

COS 109 Midterm Exam, Fall 2018

Due 4:00 PM, Friday, October 26

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 a 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, use the back or 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.

	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

Submission

(in case you need it:)

Due by 4:00 PM, Friday, Oct 26, 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.

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

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

(a) A 7-digit phone number like 5551212 requires 7 bytes if stored as ASCII characters. How many bits are required to store any particular 7-digit number if it is represented as a binary number?

(b) In Unicode, the Coptic alphabet goes from **2C80** to **2CFF**. How many characters are there in Coptic?

(c) In 1946, John von Neumann said “We are therefore forced to recognize the possibility of constructing a hierarchy of _____, each of which has greater capacity than the preceding but which is less quickly accessible.” Which of the following is the proper word to fill in the blank?

accumulators controls instructions memories orders organs processors

(d) The cartoon xkcd.com/1105 shows a geekly criminal with the license plate **111-1111**. His theory is that no one will be able to correctly record his plate number because of potential confusions between **1** and **I**. How many such plates are possible?

(e) If **n** is an integer, how many 1 bits (i.e., bits that have the value 1) are there in the binary representation of the number **$2^n \times 2^n$** ?

1 2 n 2n 2×2^n 2^{2n} 4^{2n}

(f) If a 6-inch integrated circuit wafer like the ones passed around in class has 200 chips, about how many of the same chips would there be on a 12-inch wafer?

(g) On 11/28/05 the NY Times profiled Kazushige Goto [sic], a programmer who hand-crafts mathematical function libraries for scientific computation; his “special skill was in the step-by-step reordering of software instructions to take the greatest advantage of the performance trade-offs offered by each type of [CPU] chip.” Which one of these programming tools is Mr. Goto in effect replacing?

assembler compiler debugger editor interpreter simulator

(h) Suppose a RAM package (like those passed around in class, and analogous to the one pictured here) has 8 chips on each side and each chip contains 2 G bits. What’s the total capacity of the package in gigabytes?



(i) We used a divide and conquer algorithm to quickly and efficiently count the number of people in Lewis Library 138 one day. Suppose we want to use the same algorithm to count larger crowds. If it takes 10 minutes to count 1,000 people, about how many minutes would it likely take to use the same algorithm to count a crowd of 1,000,000 people? (This is a question about algorithm complexity, not practicality.)

10 20 100 1,000 2,000 10,000 1,000,000 2,000,000

(j) Alice says “I’ve designed a brand new low-power CPU; its instruction set is specifically for cellphones. After I write the assembler for it, no one has to do anything else; people can write C programs for it right away.” Bob says “Nonsense. Someone still has to create a C compiler for it.” Carol says “You’re both wrong. Alice can just use the C compiler that she already uses to compile programs for her Mac.” Who’s right?

Alice Bob Carol none of them

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 value is zero, go to instruction BAR)
      IFPOS BAZ   (if accumulator value is >= 0, go to instruction BAZ)
      GOTO FOO    (go to instruction FOO)
BAZ  PRINT        (print value in accumulator)
      IFPOS FOO   (if accumulator value is >= 0, go to instruction FOO)
BAR  PRINT
      STOP
    
```

- (a) If you run this program and give it the sequence of input numbers **3 1 -4 -7 5 9 -2 -6 8 0**, *exactly* what number or numbers does it print, if any?

- (b) Which of these expressions best describes how the running time of the algorithm performed by this program varies as a function of or in proportion to N , the number of input numbers?

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

- (c) The computer described in Von Neumann's 1946 paper includes an instruction that shifts the bits in the accumulator *to the left* by one position, replacing the vacated position on the right end by a 0 bit. What arithmetic operation does this shift perform on the binary number in the accumulator?

- (d) If the instruction instead shifts the bits in the accumulator *to the right* by one position, discarding the rightmost bit and replacing the vacated position on the left end by a 0 bit, what arithmetic operation does this shift perform on the number in the accumulator?

3. (55 points, 5 each) Miscellaneous

(a) The familiar multiplication table for decimal numbers has exactly 100 entries.

(i) Write out the analogous multiplication table for binary numbers.

(ii) How many entries would there be in an analogous hexadecimal multiplication table? Do not write it out!

(b) The Census Bureau publishes lists of the most popular male and female given names, sorted by frequency so the most popular names are at the top. Suppose that there are n names on each list.

(i) Describe an *efficient* algorithm for finding all names, like Alex or Chris, that appear on both lists. Your description should be brief (10-15 words is enough) but very clear about the basic approach or idea.

(ii) How does the running time of your algorithm depend on n , the number of names on each list?

(c) Name 5 different kinds of transducers that one might find on a modern smartphone.

(d) The display of a really old cell phone represents colors with an RGB model that uses 3 bits for red, 3 bits for green, and 2 for blue; this fits nicely in one byte.

(i) How many different colors can the phone display?

(ii) Assuming that the bits are stored left to right in RGB order, what are the hexadecimal representations of **red**, **green**, **blue** and **yellow** (red + green)?

(e) A hard disk like the ones passed around in class spins at a rotational speed of 5,400 revolutions per minute.

(i) Assuming that the number of bits per square centimeter is uniform across the whole disk surface, where should the blocks of a file be located so their contents can be read as rapidly as possible?

near inner edge

uniformly across whole surface

near outer edge

location doesn't affect reading speed

(ii) If the rotational speed is increased to 7,200 rpm, by what factor does this increase the rate at which bits go past the read heads?

(f) A pixel is a picture element and a voxel is a volume element. Suppose you wanted to attach tiny probes all over your body to serve as “touchels”, that is, units of touch. (Whether these might be used for sensing or stimulation we will leave to your imagination.) If each touchel is 0.1 inch by 0.1 inch, estimate **very roughly** how many touchels there would be on your body. You can use metric units if you prefer; if so, assume that touchels are 1 mm by 1 mm. You must reason quantitatively.

- (g) The book *The Zero Marginal Cost Society* says that in 2007 there were 10 million sensors connected to the Internet, and that there will be 10 trillion sensors in 2027. (The numbers have been somewhat simplified.)
- (i) If this growth is a smooth exponential process, how long does it take for the number of sensors to double?

(ii) What is the rate of growth *per month* of the number of sensors?

(h) Quickies (1 or 2 word answers):

It's possible to write a C compiler in C. True or false? _____

I could run Linux in a virtual machine on a Mac. True or false? _____

What fast algorithm helped earn its inventor a knighthood and a Turing award? _____

"Bell Labs operating system, 4 letters" (crossword puzzle clue) _____

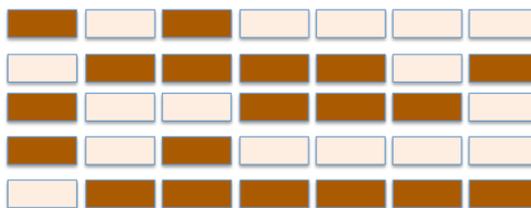
A prox card gets its power from radio waves. True or false? _____

(i) "One if by land, and two if by sea." Suppose that some modern-day Paul Revere wants to send more extensive information about an invading force. He wants to encode these three items in as few total bits as possible:

- whether the force is coming by land, sea or air
- the approximate size of the force to the nearest 1,000, with a maximum of 15,000
- what time of day or night the force set off, to the nearest hour.

How many total bits does Paul need to use, and why?

- (j) The picture on the left shows a pattern of protruding bricks on the wall of a campus building. I've drawn it more clearly on the right. **Exactly** what does the pattern say?



- (k) On 12/9/09, the *Wall Street Journal* said that the Nook e-book reader has 2 GB of memory, “enough to hold about 1,500 digital books.” On 12/10/09, the *New York Times* said that a zettabyte “is equivalent to 100 billion copies of all the books in the Library of Congress.” Assuming that these two statements are correct, compute **very roughly** how many books there must be in the Library of Congress.