DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
UNIVERSITY OF TENNESSEE
FALL 2011 Ph.D. QUALIFYING EXAMINATION
Monday, August 20, 2012

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
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16

1. Discrete Structures (CS311)

Let n = $2^{10}3^6 5^8 7^{13}$

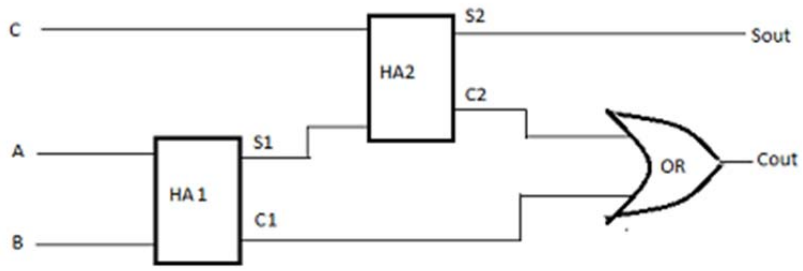
a). How many positive divisors does n have?

b). How many of the divisors in a). are

i. divisible by $2^4 3^2 5^3 7^5$?
ii. perfect squares?
iii. perfect squares divisible by $2^4 3^3 5^2 7^5$?
iv. perfect cubes?
v. perfect squares and perfect cubes?

2. Logic Design (ECE255/CS160)

(a) Give the truth tables for the two outputs C, S of a half-adder (HA) that adds two input bits A, B and outputs their arithmetic sum where output C is the carry bit and output S is the sum bit.
(b) Find a minimized sum-of-products expression (MSOP) for each output C, S for the HA.
(c) The circuit below has two HAs and one OR gate. Show that this circuit implements a full-adder (FA), which computes the two-bit arithmetic sum Cout, Sout of three input bits C, A, B.



3. Calculus (Math)

Find the extreme values of the functions

$$f(x,y) = xy - x^2 - y^2 - 2x - 2y + 4$$
$$g(x,y) = xy$$

Justify your answers.

4. Programming (ECE206/CS102)

Polling centers around the country are text messaging their vote totals to your vote counting application. A text message consists of a string, such as “Smiley 25” or “Ebber 16”, which includes the candidate’s name as a single word and the number of votes tabulated for that candidate at that polling center. To count the votes from the different polling centers, you have designed the following struct to hold a candidate’s information and the following class to tabulate the votes:

```
struct person {
  string name;
  int votes;
};

class voteCounter {
private:
  vector<person> candidates;    // the list of candidates
public:
  void addCandidate(string name);
  void vote(string textMsg);
  string getWinner();
};

void voteCounter::addCandidate(string name) {
  person newPerson;
  newPerson.name = name;
  newPerson.votes = 0;
  candidates.push_back(newPerson);
}
```

The member functions accomplish the following tasks:

1. **addCandidate:** adds a person struct for the specified candidate to the candidates list. We have given you the code for **addCandidate** above.

2. **vote**: takes the textMsg as an argument, extracts the name and vote fields, finds the candidate’s name in the candidates vector, and adds the vote count to the candidate’s total vote count. You can use an istringstream variable to extract fields from a line of text. Remember that the str() member function for an istringstream allows you to assign a string variable to an istringstream variable.

3. **getWinner**: searches the candidates vector for the person with the highest vote count and returns that person’s name.

Note: provide the entire C++ program that results from the completion of Problems 1 and 2 below on your answer sheets. Do not turn in the questions that have blanks provided for missing code.

Problem 1) Write the C++ member function definition for **vote** (we do *not* want to see a member function definition for **getWinner**).

Problem 2) We have started a main program for you that declares a VoteCounter variable and adds some candidates to it. You will complete it by:

a) Writing a loop to read text messages from the console until you encounter eof. You may assume that each text message is a single line, so you should use the getline function to read an entire line. Call the appropriate member function in the VoteCounter variable to extract the candidate's vote from the text message and record the vote.

b) Print the winner of the election by calling **getWinner** and printing the message "winner = xxxx" where xxxx is replaced by the name of the winner.

```
#include <sstream>
#include <iostream>
#include <vector>
using namespace std;

// vote member function (Problem 1): write the function header
_____________________________________________


    // declare your istringstream variable and any other variables you need
    _____________________________________________
    _____________________________________________
    _____________________________________________
    _____________________________________________
    _____________________________________________

    // assign the textMsg parameter to your istringstream variable using the
    // str() member function and then use your istringstream variable to
    // extract the candidate's name and vote count (remember how in class and
    // in the review session we used an istringstream variable named buffer to
    // extract fields from a string)
    _____________________________________________
    _____________________________________________

    // write a for loop to search the candidates vector for the candidate's
    // name and add the vote total from the text msg to the candidate's
    // vote total
    _____________________________________________
```

```
        _____________________________________________________
        _____________________________________________________
        _____________________________________________________
        _____________________________________________________
        _____________________________________________________
        _____________________________________________________

    }  // end of vote member function

int main() {  // Problem 2 (CS 102 Questions)

    voteCounter counter;            // the name of your voteCounter variable
    string textMsg;                 // the variable into which you should read a line
                                    // of input from the console
    counter.addCandidate("Ebber");
    counter.addCandidate("Jessie");
    counter.addCandidate("Smiley");

    // a priming read to read the first text message (i.e., first line of input)

    getline(cin, textMsg);

    // a while loop that calls counter's vote member function to record the
    // candidate's vote and then read the next text message. The while loop
    // should keep reading lines of input until eof is reached
    // (hint: use cin's eof function to test for eof)

    _____________________________________________________________
    _____________________________________________________________
    _____________________________________________________________
    _____________________________________________________________
    _____________________________________________________________

    // print the name of the winner by calling vote's getWinner function
    _____________________________________________________________

} // end of main( )
```

5. Probability and Random Variables (ECE313)

The number X is randomly (and uniformly) selected between -1 and 1. Let A denote the event $\{|X-0.5|<1\}$ and B the event $\{X>3/4\}$. Find $P(A|B)$ and $P(B|A)$.

6. Computer Architecture (ECE355/ECE451/CS160)

(a) Describe the difference between classic (textbook) CISC and RISC architectures. Comment on hardware as well as instruction set aspects.
(b) State whether the Pentium processor is a CISC or a RISC architecture or a combination thereof. Justify your answer.
(c) What does it mean when a processor is labeled as being superscalar? Does it tell you whether it is a CISC or RISC based architecture?

7. Data Structures (CS140)

This is a True/False problem. Just answer true/false. No explanations necessary.
Statement A: If a node in a binary search tree has two non-NULL children, you cannot delete it from the tree.

Statement B: Destructors are only important if a program calls delete.

Statement C: In C++, the statement x = y can only copy megabytes worth of data from y to x if x and y are not pointers.

Statement D: You may model recursion with a stack.

Statement E: If $f(n) = O(g(n))$, then $2f(n) = O(g(n))$.

Statement F: With B-Trees, searching for keys within a node is much less expensive than accessing a new node.

Statement G: If an AVL tree has a height of h, then the tree rooted at the left child of the tree must have a height of h-1.

Statement H: You can use a preorder traversal on binary search tree to print its elements in sorted order.

Statement I: If a B-tree has a height of h, then the tree rooted at the leftmost child the tree must have a height of h-1.

Statement J: If $f(n) = O(g(n))$, then $f(n) + \log_2(f(n)) = O(g(n))$.

Statement L: In terms of big-O, deletion from an AVL tree is more expensive than finding an element.

Statement M: Finding an element in a binary search tree with n elements can have running time complexity as high as O(n).

8. Algorithms (CS302)

```
void f(int arr[], int left, int right) {
    int i = left, j = right;
    int tmp;
    int p = arr[(left + right) / 2];

     while (i <= j) {
        while (arr[i] < p)
            i++;
        while (arr[j] > p)
            j--;
        if (i <= j) {
            tmp = arr[i];
            arr[i] = arr[j];
            arr[j] = tmp;
            i++;
            j--;
        }
    };

    if (left < j)
        f(arr, left, j);
    if (i < right)
        f(arr, i, right);
}
```

1) What does the function f do as to an array of n inputs when called f(arr, 0, n-1)?
2) What is the worst-case running time of function f as a function of input size n, expressed in big-O notation?
3) What is the fastest possible worst-case running time of a function that is equivalent to f in its effect on array arr?
4) Give one reason that this algorithm often performs better than other algorithms that have a faster worst-case running time.
5) Give one way in which the running time of f can often be improved over this implementation.

9. Operating Systems (CS360)

Explain the exact semantics of the following Unix system calls. Also explain how/why each system call is typically used.

- **int dup2(int orig, int target);**
- **int pipe(int fd[2]);**

- **int wait(int *stat_loc);**
- **int select(int nfds, fd_set *readfds, fd_set *writefds, fd_set *errorfds, struct timeval *timeout);** -- Ignore the last three arguments.

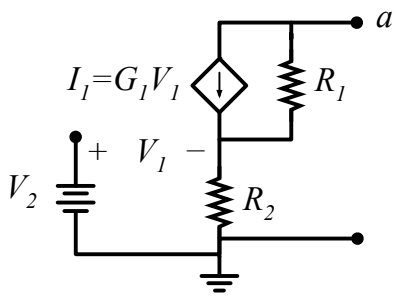
10. Linear Algebra (Math)

Given the functions $f_1(x) = x$ and $f_2(x) = x^3$ in the linear space of square integrable functions on the interval $[-1,1]$ and the inner product operator $\langle y,z \rangle = \int_{-1}^{1} y(x)z(x)dx$

a. Find an orthonormal basis (functions $e_1(x)$ and $e_2(x)$) for the span of these two functions.
b. Show that this span is a subspace.
c. Find the function in this subspace, represented as a linear combination of the elements of the basis, having the smallest norm and the least squared error from (closest approximation to, in the least square sense) g(x)=sin(x).

11. Circuits (ECE300)

For the circuit shown, find the Norton equivalent circuit (current source with parallel resistance) with respect to terminal "*a*" and ground. Use G_1 = 10 mA/V, R_1 = 10 kΩ, R_2 = 5 kΩ, V_2 = 1 V.



12. Signals & Systems (ECE315/316)

A periodic rectangular-wave signal $x(t)$ is graphed below.

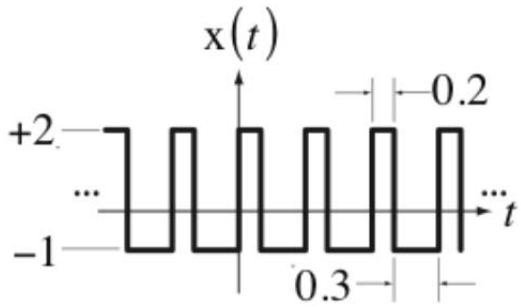
(a) Given the definition of average signal power as the average of the square of a signal, find the signal power P_x of $x(t)$.

(b) The Fourier series harmonic function for $x(t)$ is $c_x[k]$ where *k* is harmonic number and $x(t)$ and $c_x[k]$ are related by

$$x(t) = \sum_{k=-\infty}^{\infty} c_x[k] e^{j2\pi kt/T_0} \quad \text{where } c_x[k] = \frac{1}{T_0}\int_{T_0} x(t) e^{-j2\pi kt/T_0}\, dt$$

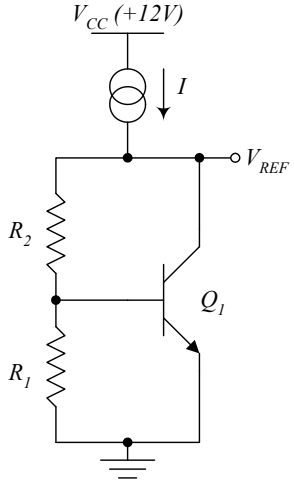
and T_0 is the fundamental period of $x(t)$. Find the harmonic function $c_x[k]$.

(c) The total average signal power of $x(t)$ is the sum of the square of the magnitude of $c_x[k]$ over all harmonic numbers *k*. What fraction of the signal power of $x(t)$ is in its fundamental frequency?



13. Electronics

Find voltage V_{REF} and current I for the circuit provided below. Assume that Q_1 is operating in forward-active mode with V_{BE} = 0.7 V, and use $I_S = 10^{-16}$ A, β_F = 300, $V_T = kT/q$ = 25 mV. You may neglect Early effect. Resistors R_1 = 1 kΩ and R_2 = 6 kΩ.



14. Power (ECE325)

A single phase transformer with rating 5kVA, 600V/120V, 60Hz has the following test data:

Short Circuit test (LV side shorted): V=64 volts, I=8.0 amps, P=175 watts

Open Circuit test (HV side open): V=120.0 volts, I=2.0 amps, P=150 watts

1) What are the winding resistance (R_{eq}) and leakage reactance (X_{eq}) parameters referred to the low voltage side?
2) What are the core impedance parameters R_c and X_m referred to the high voltage side?

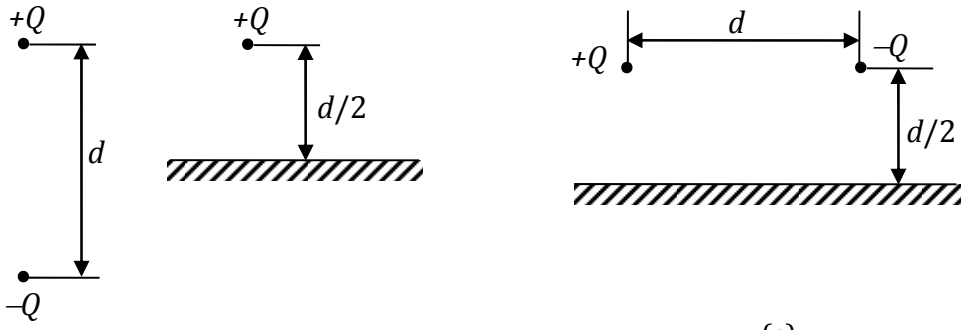
15. Electromagnetics (ECE341)

(a) Two charges $+Q$ and $-Q$ are apart by a distance d, as shown in Fig. (a). What is the force exerted by $-Q$ on $+Q$? Indicate the direction of the force by an arrow on the figure.

(b) A charge $+Q$ is a distance $d/2$ above an infinitely large metal sheet, to be considered as an ideal conductor, as shown in Fig. (b). What is the force on $+Q$? Indicate the direction of the force by an arrow on the figure.

(c) Two charges $+Q$ and $-Q$ are a distance d apart and are both $d/2$ above an infinitely large metal sheet, to be considered as an ideal conductor, as shown in Fig. (c). What is the force on $+Q$? Indicate the direction of the force by an arrow on the figure.

Note: You need to re-draw the figures on your answer sheets and indicate the directions of the forces there, since no answers are allowed on this packet.



(a) (b) (c)

16. Communications (ECE342)

Explain what are BPSK, QPSK and QAM. Consider Gaussian noise. Given the energy of each bit E and the noise power spectral density N_0, derive the bit error rate (BER) of BPSK at the receiver, as well as the BER of QPSK.