DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

UNIVERSITY OF TENNESSEE, KNOXVILLE

SPRING 2013

Ph.D. QUALIFYING EXAMINATION

QUESTION PACKAGE

DEPARTMENT OF
ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
UNIVERSITY OF TENNESSEE, KNOXVILLE

SPRING 2013 Ph.D. QUALIFYING EXAMINATION

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. Do 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

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

1. Discrete Structures (CS311)

Consider the following code:

```
int fact(int n)
{
        if (n == 1)
                return 1;
        else
                return fact(n-1)*n;
}
```

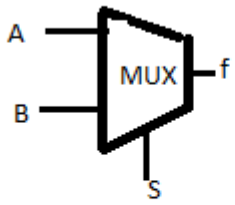
(a) Give a proof using mathematical induction that

fact(i) = i * (i-1) * … * 2 * 1 for all i >= 1

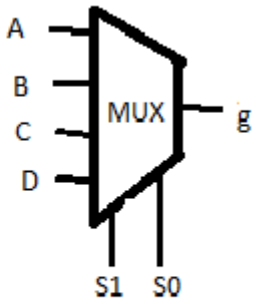
(b) What will be the effect of evaluating fact(0)?

(c) Give an algorithm for evaluating this function using a fixed amount of memory.

2. Logic Design (ECE255/CS160)



2-to-1 MUX



4-to-1 MUX

The multiplexer on the left in the figure is a 2-to-1 MUX that sends (or "multiplexes") the top data input A to its output f if control input S = 0 and sends the lower data input B to output f if control input S = 1.
The multiplexer on the right in the figure is a 4-to-1 MUX that sends

input A to output g if S1S0 = 00
input B to output g if S1S0 = 01
input C to output g if S1S0 = 10
input D to output g if S1S0 = 11

(a) Find a minimized sum-of-products expression (MSOP) for output f of 2-to-1 MUX.
(b) Write a sum of products expression for g as a function of A, B, C, D, S1, S0 for the 4-to-1 MUX. (This does not have to be minimized: any SOP form that correctly defines g is acceptable.)
(c) Draw a logic circuit that implements the 4-to-1 MUX using only 2-to-1 MUXs---use as many 2-to-1 MUXs as you want to, **but don't use any other logic modules or gates**.

3. Calculus (Math)

1) What is the average value of the function $f(x) = \sqrt{x}$ with respect to x from $x = 0$ to $x = 4$.
2) What is the distance traveled by a body moving with speed $v(t) > 0$ along a straight line from $t = a$ to $t = b$? What is the average speed of the trip?

Justify your answers.

4. Programming (ECE206/CS102)

Write a void function named balanceCheckbook that takes no arguments and that balances a checking account. The function should read from stdin, write to stdout, and operate as follows:

a. prompt the user for an initial balance
b. repeatedly prompt the user to enter the type of transaction and the amount of the transaction. For a transaction, the user may enter one of "check", "deposit", or "done".
    i. if the user enters "check", then subtract the amount input by the user from the balance
    ii. if the user enters "deposit", then add the amount input by the user to the balance
    iii. if the user enters "done", then print "done" and exit the function. The user should not have to enter an amount if they type "done".
    iv. otherwise print the message "transactionType is invalid" where transactionType should be replaced by whatever transaction type the user input
c. after processing each transaction, print the updated balance in the checking account using the message "checking account balance = xx.xx" where xx.xx is replaced by the final account balance.

You may use C, C++, or Java. Please specify which language you use. A sample interaction with your function might look as follows:

enter an initial balance: 38.45
enter a transaction and amount: deposit 10
checking account balance = 48.45
enter a transaction and amount: check 8.45
checking account balance = 40.00
enter a transaction and amount: atm 40
atm is an invalid transaction
checking account balance = 40.00
enter a transaction and amount: deposit 4.6
checking account balance = 44.60
enter a transaction and amount: done

5. Probability and Random Variables (ECE313)

A continuous random variable X has the following cumulative distribution function (cdf):

$$F(x) = \begin{cases} a & \text{for } x \leq 0, \\ x^2 & \text{for } 0 < x < 1, \\ b & \text{for } x \geq 1. \end{cases}$$

Find $f_X(x)$ - the probability distribution function (pdf) of X. Be sure to provide a formula for $f_X(x)$ that is valid for all x.

6. Computer Architecture (ECE355/ECE451/CS160)

(a) Consider the signed integers represented in binary by X = 1000 1111 and Y = 0001 0100.

a.1. Determine the decimal values of X and Y.

a.2. Compute the sum S = X + Y and determine the decimal value and validity thereof.

a.3. Compute the difference D = X − Y and determine the decimal value and validity thereof.

(b) Interpret the hexadecimal number Z = 0x3aa3d70a as follows:

b.1. Assume Z is an unsigned integer. Express your answer in the form 2.5K, 8.0M, 0.4B, etc. That is, determine an approximate but close-to-accurate order-of-magnitude value.

b.2. Assume Z is an IEEE floating-point number. Let s be the sign bit, f the 23-bit fraction, and e the 8-bit biased exponent. Determine the values of s, 1.f, and e first in binary, then in decimal before expressing the answer $(-1)^s \times 1.f \times 2^e$ followed by the decimal value. Approximate as necessary to make the computation feasible.

7. Data Structures (CS140)

The programs **acmhash** and **djbhash** are two programs that perform hashing on strings. They each emit a hash value between 0 and 2^{31}-1 on strings given to them on standard input. Here is their output on two strings, "Jet" and "Naomi":

```
UNIX> echo Jet | acmhash
1264874752
UNIX> echo Naomi | acmhash
2439016044
UNIX> echo Jet | djbhash
193461032
UNIX> echo Naomi | djbhash
230264537
UNIX>
```

Part A: Suppose we are using open addressing with linear probing, the function **acmhash**, and a hash table whose size is 50. Tell me the first four indices one would look to find "Naomi," assuming that every lookup attempt ends up with a collision. In other words, give me four numbers.

Part B: Repeat part A, but using quadratic probing.

Part C: Repeat part A, but use double hashing, with **djbhash** as the second hash function.

Part D: Repeat part C, but look for "Jet" instead of "Naomi."

8. Algorithms (CS302)

Consider a connected undirected graph G = <N, E> where N is a set of nodes and $E \subseteq N \times N$ is a set of edges. Given any two nodes m, $n \in N$, let minlen(m, n) be the minimum length of a path from m to n.

(a) Give an algorithm which, given a distinguished start node n_0, returns a list of the nodes of G in topological order of distance to n_0. That is, if m precedes n in the list, then $\text{minlen}(n_0, m) \leq \text{minlen}(n_0, n)$.

(b) Give a modification of this algorithm to account for an integer weight on each edge. The output list must ordered according to $\text{minweight}(n_0, m)$, the minimum total weight of a path from n_0 to each node. This modification need not be efficient.

9. Operating Systems (CS360)

Part A: Write a program that generates the **SIGPIPE** signal, catches it by printing the string "Got it", and then exits. This program is not allowed to call **fork()**, **system()** or **popen()**.

Part B: Give me an example Unix command line that executes two standard Unix programs in such a way that one of them will exit because it generates **SIGPIPE**. Tell me why **SIGPIPE** is generated in your example, and make sure that your example generates **SIGPIPE** even if the operating system / standard IO library perform some buffering.

Part C: Consider the program below. Assume that standard output is going to the terminal. Tell me *every* potential output that this program can have, and how that output comes about.

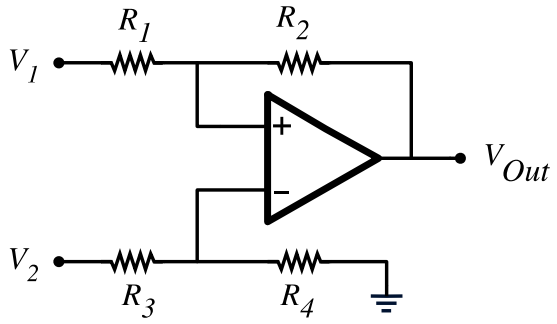
```
#include <stdio.h>
#include <stdlib.h>
#include <fcntl.h>

main()
{
  int i;

  i = write(10, "J\n", 2);
  printf("%d\n", i);
  exit(0);
}
```

10. Linear Algebra (Math)

1. Given the matrix $A = \begin{bmatrix} -1 & 1 \\ 0 & 3 \end{bmatrix}$,
   a. What are the eigenvalues and normalized eigenvectors (use Euclidean length) of A ?
   b. Give the formula for the solution to the unforced vector differential equation $\dot{x} = Ax$ for time $t \geq 0$ with the (arbitrary) initial condition $x = \begin{bmatrix} k_1 \\ k_2 \end{bmatrix}$ using the eigenvalues and eigenvectors of the matrix A, and prove that the formula satisfies the differential equation.
   c. What is this solution when the initial condition is $x(0) = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$?

11. Circuits (ECE300)

In the op-amp circuit shown, find V_{Out} in terms of the input voltages V_1 and V_2 and the resistor values R_1-R_4. Assume that the op-amp is ideal.



12. Signals & Systems (ECE315/316)

A digital filter is defined by its recursion relationship,

$$y[n] = 2x[n] - 0.8y[n-1]$$

in which x is the input signal and y is the output signal. Its transfer function is defined by $H(z) = \frac{Y(z)}{X(z)}$ where the z transform is defined by $X(z) = \sum_{n=-\infty}^{\infty} x[n]z^{-n}$.

(a) Find the transfer function of this digital filter.

(b) If discrete-time radian frequency Ω is related to z by $z = e^{j\Omega}$, at what discrete-time radian frequency, in the range $-\pi < \Omega \le \pi$, is the response of the digital filter maximum in magnitude? At what discrete-time radian frequency is the response of the digital filter minimum in magnitude?

(c) If $x[n] = u[n] = \begin{cases} 0 & , n < 0 \\ 1 & , n \ge 0 \end{cases}$, what is the numerical value of $y[5]$?

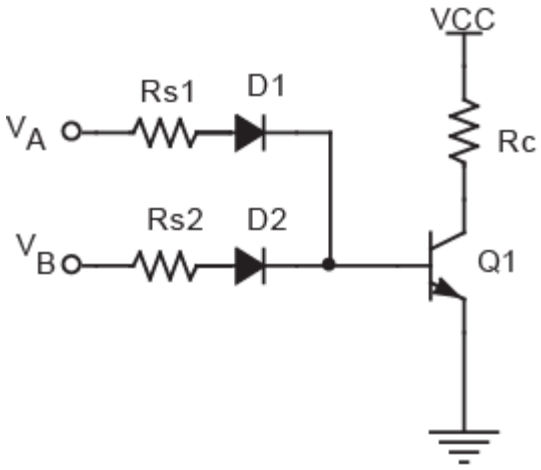
13. Electronics (ECE335/336)

For the circuit shown to the right, assume the BJT has parameters as follows: saturation current I_S=6.734 fA, forward current gain β_f = 416.4, reverse current gain β_r = 0.7371, and the Early voltage V_A = 74.03 V. The diode has parameters as follows: saturation current I_S = 400 pA. Assume the on voltage for the diodes are 0.7 V. For VCC = 5 V, Rc= 10 kΩ, Rs1 = Rs2 = 1 kΩ;

(a) Determine the DC collector current and voltage of transistor Q1 and the current and voltage of diodes D1 and D2 when the input voltages are both 5 V. How much power is supplied to the circuit?

(b) Determine the DC collector current and voltage of transistor Q1 and the current and voltage of diodes D1 and D2 if one of the inputs is at 5 V and the other is at 0 V. How much power is supplied to the circuit?

(c) What does this circuit do?



14. Power (ECE325)

A balanced, three-phase, 6-pole, 60 Hz induction motor runs at 1164 rpm when it delivers rated output power. Determine:

1) The synchronous speed.
2) The value of slip.
3) The frequency of the rotor currents.
4) The speed of the rotor field relative to the rotor structure.
5) The speed of the rotor field relative to the stator structure.

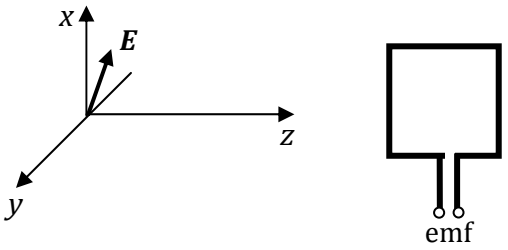
15. Electromagnetics (ECE341)

A plane EM wave is propagating towards the +*z* direction. At one location, its electric field is $\boldsymbol{E} = (\hat{\boldsymbol{x}} - \hat{\boldsymbol{y}})\boldsymbol{E}_1 \cos(2\pi ft)$, where *t* is time and *f* the frequency, and $\hat{\boldsymbol{x}}$ and $\hat{\boldsymbol{y}}$ are unit vectors along the x and y axes, respectively, as shown in the Left Figure.

a) Determine the magnetic field $\boldsymbol{B}(t)$ at the same location. Note: You must give both the magnitude and the direction. You may describe the $\boldsymbol{B}$ field with an expression similar to that of the $\boldsymbol{E}$ field.

b) A square wire loop, as shown in the Right Figure, is used as an antenna to receive the signal carried by this wave. In what direction should the wire loop be oriented to maximize the induced emf (electromotive force)? For clarity and convenience, you may specify the loop orientation by the angle between its normal and the *x* axis.

c) The *y* axis points towards south. The earth's magnetic field at the location of the antenna is about 30 μT. The amplitude of $\boldsymbol{B}(t)$ is on the order of nT. Will the earth's magnetic field overwhelm the antenna reception? Why?



16. Communications (ECE342)

Explain what Aloha and slotted Aloha are. Suppose the data arrival rate is G. Then, derive the formula for computing the throughputs of both schemes. Explain the difference between Aloha and carrier sense multiple access (CSMA).