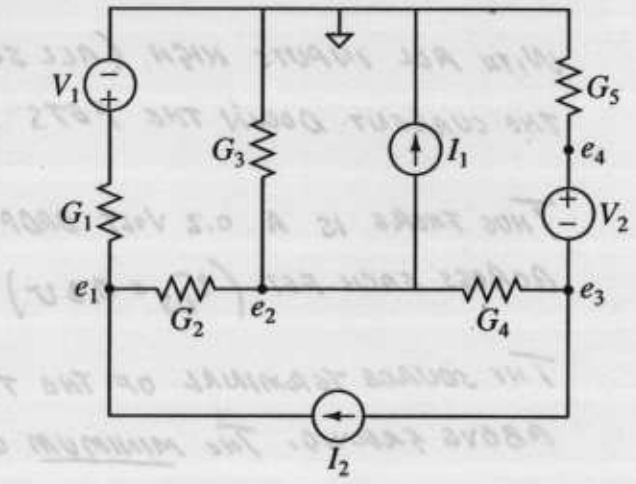
(C) What is the value of the 0-state output voltage?

THE ZERO-STATE OUTPUT VOLTAGE IS AT THE DRAIN OF THE TOP FET WHEN ALL SWITCHES ARE CLOSED. IT IS 0.2×3 = 0.6 VOLTS

Name: _____

PROBLEM 2

Use the node-to-reference voltages indicated on the circuit below to write a set of independent node equations (KCL statements) sufficient to solve for the unknown voltages. **Do not solve them**.



Please put your equations in a form in which all conductances are collected in factors. That is:

[conductances] $\cdot e_1 \pm$ [conductances] $\cdot e_2 \pm \cdots$ ETC.

NOTE THAT e_3 AND e_4 ARE NOT INDEPENDENT BUT ARE CONSTRAINED BY V_2

$$e_4 = e_3 + V_2$$

KCL AT e_1, e_2, e_3 YIELDS (ADDING CURRENTS OUT)

$$(e_1 - V_1)G_1 + (e_1 - e_2)G_2 - I_2 = 0$$

$$e_2 G_3 + (e_2 - e_1)G_2 + (e_2 - e_3)G_4 + I_1 = 0$$

$$(e_3 - e_2)G_4 + \underbrace{(e_3 + V_2)}_{= e_4} G_5 + I_2 = 0$$

COLLECTING TERMS:

$$(G_1 + G_2)e_1 - (G_2)e_2 = I_2 + G_1 V_1$$

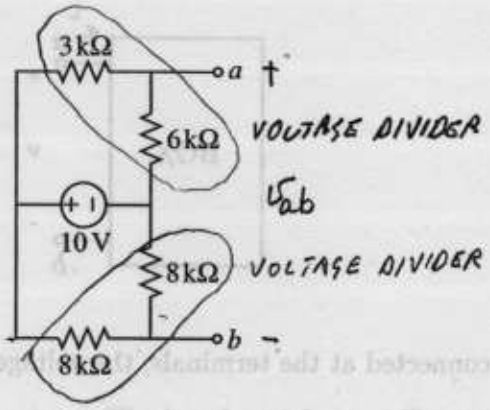
$$-(G_2)e_1 + (G_3 + G_2 + G_4)e_2 - (G_4)e_3 = -I_1$$

$$-(G_4)e_2 + (G_4 + G_5)e_3 = -I_2 - G_5 V_2$$

Name:_____

PROBLEM 3

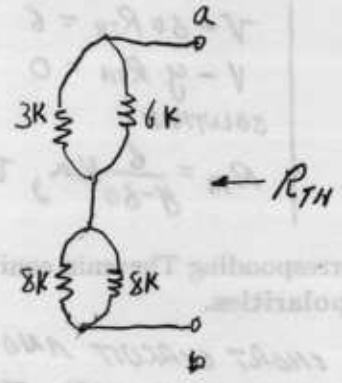
Devise Thevenin *And* Norton equivalent circuits at terminals a, b for the circuit below. **Be sure to specify units and polarities.**



DETERMINING $V_{OC} = V_{ab}$ $\quad V_{ab} = +10 \times \frac{6}{3+6} - 10 \times \frac{8}{8+8} = +\frac{20}{3} - 5$

$= +5/3$ VOLTS

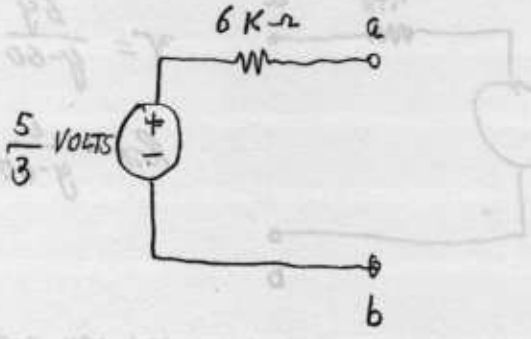
WITH THE 10V SOURCE REPLACED BY A SHORT-CIRCUIT, THE CIRCUIT REDUCES TO:



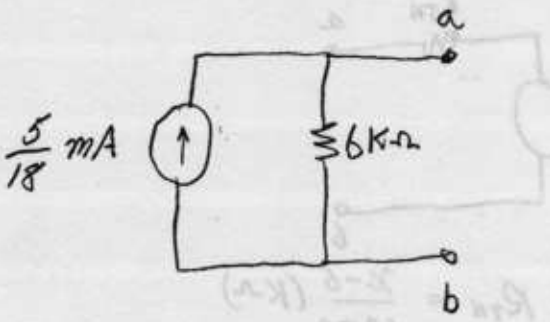
BY INSPECTION, $R_{TH} = 3\|6 + 8\|8 = 2 + 4 = 6\,K\Omega$

$I_{SC} = \frac{V_{OC}}{R_{TH}} = \frac{5/3}{6K} = \frac{5}{18}$ mA

THEVENIN EQUIVALENT



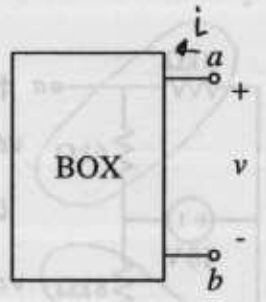
NORTON EQUIVALENT



Name:_____

PROBLEM 4

The box in the circuit below contains linear elements (resistances) and independent sources.



AND THE CURRENT i IS

$$i = \frac{-6}{100} = -60\ \text{mA}$$

With a 100Ω resistor connected at the terminals, the voltage is $v = 6$ Volts.

One other measurement suffices to determine the Thevenin equivalent circuit of the box.

(A) Decide what circuit element, if any, you would connect, and describe the one measurement you would make.

ANY RESISTANCE NOT 100Ω, A SHORT-CIRCUIT, AN OPEN-CIRCUIT OR A SOURCE OF KNOWN VOLTAGE OR CURRENT WILL DO.

EQUATIONS FOR SHORT-CIRCUIT CASE

$V - 60 R_{TH} = 6$ $\quad R_{TH}$ IN KΩ

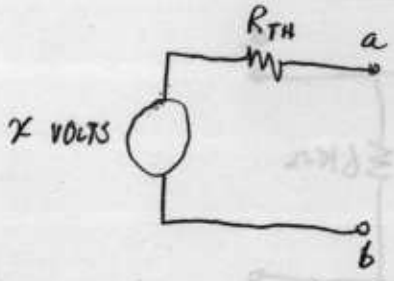
$V - y R_{TH} = 0$

SOLUTION:

$$R_{TH} = \frac{6}{y-60}\ \text{K}\Omega, \quad V = \frac{6y}{y-60}\ \text{VOLTS}$$

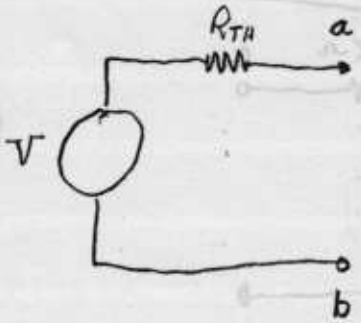
(B) Assume a numerical value for that measurement and draw the corresponding Thevenin equivalent circuit with element values attached. **Specify units and polarities.**

FOR AN OPEN CIRCUIT AND v ASSUMED TO BE x VOLTS, THEVENIN EQUIVALENT IS



$$R_{TH} = \frac{x-6}{60\text{mA}}\ (\text{K}\Omega)$$

FOR A SHORT CIRCUIT AND I_{SC} ASSUMED TO BE y mA, THE THEVENIN EQUIVALENT IS:



$$V = \frac{6y}{y-60}\ \text{VOLTS}$$

$$R_{TH} = \frac{6}{y-60}\ \text{K}\Omega$$

NOTE: IF $x < 6$ VOLTS OR $y < 60$mA, R_{TH} WILL BE NEGATIVE. OK UNTIL YOU ASK FOR ONE AT THE INSTRUMENT ROOM