THE MIN H. KAO DEPARTMENT OF
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
Ph.D. QUALIFYING EXAMINATION
Monday, August 16, 2010

Exam Packet Number: _____

You are allowed 4 hours to complete this exam.

- This exam is closed book and closed notes. No calculators or cell phones are allowed.
- **All your work should be done on the papers that are supplied to you. Do not write on the back of any page. D**o not write any answers on this packet!
- Be sure to put your exam packet number on each sheet that has material to be graded. Do not put your name on any sheet!
- There are 16 equally weighted problems. You are to SELECT ANY EIGHT of these to answer. You must make it very clear which eight you choose (see below). If it is not made clear by you, then the first eight problems that you attempt to answer will be graded. Circle only the eight (8) questions that you want graded below:

1
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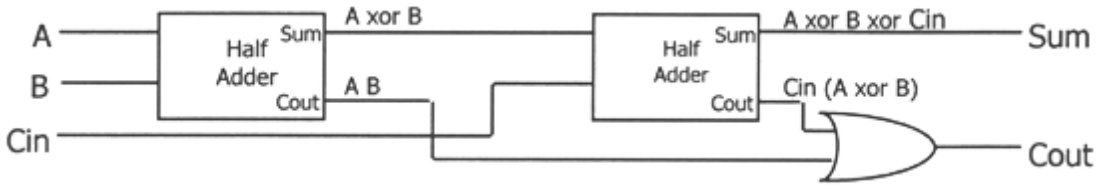
Question #1: Discrete Structures

Assume a function f: A$\rightarrow$B and sets A_1, $A_2 \subseteq$ A, for which $f(A_1 \cap A_2) \neq f(A_1) \cap f(A_2)$. Demonstrate this inequality.

Question #2: Logic Design

Consider the following implementation of the full adder in terms of cascaded half adders:



Show how to implement the full adder Sum and Carryout in multilevel form using **NAND gates only**. You may assume that the input variables A, B, Cin and their complements are available. Sketch your solution as a logic schematic (you may only use NAND gates).

Question #3: Calculus

Find the distance from the point *P* with coordinates $(4,3)$ to the line $\boldsymbol{x}+3\boldsymbol{y}=6.$

Question #4: Programming

Write a C or C++ function whose header is

```
char eval (char * s);
```

where `s` is a pointer to the first element of a string of ASCII characters. Assume all binary values of a character except zero are valid characters, and that the string is null-terminated. The function is to return the character value (having decimal equivalent in the range [1,255]) that occurs most often in the string, or the null character (binary zero) if the string has zero length. In the event that two character values have the same minimum number of occurrences, the function is to return the character having the smaller integer value. The algorithm must have complexity $O(n)$, where n denotes the size of the array.

Question #5: Probability and Random Variables

Each time a coin is flipped, it has probability p of a HEAD and q of a TAIL. Let random variable X denote the number of flips until the first HEAD.

(i) Show that $P(X>1) = q$.
(ii) Write an expression for the conditional probability mass function $P(X=x|X>1)$ in terms of p and q.

Question #6: Computer Architecture and Organization

(a) Consider a classic textbook CPU. What are the key components of its data path, and what is the purpose of the control unit?

(b) The standard textbook instruction pipeline has 5 stages: s1 instruction fetch, s2 operand fetch, s3 ALU operation, s4 memory data access, and s5 register write. Briefly explain how pipelining speeds things up when each instruction now takes more clock cycles to finish.

(c) Name the three types of hazards encountered in a pipelined CPU, describe their root causes, and outline a way to resolve them as well as ways to deal with them should they actually occur.

Question #7: Data Structures

What is the average and worst case Big-O running times for a find operation that is performed on each of the following data structures? Assume that the number of elements in the data structure is n.

a)

	Average Case	Worst Case
Unordered linked list		
Ordered linked list		
Hash table		
Binary search tree		
Balanced binary search tree		

b) For those data structures where the average and worst-case running times are different, explain what type of data would lead to the worst-case running time.

Question #8: Algorithms

Suppose you have an array of n elements containing only two distinct keys, **true** and **false**. Give an O(n) algorithm to rearrange the list so that all **false** elements precede the **true** elements. You may use only constant extra space.

Question #9: Systems Programming and Operating Systems

Assume there are five jobs that must be scheduled to run. Their expected running times are 21, 12, 17, 5, and X. In what order should they be executed to minimize their average completion time? State the scheduling algorithm to be used as well as the order in which they should execute. (Note that the correct answer depends on the value of X.)

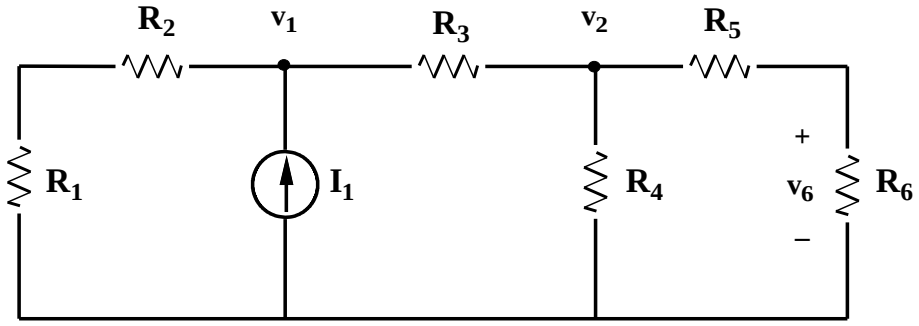
Question #10: Linear Algebra

Consider the following matrix A=$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$. Answer the following:

1. Compute the determinant of A.
2. Compute the eigenvalues of A.
3. Is A positive definite?
4. How many solutions are there to the equation $Ax = \begin{pmatrix} 2 \\ 1 \end{pmatrix}$?

Question #11: Circuits

List the nodal analysis equations for the following circuit. (Note: You need not solve it)



Question #12: Signals and Systems

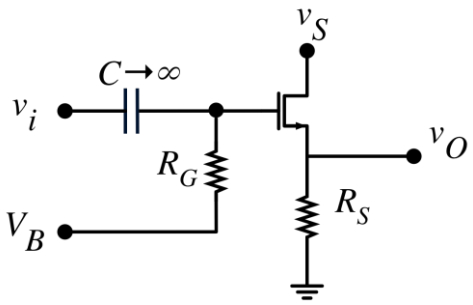
The bilateral *z* transform of a discrete-time function $\mathrm{x}[n]$ is defined by $\mathrm{X}(z)=\sum_{n=-\infty}^{\infty}\mathrm{x}[n]z^{-n}$. Find the inverse bilateral *z* transforms of the following functions.

(a) $\mathrm{X}(z)=\dfrac{z}{z^2-0.2z-0.03}$, $|z|>0.3$

(b) $\mathrm{X}(z)=\dfrac{z}{z^2-5z+6}$, $|z|<2$

Question #13: Electronics

Consider the common-drain amplifier shown below. If there is noise on the supply v_s, find an expression for the mid-band gain ***from the supply*** to the output: $A_S = v_o/v_s$. Assume that the input is grounded and that the transistor is in saturation. Neglect C_{GD} and C_{GS}. Your answer should be in terms of component values and small-signal transistor parameters (R_S, g_m, r_o, etc.). Begin by drawing the small-signal equivalent circuit.



Question #14: Power Electronics

A balanced, three-phase, 60 Hz induction motor delivers rated output power. The rotor speed is 1140 rpm. The rotor circuit frequency (i.e., the slip frequency or f_2) is 3Hz. Determine the following:

1) The synchronous speed in rpm.
2) The number of poles.
3) The speed of the rotor relative to the stator rotating field.
4) The speed of the rotor relative to the rotor rotating field.
5) The speed of the rotor rotating field relative to the stator structure.

Question #15: Electromagnetics

With an unknown load connected to a slotted air line, s=2 is recorded by a standing wave indicator and minima are found at 11 cm, 19 cm, ….on the scale. When the load is replaced by a short circuit, the minima are at 16 cm, 24 cm, …. If $Z_o = 50\ \Omega$, calculate λ, f, and Z_L. Then use a single stub matching and determine the stub length and its location. Note: a Smith chart is appended to this exam.

Question #16: Communication Systems

1. Answer, explain or describe the following:
   (a) Consider a 3000 Hz bandwidth channel that is capable of a data rate of 100,000 bits/second (100 Kbaud). This channel is also operating at nearly its theoretical limit. What channel signal-to-noise ratio in decibels would be required in order to triple the bit rate?
   (b) Consider a conventional amplitude modulated (AM) system, what are the two primary advantages of using an envelope detector?
   (c) Consider a conventional AM system, what is the primary advantage of using a synchronous detector versus an envelope detector?
   (d) What is meant by the threshold effect in FM systems?

2. You have a SSB transmitter with an output power of 100 watts and is received such that the designation signal-to-noise ratio $(SNR)_D$ is 30 dB. What would be the output power of a conventional AM system that achieves the same destination 30 dB $(SNR)_D$. Assume 100% modulation and a message power of 1.