ECE 110 **October 22, 2012**
Professors Goddard and Trick

HOUR EXAMINATION #2

1) Write your official name (*not a nickname*):
Last Name (use CAPITAL letters): Solution
First Name (use CAPITAL letters): _____
NetId & UIN: _____

2) Write your name and section at the *back* of the test.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD

Make sure to write your name AGAIN at the top of every page of your exam.

A. Write or print clearly. Answer each problem on the exam itself. If you need extra workspace, use the back of the previous page. Clearly identify the problem number on any additional pages.

B. In order to receive **partial or full credit**, you must **show all your work**, e.g., your solution process, name the equation(s) that you use, the values of the variables used in the equation(s), etc. You must also **include the unit of measurement** in each answer.

Students caught cheating on this exam will earn a grade of F for the entire course. Other penalties may include suspension and/or dismissal from the university.

I have read and acknowledge the above statements.

Signature: _____

Problem 1 *(10 points)*

Reduce $\overline{\overline{XY} + Z}$ into a sum of products (i.e. can be implemented with AND-OR logic assuming complementary inputs are available). Show each of your steps by circling the correct Boolean identity used. More spaces for steps than are actually needed are given because there are many ways to do this problem. **Hint:** This can be solved quickly if you start with the outermost negation.

Start with $\overline{\overline{XY} + Z}$. After using the Boolean identity:

(CIRCLE ONE)

OR	AND
Identity	Identity
Null	Null
Idempotence	Idempotence
Complementary	Complementary
Involution	Involution

OR	AND
Commutative	Commutative
Associative	Associative
Distributive	Distributive
De Morgan	De Morgan
Absorption	Absorption
No Name	No Name

the expression becomes $\overline{\overline{X}Y}\,\overline{Z}$.

After using the Boolean identity:

(CIRCLE ONE)

OR	AND
Identity	Identity
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Idempotence	Idempotence
Complementary	Complementary
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OR	AND
Commutative	Commutative
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the expression becomes $\overline{X}\,Y\overline{Z}$.

After using the Boolean identity:

(CIRCLE ONE)

OR	AND
Identity	Identity
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Idempotence	Idempotence
Complementary	Complementary
Involution	Involution

OR	AND
Commutative	Commutative
Associative	Associative
Distributive	Distributive
De Morgan	De Morgan
Absorption	Absorption
No Name	No Name

the expression becomes _____.

Problem 2 *(10 points)*

Given the truth table, mark **ALL** the correct expressions for F.

X	Y	Z	F
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

☐ $F = \overline{X}\overline{Y}\overline{Z} + \overline{X}\overline{Y}Z + \overline{X}Y\overline{Z} + \overline{X}YZ$

☐ $F = X\overline{Y}\overline{Z} + XY\overline{Z}$

No, there must be six minterms.

☑ $F = \overline{X} + Z$

☑ $F = Z + \overline{X}\overline{Y} + \overline{X}Y = Z + \overline{X}(\overline{Y} + Y) = Z + \overline{X}$

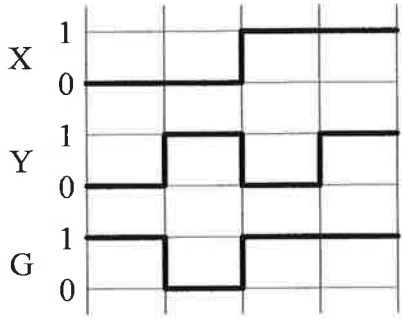
☑ $F = \overline{X\overline{Z}}$

$\overline{F} = X\overline{Y}\overline{Z} + XY\overline{Z} = X\overline{Z}(\overline{Y} + Y) = X\overline{Z}$

$\overline{\overline{F}} = F = \overline{X\overline{Z}} = \overline{X} + Z$

Problem 3 *(15 points)*

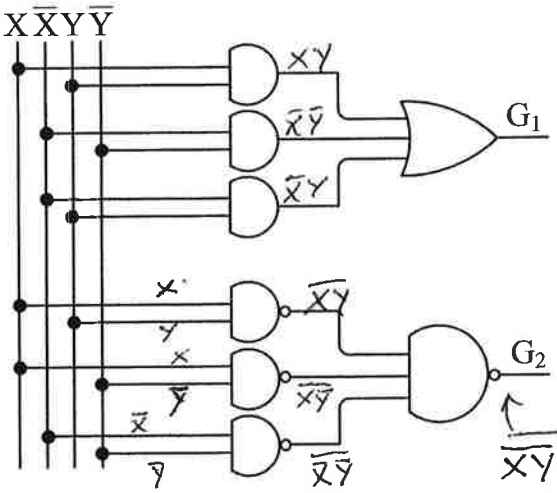
(a) *(6 pts)* Given the timing diagram, write out G as the canonical sum of products.



X	Y	G	
0	0	1	$\bar{X}\bar{Y}$
0	1	0	
1	0	1	$X\bar{Y}$
1	1	1	XY

Canonical Sum of products = $\bar{X}\bar{Y} + X\bar{Y} + XY$

(b) *(6 pts)* For each circuit below, answer whether the circuit correctly implements G and write a Boolean expression for the circuit. You do not need to simplify the expression.

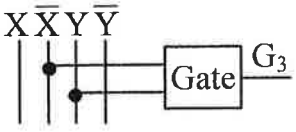


Yes ☐ No ☒ Boolean expression $XY + \bar{X}\bar{Y} + \bar{X}.Y$

Yes ☒ No ☐ Boolean expression $XY + X\bar{Y} + \bar{X}.\bar{Y}$

$\bar{X}\bar{Y} \cdot X\bar{Y} \cdot \bar{X}\bar{Y} = (\overline{\bar{X}\bar{Y}} \cdot \overline{X\bar{Y}}) + \bar{X}\bar{Y} = XY + X\bar{Y} + \bar{X}\bar{Y}$

(c) *(3 pts)* The optimal circuit for G is shown below. Circle the unknown gate.

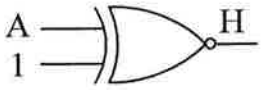


AND OR XOR
(NAND) NOR XNOR
None of these

$G = \bar{X}\bar{Y} + X\bar{Y} + X\bar{Y} + XY = (\bar{X}+X)\bar{Y} + X(\bar{Y}+Y) = \bar{Y} + X$

$\bar{\bar{G}} = \overline{\overline{\bar{Y} + X}} = \overline{\bar{X}Y}$

Problem 4 *(10 points)* Check ONLY ONE correct answer.

(a) The result H of the circuit 

is

A	H
0	0
1	1

☑ A ☐ 1 ☐ $\overline{A}$ ☐ 0

(b) With 16 bits, you can represent

☐ 16 numbers ☑ $2^{16} = 65536$ numbers

☐ 4 numbers ☐ 1 hexadecimal digit

(c) The largest decimal number that can be represented using 5 hexadecimal digits is

☐ 5 x 16 -1 ☐ 5^{16} -1 ☑ 16^5 -1 ☐ 2^{5x16} -1

(d) When you add

$A = (0\ 1\ 0\ 1\ 0\ 1)_2$
$B = (1\ 0\ 1\ 0\ 1\ 1)_2$
1000000
, the result in binary is:

☐ $R = (1\ 1\ 1\ 1\ 1\ 1)_2$

☐ $R = (1\ 1\ 1\ 1\ 1\ 2)_2$

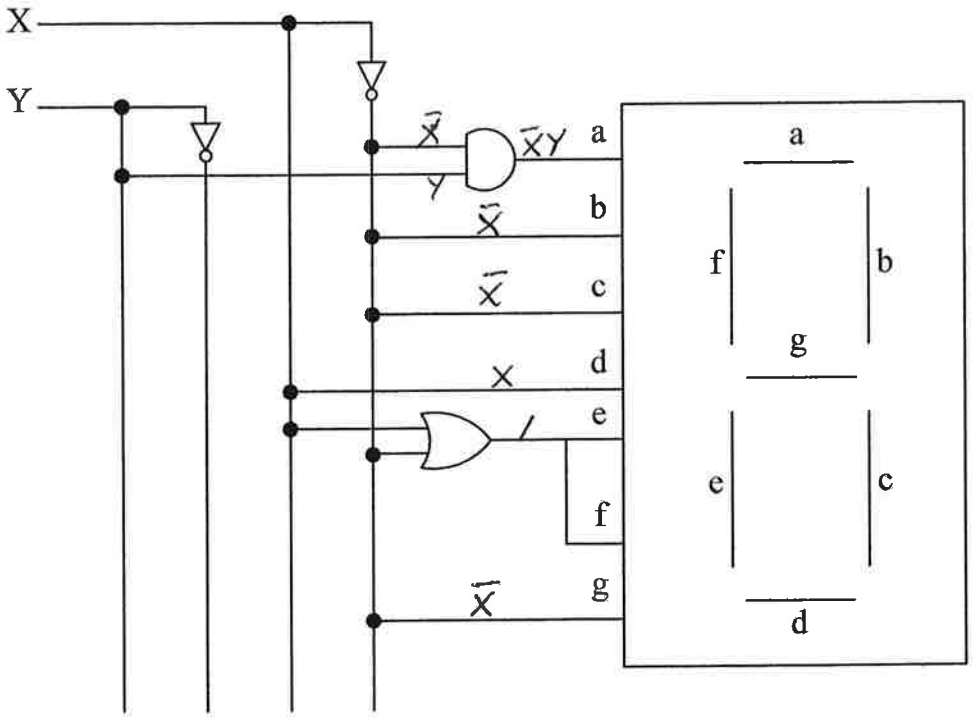
☐ $R = (1\ 0\ 0\ 0\ 0\ 0)_2$

☑ $R = (1\ 0\ 0\ 0\ 0\ 0\ 0)_2$

(e) To display the decimal value of one hexadecimal digit, we would need

(☐ one ☑ two ☐ four ☐ sixteen) 7-segment displays

Problem 5 *(10 points)*



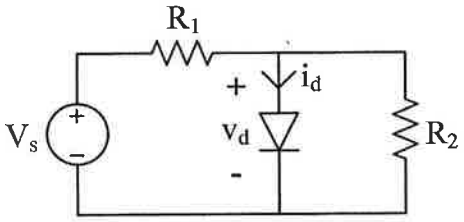
Complete the table below. **Hint:** To save time, first write a Boolean expression for each of the 7 segments.

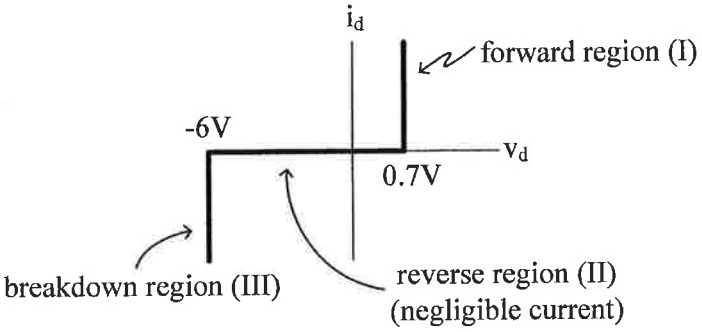
$a = \bar{X}Y$; $b = c = \bar{X}$; $d = X$; $e = f = 1$, $g = \bar{X}$

X	Y	a	b	c	d	e	f	g	letter or number displayed
0	0	0	1	1	0	1	1	1	H
0	1	1	1	1	0	1	1	1	A
1	0	0	0	0	1	1	1	0	L
1	1	0	0	0	1	1	1	0	L

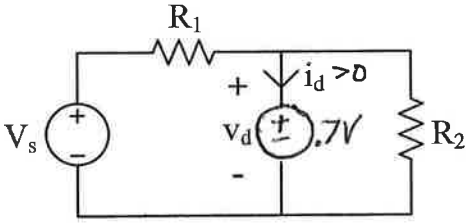
Problem 6 *(15 points)*

The diode in the circuit below can operate in one of three possible regions depending on the values of V_S, R_1, and R_2.

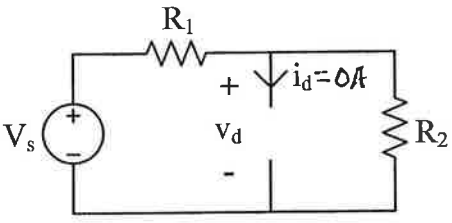




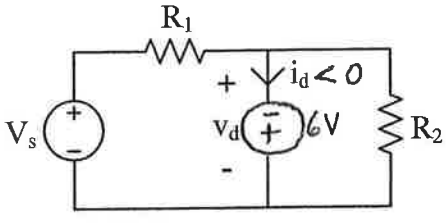
(a) *(5 pts)* Complete each of the circuit models below by inserting in place of the diode the linear model appropriate for the specified region of operation, for example, resistor, open or short circuit, voltage or current source and its value.



Region I (2)

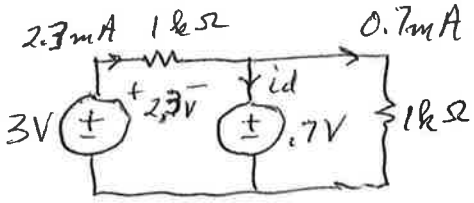


Region II (1)



Region III (2)

(b) *(5 pts)* Find the correct circuit model above to solve for i_d and v_d given $V_S = 3V$, and $R_1 = R_2 = 1k\Omega$.

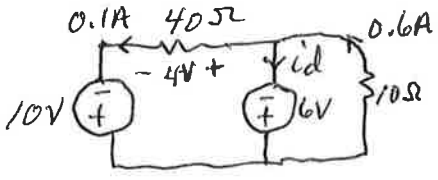


$i_d = 2.3mA - 0.7mA = 1.6mA > 0$ OK

$i_d =$ 1.6mA (3)

$v_d =$ 0.7V (2)

(c) *(5 pts)* Repeat Part (b) for $V_S = -10V$, $R_1 = 40\Omega$, and $R_2 = 10\Omega$.



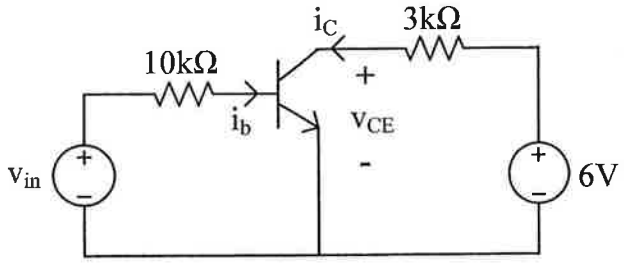
$i_d = 0.6A - 0.1A$
$= 0.5A > 0$ X

$v_d = (10\Omega)(-0.2A)$
$= -2V$
$-6V \le v_d \le 0.7V$ OK

$i_d =$ 0A (2)

$v_d =$ -2V (3)

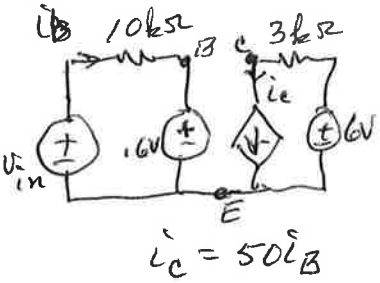
Problem 7 *(20 points)* BJT Transistor Inverter Circuit



$\beta = 50$

$v_{BEON} = 0.6V$

$v_{CESAT} = 0.1V$



$i_C = 50 i_B$

(a) *(10 pts)* Given $v_{in} = 0.8 + 0.3 \sin\omega t$ volts, use the linear active circuit model to calculate i_b, i_c, and, v_{CE} that is, assume that the transistor does not cutoff or saturate.

$$i_b = \frac{v_{in} - 0.6V}{10k\Omega} = \frac{0.2V + 0.3\sin\omega t}{10k\Omega}\ A$$

$$i_b = (20 + 30\sin\omega t)\ \mu A$$

$$i_c = 50\, i_b = (1 + 1.5\sin\omega t)\ mA$$

$$v_{CE} = 6V - (3k\Omega)\, i_c = 6V - 3V - 4.5\sin\omega t\ V$$

$$v_{CE} = 3V - 4.5\sin\omega t\ V$$

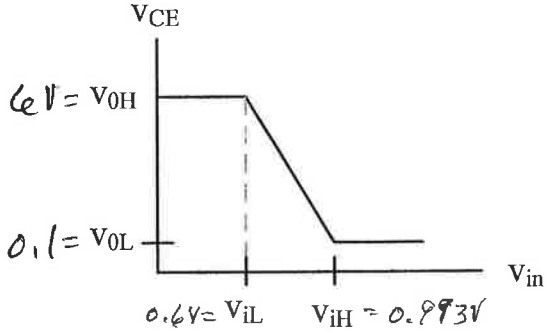
Note: $i_b < 0$ for some $t \rightarrow$ trans. off, and $v_{CE} < v_{CESAT}$ for some t means trans. saturates.

$i_b =$ $20 + 30\sin\omega t$ μA (3)

$i_C =$ $1 + 1.5\sin\omega t$ mA (3)

$v_{CE} =$ $3 - 4.5\sin\omega t$ V (4)

(b) *(5 pts)* For the above circuit find v_{iL}, v_{iH}, v_{0L}, and v_{0H}.



$v_{0L} = v_{CESAT} = 0.1V$

$v_{0H} = 6V$

$v_{iL} = v_{BEON} = 0.6V$

$$v_{iH} = 10k\Omega\left(\frac{I_{cMAX}}{\beta}\right) + 0.6V$$

$$I_{cMAX} = \frac{6V - 0.1V}{3k\Omega} = 1.97mA$$

$$v_{iH} = 10k\Omega\left(\frac{1.97mA}{50}\right) + 0.6V = 0.993V$$

$v_{iL} =$ 0.6V (1)

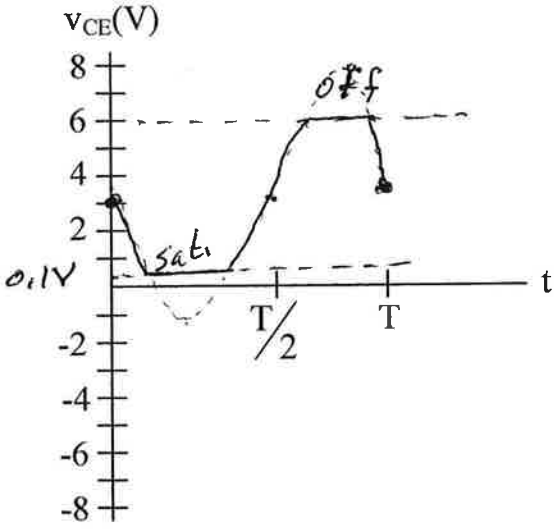
$v_{iH} =$ 0.993V (2)

$v_{0L} =$ 0.1V (1)

$v_{0H} =$ 6V (1)

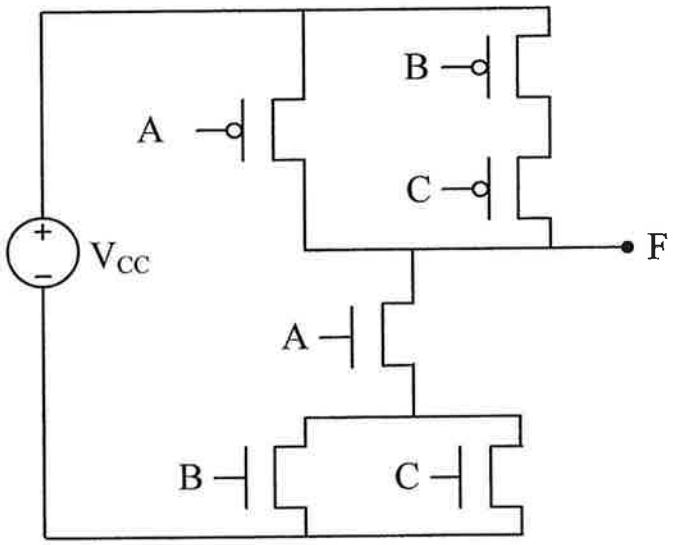
Problem 7 *(continued)*

(c) *(5 pts)* Below plot the actual waveform of $v_{CE}(t)$. Hint: Use the results in Part (b).



– 2 if inverted

Problem 8 *(10 points)* Complete the truth table for the CMOS logic gate.



A	B	C	F
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0

– 2 each incorrect answer

– 5 if inverted truth table

– 10 if student guessed all "1s" or all "0s."