COS 109 Midterm Exam, Fall 2016                In class, Tuesday, October 25

PRINT your name here ____________________________________________

Do not discuss the exam with, or accept help from, anyone. You must write and sign this statement:

“This examination represents my own work in accordance with University regulations.”

Rules

This examination is open-book and open-note:

• You may use the textbook, course notes, your own notes, corrected problem sets and solutions, old exams and answer sheets from the course web page, lab instructions, etc.
• You may use a calculator.
• You may not use anything else; specifically, you may not use a computer, phone or tablet (except that you can use the calculator program on one of these, and you can use your computer to view course notes if you did not print them). You cannot use your computer to access the internet except for the course materials.

Procedure

There are a total of 90 points for the questions; use the point values for each question to allocate your time appropriately (one point per minute).

Write your answers directly on these pages; if you need more space, there is a blank page at the end and you can write on the backs of pages. It's quite all right to be brief as long as you're clear. We have tried to leave plenty of room for answers; if you are writing or computing a lot, you may be off on the wrong track.

Good luck.
1. (15 points) Warmup question

We estimated that there are about 120,000 gas stations in the United States in 2015. We also learned (from Google searching) that there was 1 gas station in the United States in 1913. It is ok to approximate answers to this question. You may want to use the rule-of-72.

(a) What is the annual rate of growth in the number of gas stations over the 102 years from 1913 to 2015 assuming that the rate of growth didn’t change over time

(b) If this rate were to continue into the future, when would we expect there to be about 1,000,000 gas stations in the United States?
2. (20 points, 2 each) Short Answers. Write your answer in the space provided.

(a) How many bits are used in the ASCII code for each character and how many characters can be represented in the ASCII character set? Do not distinguish between printable and unprintable characters.

(b) October 11 is Ada Lovelace day. Why is this relevant to COS 109?

(c) For each of the following representations of RGB colors, what are the decimal values for red, green and blue?

ACCEDE       BEADED       EFFACE
(d) Computers today employ the von Neumann architecture. What is the most significant feature of the von Neumann architecture?

(e) Your laptop computer has a faster CPU and more RAM than the computer that students may have purchased a few years ago. But, it might not have more disk storage. Why is this?

(f) Give an example of a problem that requires exponential time for its solution.

(g) Give an example of an NP-complete problem.
(h) As the number of transistors in a CPU has grown, caches have been added to the CPU chip. What is the advantage of this?

(i) The tweet below was sent this past summer. Why do you think WhatsApp settled on “such an oddly specific number”?

![Tweet](image)

(j) How many kilobytes in a peta byte?
3. (15 points) Machines

Here is a program in the Toy assembly language, with reminders about what the instructions do.

```
Foo   GET
     get a number from keyboard into accumulator
IFZERO Bar
     if accumulator is zero, go to Bar
LOAD   Sum
     load accumulator with value in location Sum
ADD    1
     add 1 to accumulator
STORE  Sum
     store accumulator in location Sum
GOTO   Foo
     go to instruction labeled Foo
Bar
     LOAD   Sum
     print contents of accumulator
PRINT
STOP
Sum 0
     reserve a memory location called Sum, set its initial
     value to 0
```

(a) If this program is given the sequence of inputs 3 –1 4 1 –5 9 2 –7 0 exactly
what does it print?

(b) What would happen if the order of the 2 statements ADD 1 and STORE Sum was reversed?

(c) Starting from the original program, if the command ADD 1 was replaced by the command SUB 1, what would be printed?
4. (15 points) State Machines

Design a state machine to sell PopCorn (P) and Candy (C) for tokens(T).

Inputs to the machine are either tokens (T) (all tokens have the same value) or P (asking for popcorn which costs 2 tokens) or C (asking for candy which costs 3 tokens).

Outputs from the machine are P (to signify that popcorn has been delivered) and C (to signify that candy has been delivered).

The machine goes into an Error state if it receives a P or C command and there are not enough tokens to cover the purchase. After a successful purchase, the machine returns to its initial state.

You do not have to worry about giving change. So, e.g. if someone inserts 5 tokens and then asks for popcorn, they get popcorn and you reset to there being no tokens in the machine (as you were at the beginning)
5. (25 points, 5 each) Miscellaneous

You need answer only 5 of these 7 questions!! If you do more, please indicate which should be graded.

(a) If you wanted to store the userid (no more than 8 characters), social security number, class year and date of birth (mm/dd/yyyy) all as characters for every undergraduate Princeton student, how much memory would you need? You can assume that an individual’s information would be stored as a character strings with no effort to simplify. For example the social security number should be taken as a string of 9 characters (rather than as a 9 digit number that could be otherwise simplified). Explain your answer.

(b) State Moore’s Law. If Moore’s Law continues to hold for the next 12 years, how different will my current machine (which has 16GB of RAM and 1 TB of disk) be at the end of 12 years?
(c) For the function \((\text{NOT} \ (A \text{ OR } B) \text{ AND} \ (\text{NOT}) \ C)\)

(i) Draw the circuit (in terms of basic AND, OR and NOT gates) that represents this function

(ii) Give a truth table for the function

(iii) Find a simpler expression for the function
(d) A car odometer with 6 decimal digits rolls over to zero after 999,999 miles. Suppose that the odometer in a car works in binary, not decimal.

(i) If the odometer is 12 binary digits long, what binary value does it show just before it rolls over to zero?

(ii) What is that value expressed in decimal?

(iii) What is that value expressed in hexadecimal.

(e) Convert the numbers 127, 310, 7835 to hexadecimal, then add them as hexadecimal numbers and convert the sum to decimal to check your result. DO not use a calculator for this problem and show all work.
(f) I am looking at 3 algorithms. Algorithm A runs in linear time and performs 100 operations on an input of size 10. Algorithm B runs in quadratic time and performs 10 operations on an input of size 10. Algorithm C runs in cubic time and performs 1 operation on an input of size 10.

(i) As the input size grows, will there come a time when algorithm A requires fewer operations than algorithm B? If so, what is that input size?

(ii) As the input size grows, will there come a time when algorithm A requires fewer operations than algorithm C? If so, what is that input size?

(iii) As the input size grows, will there come a time when algorithm B requires fewer operations than algorithm C? If so, what is that input size?

(h) The picture on the left is a close-up of a seriously geeky t-shirt from Thinkgeek.com. **Exactly** what does it say?