DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
UNIVERSITY OF TENNESSEE
SPRING 2012 Ph.D. QUALIFYING EXAMINATION
Monday, January 9, 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. 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:

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Spring 2012 EECS PhD Qualifying Exam Question Booklet

1. Discrete Structures (CS311)

(a) Quicksort is based on the principle of ________________________________. A ________________ is used to partition the input into two sublists that contain values that respectively are $\leq$ and $\geq$ than that value. Quicksort is applied ________________ to these sublists. Using an approximation of the ________________ of the input values yields good performance since each pair of sublists will contain ______________________ elements which leads to the well-known ________________ complexity. Worst case performance results when either sublist repeatedly is ________________.

(b) The idea behind mergesort is to recursively form two sublists that each contain half as many elements as the list they are created from. The recursion stops when a sublist contains just a single element. At this point, the sublists are merged while ensuring the elements are sorted with respect to one another. When all sublists have been processed in this manner, the original list is sorted.

State the recurrence relation that describes the computational cost associated with mergesort, then solve it. Show your work and avoid magic steps.

2. Logic Design (ECE255/CS160)

The three-input XOR function *f(A,B,C)* equals 1 if an odd number of inputs are 1 and equals 0 if an even number of inputs are 1 ("even" includes no inputs equal to 1).

(a) Give the Truth Table for *f*.

(b) Write the canonical sum-of-products (CSOP) for *f*.

(c) Find a minimized SOP (MSOP) for *f* and write your MSOP expression.

(d) Show an implementation of *f*(*A*,*B*,*C*) that uses two-input XOR gates (do not use any other kinds of logic gates).

3. Calculus (Math)

Find the limit of $\frac{\ln(n)}{n}$ as n tends to infinity (i.e., $n \to \infty$). Also find the limit of $\sqrt[n]{n}$ as n tends to infinity (i.e., $n \to \infty$).

4. Programming (ECE206/CS102)

The *golden ratio* is the positive real number φ satisfying $\varphi = 1 + 1/\varphi$. Write a program (in any language) to calculate, without using any functions from a math library (such as sqrt) the golden ratio, accurate to at least one part in 10,000. The program is to print this value to the standard output.

5. Probability and Random Variables (ECE313)

Let Y be a Bernoulli random variable with $P(Y=0) = P(Y=1) = 0.5$. Once Y is chosen, the random variable X is chosen according to:

$$X = \begin{cases} \sim N(0,1) & \text{if } Y = 0 \\ \sim N(1,1) & \text{if } Y = 1 \end{cases}$$

where $N(\mu,\sigma)$ denotes a Gaussian distribution with mean μ and standard deviation σ. That is, X is drawn from a Gaussian distribution with mean and variance determined by Y. Answer the following:

(a) Calculate $E(X|Y)$.

(b) Calculate $Cov(X,Y)$.

6. Computer Architecture (ECE355/ECE451/CS160)

Computer Architecture: Data Path

(a) Consider a classic single-core textbook microarchitecture.

What are the main components of the data path?

What is the purpose of the control unit?

(b) Sketch a textbook instruction pipeline with five stages. Indicate how the ARM instruction `ldr r0,[r1,c2]` whose RTN equivalent can be expressed as `R0 <- M[R1+C2]` gets executed.

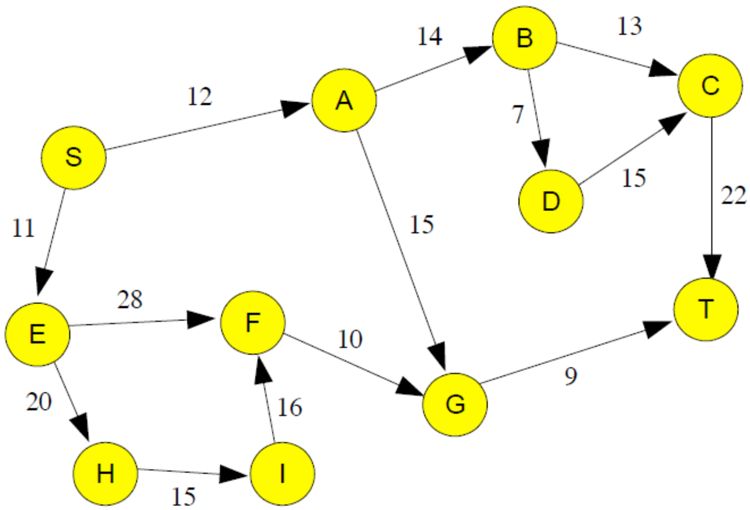
(c) Explain what is meant by pipeline data hazards and branch hazards.

7. Data Structures (CS140)

Let a priority queue be implemented by a binary max heap *T*. Give an efficient algorithm that computes and prints the priority of each node *v* of *T*.

8. Algorithms (CS302)

Behold the following graph with source S and sink T:



Your job is to perform a maximum flow determination on this graph using a standard augmenting path algorithm. To determine each augmenting path, you must perform a depth-first search on the graph, where you traverse edges in the depth-first search in order from greatest capacity to least capacity. In CS302, we called this the "greedy DFS" path determination.

Part A: What is the maximum flow of this graph?

Part B: What edges compose a minimum cut of this graph?

Part C: What are the augmenting paths to find the maximum flow?

Part D: Draw the final flow graph.

I have included an answer sheet for you to hand in your final answer, and some work sheets for your intermediate calculations. Just hand in the final answer. I don't want to see your work.

9. Operating Systems (CS360)

The following are True-False questions and answers from a CS360 final exam. The answers are correct. Explain why they are correct.

Part A - *True or False:* In a non-preemptive thread system, you do not have to worry about race conditions: **False**

Part B - *True or False:* There are programs for which mutexes do not provide flexible enough synchronization operations: **True**

Part C - *True or False:* With mutexes, you may have a thread execute instructions atomically with respect to other threads that lock the mutex: **True**

Part D - *True or False:* There are programs that will work correctly in a non-preemptive thread system that will not work correctly in a preemptive thread system: **True**

Part E - *True or False:* There are programs that will work correctly in a preemptive thread system that will not work correctly in a non-preemptive thread system: **True**

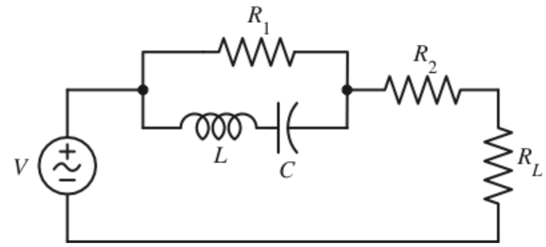
10. Linear Algebra (Math)

Consider two matrices of the same size. Compare rank(A)+rank(B) and rank(A+B). If there is a certain conclusion, prove it. If there is no certain conclusion, provide some examples.

11. Circuits (ECE300)

In the circuit below, the frequency of the sinusoidal voltage source can be varied. At what frequency (in Hz) is the power delivered to resistor R_L a maximum, and how much power (in watts) is delivered to R_L at that frequency?

$V = 120$ Vrms , $R_1 = 200\Omega$, $L = 400$ mH
$C = 50\ \mu$F , $R_2 = 50\Omega$, $R_L = 100\Omega$



12. Signals & Systems (ECE315/316)

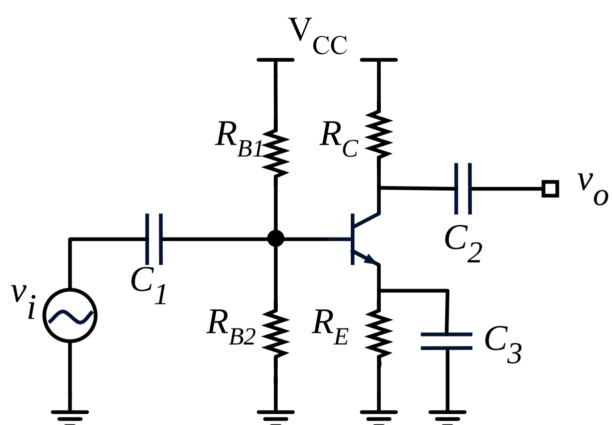
A discrete-time system is described by the difference equation

$$3\mathrm{y}[n] + K\,\mathrm{y}[n-1] - 3\mathrm{y}[n-2] = \mathrm{x}[n].$$

in which "x" is the excitation and "y" is the response. What range of real values of K makes this system stable?

13. Electronics

Consider the common-emitter amplifier shown to the right. Use the following values: R_{B1}=R_{B2}=500 kΩ, and R_C =25 kΩ, R_E =50 kΩ, V_{CC}=12V, V_{BE}=0.7V, ß = 100. Ignore the Early effect. Find the DC value of the collector current.

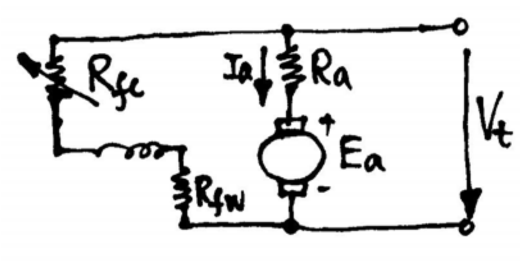


14. Power (ECE325)

1. A self-excited DC motor is show as below. R_a=0.1 Ω and R_{fw}=150 Ω. When the machine is driven at 1200 rpm, we have V_t=250V and I_a=100A. Also, the data for the magnetization curve at 1200 rpm is given as

I_f (A)	…	1.10	1.20	1.35	1.40	1.65
E_a (V)	…	230	240	250	260	270

Determine:
1) The back emf, i.e., E_a.
2) The developed torque.
3) The current in the field circuit. Neglect the armature reaction.
4) The value of R_{fc}
5) The efficiency. Assume the rotational loss is 5% of the output power.



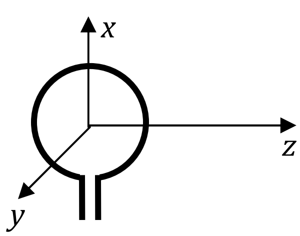
15. Electromagnetics (ECE341)

When a TV antenna is very far from a TV station, the wave carrying the TV signal can be regarded as a plane wave. A circular-loop TV antenna with a 0.02 m^2 area is in the presence of a f = 300 MHz signal with a magnetic field $B = B_0\sin(2\pi ft)$, where t is time. When the loop is oriented in the x-z plane, the loop antenna develops the maximum response with a peak response of 30 mV.

a) Determine B_0 and the direction (along which axis?) of the magnetic field.

b) The TV station is in the $-z$ direction. Determine the direction (along which axis?) of the electric field and find the expression for the electric field (as a function of t).

c) The y axis points towards south. The earth's magnetic field at the location of the antenna is about 30 μT. Compare this value with B_0, and you will see it is orders of magnitude larger than B_0. Will the earth's magnetic field overwhelm the TV signal? Why?



16. Communications (ECE342)

a) Consider a system where the input noise has a power spectral density, $N_0 = 10^{-12}$ W/Hz and passes through a receiver low pass filter whose transfer function is described as $\left|H_R(r)\right|^2 = 10e^{-0.5|f|}$. What is the total output noise power?

b) Consider a bandpass signal consisting of a DSB signal at carrier frequency f_c that has been corrupted by additive white noise. Let the DSB signal be $x_c(t) = x(t)\cos 2\pi f_c t$ and the noise be $n(t)$. Note that both the noise and DSB signal are bandpass signals and therefore can be described in either quadrature-carrier or envelope-phase form. What is the expression for the synchronous detector output?