DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
UNIVERSITY OF TENNESSEE
SPRING 2014 Ph.D. QUALIFYING EXAMINATION
Monday, January 6, 2014

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
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16

1. Discrete Structures (CS311) -

. (a) Determine the number of sequences of s send operations and r receive operations with no consecutive sends. [State any needed condition(s) for s, r.] You do not have to simplify your formula.

. (b) Let U = {1,2,3,...,n}. How many sets A □ U are such that |A| = k (i.e., A has k elements) with A containing no consecutive integers? [State any needed condition(s) for n, k.] You do not have to simplify your formula.

. (c) Prove by induction that for all n □ N (the non-negative integers), $2^{2n+1} + 1$ is divisible by 3.

2. Logic Design (ECE255/CS160)

a) A multiplexor has three inputs X0, X1, and Sel. When Sel=1, the output Y=X1. When S=0, Y=X0. Design a multiplexor using only two-input NAND gates.

b) The sum output S of a half adder with inputs A and B provides the output shown in the truth table. Implement the sum function of a half adder using only multiplexors. You can connect the inputs to the inputs, their complements, or a constant '0' or '1'.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

3. Calculus (Math)

If k is any number, then the constant sequence $\{k\}$ is defined by $a_n = k$ for all n . What is the limit? Justify your answer using the definition of a limit.

4. Programming (ECE206/CS102)

Write a function named avgRainfall that prompts users for integers that represent daily rainfall amounts, print the average rainfall amount to one decimal digit, and returns the average rainfall amount as a double. If the input value of rainfall is less than 0, then inform the user of the error and prompt the user for a new rainfall amount. Keep prompting the user for input until you encounter end of file. avgRainfall should take no arguments. You may assume that the user enters at least one valid rainfall amount. Here is a sample interaction with your function and sample output:

enter a rainfall amount: 2
enter a rainfall amount: -3
rainfall cannot be < 0. Please enter a rainfall amount: 3
enter a rainfall amount: 3
enter a rainfall amount: ^D (^D represents EOF)
average rainfall = 2.7

You may use Java, C++, or C. Please specify which language you use.

5. Probability and Random Variables (ECE313)

Let X be a random variable that is uniformly distribution on the interval (0, 1). Given $X = x$, let Y have uniform distribution on the interval $(0, x)$. Find the joint density function of X and Y. Be sure to specify the range.

6. Computer Architecture (ECE355/ECE451/CS160)

Processor	Clock rate	CPI	No. Instructions.
P1	4 GHz	0.9	5.00×10^6
P2	3 GHz	0.75	1.00×10^6

PART a:

One usual fallacy is to consider the computer with the largest clock rate as having the larger performance. Check if this is true for P1 and P2.

PART b:

Considering that processor P1 is executing a sequence of 10^6 instructions and that the CPI of processors P1 and P2 do not change, determine the number of instructions that P2 can execute in the same time that P1 needs to execute 10^6 instructions.

7. Data Structures (CS140)

This is a general programming question. You may solve it any language that you'd like. However, your solution should be $O(n \log(n))$, where n is the number of lines of input. If you don't know how to read from standard input, then read from a file. You may hard-wire the name of the file into your program. Please specify your language. You do not have to specify include files or the like.

Additional Constraints:

- Each line will contain exactly seven names.
- Each name will contain up to 50 characters, all of which are lowercase letters.

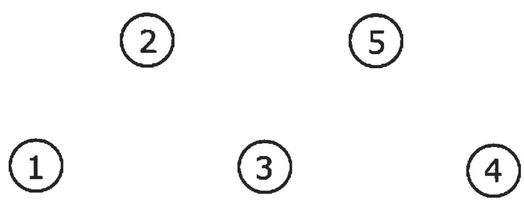
Hint: I did this in C++ with a vector, a set, two strings and an integer. You only need one string, but using two made it clearer.

You may assume that your language has a sorting procedure, like **sort(v.begin(), v.end()),** which sorts the vector **v** in C++.

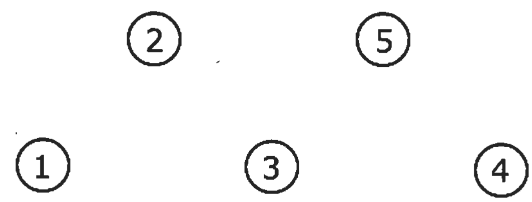
8. Algorithms (CS302)

Use the breadth-first search version of the Ford-Fulkerson algorithm to compute the maximum flow from vertex 1 to vertex 5 in the graph shown. Use lowest numbered vertex to break a tie. Sketch the augmenting paths and their flow along with the resulting residual capacity graphs in sequence. Include negative flow. Extract the min-cut edge set.

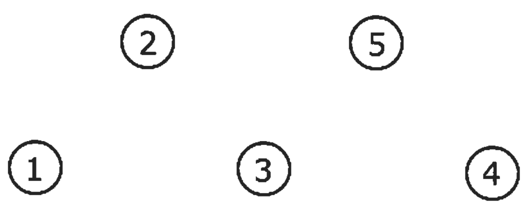
Augmenting flow path 1:



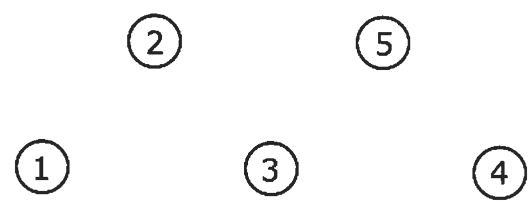
Residual capacity graph 1:



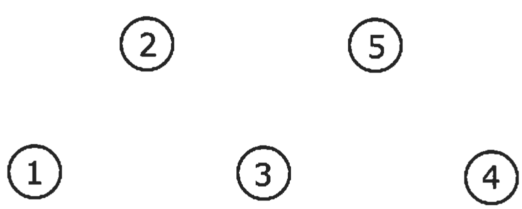
Augmenting flow path 1:



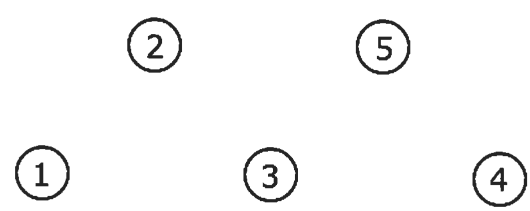
Residual capacity graph 1:



Augmenting flow path 1:



Residual capacity graph 1:



Maximum flow =

Min-cut edge set =

(Note: you are allowed to submit the question sheet as the answer sheet)

9. Operating Systems (CS360)

Knowing how stack works, let's look at a buggy code.

```
int main()
{
  double x;
  double y;
  double z;

  x = 4000.0;
  y = 20;
  z = -17;

  printf("%d %f %s\n", x, y, z);
  return 0;
}
```

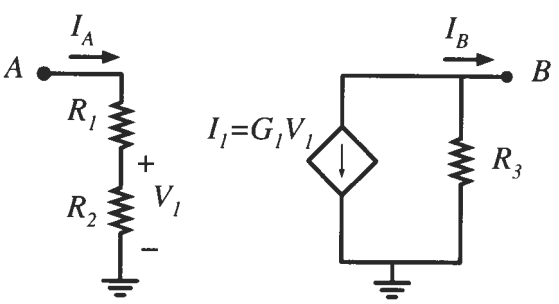
Explain (i) what happens at runtime; (ii) when running this code on different kind of systems, there are several factors that will affect the outputs. Please describe two of such factors and how each changes the output. Each extra factor that you can think of and correctly describe will be worth 5 extra points. Finally, (iii) how to fix the bug?

10. Linear Algebra (Math)

Consider a full rank and symmetric real matrix A with size $n \times n$. Prove that A maps a basis to another basis in R^n. We say that a 1-dimensional subspace of R^n is invariant under A if it is mapped by A to itself. The, how many invariant (under A) subspaces are there in R^n?

11. Circuits (ECE300)

A circuit of the form shown is subjected to the following tests, with the indicated results. It is known that $R_1 = R_2$. Find the value of the circuit parameters R1, R2, G1, R3. G1 should be expressed in conductance (A/V).



Test Conditions	Measurement
Terminal A set to 1 V. Terminal B set to 0 V.	I_A is measured to be 2 mA. I_B is measured to be 1 mA.
Terminal A set to 2 V. Terminal B left as an open circuit.	I_A is measured to be 4 mA. V_B is measured to be 6 V.

12. Signals & Systems (ECE315/316)
With reference to the feedback system below,

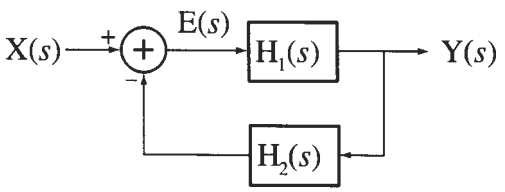
(a) If $H_1(s)=\frac{K}{s}$ and $H_2(s)=\frac{5}{s+10}$, for what real values of K is the system stable?

(b) For K values that make the system stable,

(i) What is the final value of the system's step response?

(ii) For what values of K is the step response monotonic?

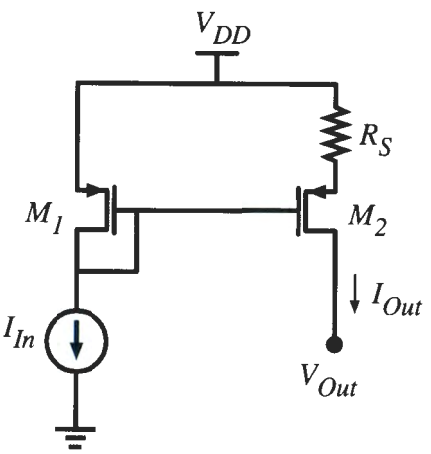
(iii) What is the area under the system's unit impulse response?



13. Electronics (ECE335/336)
Consider the PMOS Widlar current source shown at right. K_p=80 μA/V^2, V_{TP} = -0.7 V, λ = .025 V^{-1}. V_{DD} = 3 V

a) If I_{In} = 40 μA, find the value for R_S such that I_{Out} = 10 μA. Neglect channel-length modulation and assume M2 is in saturation for this part.

b) What is the maximum value of V_{Out} for which this current source operates correctly?

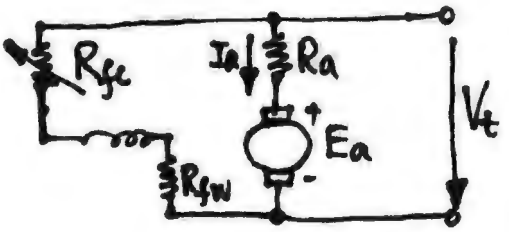


14. Power (ECE325)
A self-excited DC motor is shown in the figure below. R_a=0.1 Ω, R_{fw} =50 Ω, R_{fc} =150 Ω. When the machine is driven at 1200 rpm, we have V_t=240V. Also, the data for the magnetization curve at 1200 rpm is given as

I_f (A)	...	1.10	1.20	1.35	1.40	1.65
E_a (V)	...	220	230	240	250	260

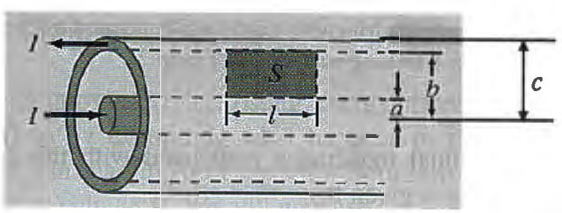
Determine:
a) The current in the field circuit. Neglect the armature reaction.

b) The developed torque.
c) The efficiency. Neglect the rotational loss (but all electrical losses must be considered).



15. Electromagnetics (ECE341)

The dimensions of a coaxial transmission line is as shown in the Figure (notice a, b and c), with the space filled by a dielectric with a relative permittivity ε_r and a relative permeability of 1 (meaning $\mu = \mu_0$). To find the unit length capacitance C' and the unit length inductance L', consider the line to be infinitely long.

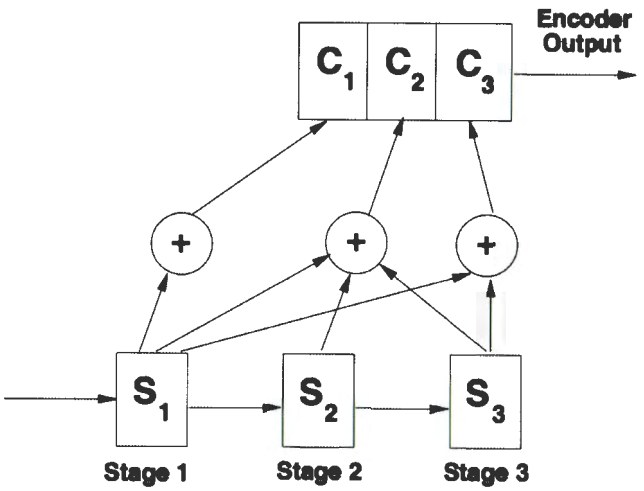


(1) Assume the current I flows only along the surface of the core (i.e. the inner conductor) and the inner surface of the outer conductor. Find the magnetic field at a distance r from the axis, for $r < a$, $a < r < b$, $b < r < c$, and $r > c$. **Note**: Start from Ampere's law.

(2) Find the magnetic flux threading through the shaded area S with a length l (see the figure). Then, use the relation $\Phi = LI$, where Φ is the flux and L is the inductance, to show that $L' = (1/2\pi)\,\mu_0 \ln(b/a)$.

(3) Using the relation $Q = CV$, where Q is charge, V is voltage, and C is capacitance, one can show that the unit length capacitance $C' = 2\pi\varepsilon_r\varepsilon_0 / \ln(b/a)$, which you are **not** required to show. Find the phase velocity v_p, assuming $\varepsilon_r = 2.25$. (**Tips**: $1/\sqrt{\mu_0\varepsilon_0} = c = 3 \times 10^8$ m/s).

16. Communications (ECE342)



(a) Draw the trellis diagram of the above convolutional encoder.
(b) When the input message bits are 11001011, what are the output code bits? (suppose that the original bits in the memory are both zero).