

COS 109 Midterm Exam, Fall 2022

Due 5:00 PM, Friday, October 14

DO NOT OPEN THIS EXAM UNTIL YOU ARE READY TO TAKE IT

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).

Procedure

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This is a 90-minute exam that you must complete in a single 90-minute period any time before it is due. Set aside a comfortable time when you will be awake, where you will not be disturbed, and where you have all your course material at hand. Then open the exam and do it.

After 90 minutes, close it and turn it in as soon as possible. Make sure that all pages are firmly attached.

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, attach extra pages (stapled) and make sure your name is on any extra pages you submit. Please write neatly -- we can't grade it if we can't read it. 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.

Submission

Due by 5:00 PM, Friday, Oct 25, in the box outside Room 311 of the Computer Science building.

Please do not discuss the exam with anyone until after the submission deadline has passed.

10/10/2022 8:39:20 AM

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1. (20 points, 2 each) Short Answers. Circle the right answer or write it in the space provided.

(a) Suppose that a group at a (very boring) party is simulating the Towers of Hanoi algorithm with half a dozen disks, and it takes them 10 minutes to perform the moves. If they decide to play again with a dozen disks, approximately how long will it take them?

(b) While cleaning up the mess in my office, I found a shiny thing that was about 8 inches in diameter, very thin and light, and covered with a repeated pattern on one side. Sadly, it was quite brittle and when I dropped it on the floor, it broke into several pieces. What was it?

(c) The ancient core memory that I passed around in class has four 64 by 64 arrays of ferrite cores. How many bytes does the core memory have?

- 64 128 256 512 1K 2K 4K 8K 16K 32K none of these**

(d) The speeds of supercomputers are measured in floating-point operations per second, or “flops.” The fastest computers listed on top500.com have now exceeded a speed of 1 exaflop. Very roughly, how much faster is this than your laptop?

- a thousand times as fast a million times as fast a billion times as fast**
a trillion times as fast a quadrillion times as fast no way to estimate

(e) If n and m are integers, how many 1 bits (i.e., bits that have the value 1) are there in the binary representation of the number $4^n / 2^m$?

(f) If on my laptop I start a big program like a browser that I haven't used recently, it takes about 10 seconds before it's ready to use. If I then quit the program and 15 seconds later restart it, the startup is much faster. **In a word or two**, what explains this behavior?

(g) If you wanted to do the most damage to the world's production of integrated circuit chips, what country would you attack?

(h) Suppose we choose the next American president as the winner of a tournament with everyone in the country participating. Two people flip a coin. If it's heads, the first person advances to the next round and if it's tails the second person advances; the loser is eliminated. (An odd person out gets a bye to the next round.) We do this for everyone in the country. About how many rounds would it take to determine the ultimate winner? [Food for thought: would this be worse than the current scheme?]

(i) Suppose that I have an old program, written in a long-obsolete assembly language, that originally ran on a computer that no longer exists anywhere. Which of these software components would I need so I could run the old program on a current computer?

assembler	compiler	simulator	assembler + compiler
assembler + simulator		compiler + simulator	all three

(j) If I want to store the contents of all of the SSDs in the laptops of all current Princeton undergrads, which of these is the smallest that would certainly be big enough to hold it all?

1 GB **1 TB** **1 PB** **1 EB** **1 ZB** **1 YB** **none of these**

2. (15 points) Playing with Toys

Here is a short program in assembly language for the toy computer used in class, with reminders about what the instructions do:

```

Foo  GET           get a number from keyboard into accumulator
     IFZERO Bar   if accumulator is zero, go to location Bar
     IFPOS  Foo   if accumulator is >= zero, go to location Foo
     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 location Foo
Bar  LOAD   Sum
     PRINT
     STOP
Sum  0       reserve a memory location called Sum, and set its initial value to 0

```

(a) If you run this program and give it the sequence of inputs **6 5 -3 2 1 -4 7 0** what number(s) does it print?

(b) *Very briefly*, summarize what it does. Do not just repeat the instructions in words.

(c) Which of these expressions best describes how the running time of this program depends on **N**, the number of input numbers?

log N **N** **N log N** **N²** **2^N** **independent of N**

(d) The line “**Sum 0**” could be moved to one other place in this program and the program would behave identically. Where is that place?

(e) In a 2007 lecture in McCosh 50, George Dyson (author of *Turing’s Cathedral*) quoted von Neumann as saying “Words coding the orders are encoded in the memory just like numbers.” Our Toy machine has 10 “orders.” If they are encoded in the memory just like numbers, how many bits are needed to encode an instruction?

(f) How many *additional* instructions could be added to the Toy’s repertoire before another bit is needed in the encoding?

3. (55 points, 5 each) Miscellaneous

- (a) Suppose that Annual Giving wants to store certain information about alumni donors in *as few bits as possible*. They plan to encode your graduation year (four digits, like 2022), your major (one of 30 departments), and your potential as a donor (in one of eight categories). How many bits will this require per alum?
- (b) This course has lots of big numbers and lots of little ones.
- (i) How many nanoseconds are there in an exasecond?
 - (ii) What power of 2 does this number most closely correspond to?
- (c) It is sometimes said that the amount of electrical power needed to perform a computing task falls by half every one and a half years, because newer equipment uses less power to accomplish the same task.
- (i) What is the monthly percentage of reduction in the rate of power consumption, assuming a uniform exponential rate of decrease?
 - (ii) If a supercomputer uses 10 megawatts for a particular computation today, how many years from now would improved hardware require 10 watts for the same task? (This is pretty improbable, of course.)

(d) A specific byte in the RAM of a computer contains the hexadecimal value **0A**. Clearly mark each of the following that this single byte could possibly represent.

The letter A in ASCII	could represent	could not represent
Part of an instruction in the Chrome browser	could represent	could not represent
A cuneiform character in Unicode	could represent	could not represent
The integer value 10	could represent	could not represent
Part of Allegri's <i>Miserere</i> in WAV format	could represent	could not represent

(e) 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 in decimal.

(i) If the odometer is 10 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?

(f) Suppose that we were to pack Aaron Burr 219 full of laptops, from floor to ceiling. Ignoring chairs, desks, power, wiring, heat dissipation, physical access, the irregular shape of the room, etc., estimate **very roughly** how many laptops would fit. You must base your answer on sound estimates and quantitative reasoning. Be brief but clear about your assumptions and computations.

(g) Some binary arithmetic:

(i) Add these two binary numbers:

$$\begin{array}{r} 110101.01101 \\ 1010.00011 \\ \hline \end{array}$$

(ii) Suppose you are adding two n -bit binary numbers by hand. Which of these expressions best describes how the amount of work you have to do depends on n , the length of each number?

- $\log n$ n $n \log n$ n^2 2^n doesn't depend on n

(h) A US social security number occupies 9 bytes when stored as ASCII digits.

(i) How many bytes does it occupy if stored as a binary number?

(ii) Eventually the USA will run out of 9-digit social security numbers. If SSNs used 9 hexadecimal digits instead of decimal, how many hexadecimal social security numbers could there be? Express your answer as a power of two.

(i) Quickies:

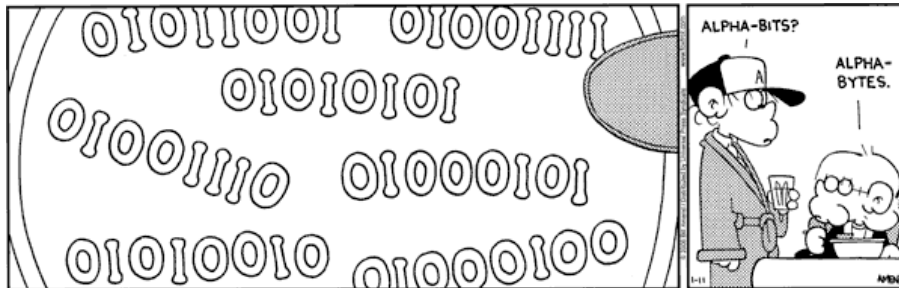
- | | | |
|---|-------------|--------------|
| Ada Lovelace and Alan Turing never met | true | false |
| John von Neumann is buried on the grounds of the Institute for Advanced Study | true | false |
| Bill Gates and Paul Allen got their start by writing a Basic interpreter | true | false |
| Tony Hoare was knighted for creating the first practical Turing Machine | true | false |
| “Tap and go” credit cards are powered by a tiny embedded battery | true | false |

(j) “A common grayness silvers everything” (*Andrea del Sarto*, by Robert Browning). The color “gray” describes any color that has equal amounts of red, green and blue.

(i) In the standard 3-byte representation of RGB colors, how many different shades of gray are there? (Hint: it’s not 50.)

(ii) There are two shades of gray that could be called “medium” gray because they are at the middle of the range of shades. Write out both of these colors in hexadecimal.

(k) **Exactly** what do the alphabites in Jason’s cereal bowl say? Write your answer clearly and **unambiguously**.



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2	SPC	!	"	#	\$	%	&	'	()	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{		}	~	DEL