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). No Internet connections.

Procedure

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 -- I can't grade it if I can't read it. It's quite alright to be brief as long as you're clear. I 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 15, 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.

ASCII table in case you need it:

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

(a) A 5-digit ZIP code like 08540 occupies 5 bytes if stored as ASCII characters. How many bytes are required to store any particular ZIP code if it is stored as a binary number?

(b) If I were to View the Source for a typical web page, which of these would I likely find there? Circle all that are likely.

- assembly language
- C++
- HTML
- Java
- JavaScript
- Python

(c) In Unicode, the the first character of the Cherokee alphabet is hex \texttt{13A0} and the last is hex \texttt{13FF}. How many Unicode characters are there in Cherokee?

(d) If you scroll a Google map by moving the mouse while holding the button down, the display reveals new map information in the direction you are moving, while old information disappears in the other direction. What basic computing technique is Google using to make this display work responsively almost all the time? A word or two is sufficient.

(e) If \(i\), \(j\) and \(k\) are integers, how many 1 bits (i.e., bits that have the value 1) are there in the binary representation of the number \(2^i \times 2^j \times 2^k\)?

\begin{tabular}{ccccccc}
1 & 2 & 3 & 8 & \(i + j + k\) & \(i \times j \times k\) & no way to tell \\
\end{tabular}
(f) If a 5-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 15-inch wafer?

(g) Which of these 3 operating systems could I run simultaneously on my Mac?

- only macOS
- macOS + Windows
- macOS + Linux
- macOS + Linux + Windows

(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 256 gigabits. What is the total capacity of the package in gigabytes?

(i) In a conventional Windows or macOS file system, which of these is the most likely relationship between the number of files and the number of physical disk blocks?

- many more files than blocks
- many more blocks than files
- about the same number of files and blocks

(j) A _______________ is a program that translates a statement like “C = 2 * pi * R” into a sequence of _______________ instructions like “load 2; mul pi; mul R; store C”. What words belong in the blanks?
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 0, go to instruction BAR)
SUB 5         (subtract 5 from value in accumulator)
IFPOS FOO     (if accumulator value is >= 0, go to instruction FOO)
ADD 5         (add 5 to value in accumulator)
PRINT         (print value in accumulator)
GOTO FOO      (go to instruction FOO)
BAR STOP      (stop running)
```

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

(b) In his 1950 paper *Computing Machinery and Intelligence*, Alan Turing includes an informal description of a computer rather like our Toy machine. The paper illustrates one kind of instruction by saying “Now obey the instruction stored in position 5606, and continue from there.” What Toy instruction would Turing use to express this computation?

(c) In another paper, Turing said “We wish to be able to arrange that the sequence of orders can divide at various points, continuing in different ways according to the outcome of the calculations to date.” Name one Toy instruction that achieves this effect.

(d) Turing also said “It is much easier to work in the scale of _______ than any other, because it is so easy to produce mechanisms which have _______ positions of stability.” What number goes in the blanks?

(e) 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?

(f) 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? \textit{Do not write it out!}

(b) Suppose that the CS department wants to determine whether there is any student who is enrolled in both COS 109 and COS 126 this semester. For simplicity, assume that there are \( N \) students in each course.

(i) Describe an efficient algorithm for determining whether the same student is in both courses. Your algorithm should be \textit{as efficient as possible}, not something easily improved upon. Your description should be brief (10 to 15 words is enough) but clear about the basic approach or idea.

(ii) How does the running time of your algorithm depend on \( N \), the number of students in each course?

(c) The next names in the International System of Units (SI) series mega, giga, tera, and peta are \textit{exa}, \textit{zetta} and \textit{yotta}.

(i) What power of 2 is closest to the power of 10 that yotta represents?

(ii) How many megabytes are there in a yottabyte?
(d) Suppose we filled Friend 008 with disk drives like the ones that were passed around in class and shown in the picture here. If each drive holds 1 TB, estimate very roughly the number of petabytes that the room would hold. Ignore power, wires, seats, etc., and assume that the whole volume of the room is filled.

(e) A webpage like the one you created in Lab 2 displays a group of $N$ checkboxes for setting combinations of properties, and a group of $N$ radio buttons for selecting a single property from the group.

(i) How many bits are necessary to store any specific set of choices for the checkboxes?

- $1$
- $\log N$
- $N$
- $N \log N$
- $N^2$
- $2^N$

(ii) How many bits are necessary to store a user’s specific choice among the radio buttons?

- $1$
- $\log N$
- $N$
- $N \log N$
- $N^2$
- $2^N$

(f) The display of a really old cell phone represents colors with an RGB model that uses 3 bits for red, 2 bits for green, and 3 for blue; this fits in exactly 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 magenta (red + blue)?
(g) In Click Here to Kill Everybody, Bruce Schneier says “If 100 systems are interacting with each other, that's about 5,000 interactions and 5,000 potential vulnerabilities resulting from those interactions. If 300 are all interacting with each other, that’s 45,000 interactions.”

(i) If 1,000 systems interact with each other, approximately many interactions would Schneier report?

(ii) How does the number of such interactions grow as a function of or in proportion to the number of systems?

(h) 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.

(i) If this growth is a smooth exponential process, how many years would it take for the number of sensors to double?

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

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

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

If a fullback is 1.0 in binary and a halfback is 0.1, what is a quarterback? _______________________

His picture appears on the new UK £50 note _______________________

Car manufacturers are cutting back production because of a shortage of … _______________________

Hexadecimal notation was invented by Charles Babbage: true or false? _______________________

(j) "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 100, with a maximum of 1500
- 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?

(k) *Exactly* has Jason said in this cartoon?