ELECTRICAL AND COMPUTER ENGINEERING

PhD QUALIFYING EXAMINATION

Session 1

August 22, 2005

Be sure to put your ID number on each sheet that has material to be graded. Do not put your name on any sheet.

There are 13 equally weighted problems. You are to SELECT ANY EIGHT of these to answer. You must make it very clear which eight that you choose. (If it is not clear, then the first eight problems that you attempt will be graded). Indicate your selections in two ways:

1. Circle below which eight problems that you want graded.
2. If you write anything other than your ID number on the page of a question that you do not want graded, then cross out that page with a large X from corner-to-corner.

Circle the eight questions that you want graded:

1
2
3
4
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9
10
11
12
13

Do all work on the paper supplied to you. Do not write on the back of any page.
Consider the circuit below, which implements the functions $f$ and $g$.

1. Determine the cost of the circuit, assuming that the input variables are available in both true and complemented forms.

2. Redesign the circuit to implements the functions $f$ and $g$ at a minimum cost. What the minimum cost of the circuit?
Problem 2-1

Find the value of the phasor for $I_2$. 

![Electrical Circuit Diagram]

- Voltage source: $12 \angle 30^\circ \text{V}$
- Resistances: $2 \Omega$, $-j1 \Omega$, $8 \Omega$
- Transformers: 1:4

Phasor $I_2$ needs to be calculated based on the given circuit diagram.
Problem 3-1

Referring to the system below,

(a) For what range of real values of $K$ is the system stable?

(b) Identify a value of $K$ for which the system is marginally stable and sketch its unit-step response versus time.

\[ X(s) \xrightarrow{+} K \xrightarrow{-} Y(s) \]

\[ 0.1 \]

One-second time delay
Problem 4-1

Use Green's Theorem to evaluate the integral

\[ \oint xy \, dy - y^2 \, dx \]

around the square cut from the first quadrant by the lines \( x = 1 \) and \( y = 1 \), i.e.,
Problem 5-1

Write a header file and an implementation of the constructor with prototype

```
.matrix::matrix ( int nr = 0, int nc = 0 );
```

and the destructor for the matrix class, whose objects can contain any rectangular matrix. The private data members of the class are to be

```c
int nrows;     // number of rows of the matrix
int ncols;     // number of columns of the matrix
double ** data;  // explained below
```

The member data is to be a pointer to a dynamically allocated array of pointers to arrays of variables of type double. Each of these arrays of doubles is to be the exact size needed to contain the values from one row of the matrix.

The constructor is to dynamically allocate storage for the rows of values from a matrix, unless one or both of its arguments is zero (or absent), in which case no space is to be allocated and data is to be initialized to a null pointer. The members nrows and ncols are to be initialized by the constructor using the values of its first and second arguments, respectively.

The destructor is to reclaim all dynamically allocated storage space.

All of your code must be written in C++.
Assume you have a collection of assembly code files and libraries. Explain how the assembler, linker, and loader act to create an object file for the program and perform tasks to enable program execution to commence. Be sure to discuss how external labels are resolved, addresses and offsets are computed for branches, and relocatable code is supported. Where are local and global variables stored? Where are the program instructions placed? How do we make the code reentrant?
You are given a sequence of n positive integers, for example, [32, 13, 23, ... 120]. Please consider an algorithmic solution that can divide them into 3 piles, and the sum of the numbers in each pile should be as close as they can be or equal.

4.1 Under what circumstances will there be an exact solution? In other words, when will the sum of each pile of numbers be equal?
4.2 In the case of an exact solution, design an algorithm to implement it and give an analysis of its complexity.
4.3 If you are only required to provide an approximate solution, i.e., the sum of each pile is approximately equal to each other, design an algorithm and analyze its complexity.
What is an i-node and how does it relate to operating systems and storage? Assuming a typical operating system (e.g., Unix, Windows), explain the steps for creating files, deleting files, and listing directory contents. Explain how i-nodes are involved in this process. Explain how an "undelete" program can work, particular with respect to i-nodes.
Suppose the rabbit population \( r \) and the wolf population \( w \) are governed by the differential equations

\[
\begin{align*}
\frac{dr}{dt} &= 4r - 2w \\
\frac{dw}{dt} &= r + w
\end{align*}
\]

(a) Represent the differential equations in the form of \( \frac{du}{dt} = Au \) with \( u = [r \ w]^T \).

(b) Find the eigenvalues and eigenvectors of the matrix \( A \). Is this system stable? Why or why not?

(c) If initially \( r = 300 \) and \( w = 200 \), what are the populations at time \( t \)?

(d) After a long time, what is the proportion of rabbits to wolves?
(a) What is the output current $I_o$ in the circuit shown below, if $V_{EE} = 15$ V, and $R = 30 \, \Omega$? Assume that the BJT is in forward active region and $\beta_F = 30$. Also assume that the op-amp is ideal.

(b) What is the voltage at the output of the op-amp if the saturation current $I_S$ of the BJT is $10^{-13}$ A?
Problem 11-1

A dc motor has its field winding connected in series with its armature.

a) Explain why this motor will run from either a dc or an ac source.

b) How could one reverse the direction of rotation of this motor?
An oblique incidence perpendicular-plane wave from media 1 ($\varepsilon_r=4$) impinging on a second media 2 with $\varepsilon_r=1$. Find the reflection coefficient as a function of angle of incidence. Check for conditions for complete transmission and complete reflection.
Problem 13-1

You would like to transmit a video quality signal from Knoxville to Washington DC over a cable whose loss is such that \( \alpha = 0.6 \text{ dB/km} \). The distance between these two cites is about 900 km and experimental measurements have shown that the additive noise of the system is \( 10^{-18} \text{ watts/Hz} \). Video quality is such that the destination signal-to-noise ratio is 50 dB and the bandwidth is 4 MHz. You are allowed to insert 8 repeaters in the line. What is the minimum transmitter power necessary for this system to meet the stated objective?

b. A digital signal consists of two values. Logic 1 has a level of +1 volts and logic 0 has a level of -1 volts. Both signals are corrupted by zero mean noise that is uniformly distributed over +/- 5 volts. Therefore when a logic 0 signal is sent, it may be received as a logic 1 and vice versa. The detector is set up such that if the received signal has a value greater or equal to 0.5 volts, it is interpreted by the detector as a “1”, but otherwise it is interpreted as a “0.” You can assume the zeros and ones are equally probable.

What is the total probability of error for your detector system?

*Suggestion: You might want to draw the pdfs of the two digital signals before you do any calculations*