Please PRINT your name here

Honor Pledge: “I pledge my honor that I have not violated the Honor Code during this examination.”

Please write the pledge in full and sign it:

This examination is open-book and open-note:
- you may use course materials including the text book, course PowerPoints, your own notes, corrected problem sets and solutions, lab instructions, etc.
- you may use a computer or tablet to access these course materials but not for other purposes.
- you may not use a calculator as questions requiring calculation will accept solutions that are approximations as we have done in class.

There are 180 points for the questions; use the point values for each question to allocate your time (one point per minute). There are choices in the second and third sections of the exam. No extra credit will be given for answering extra questions.

If you're writing or calculating a lot on any question, you may be off on the wrong track.

Write your answers directly on these pages; use the back if necessary. In general, be brief, but if you need more space, attach extra pages and make sure your name is on every extra page. Please write legibly — I can't grade it if I can't read it.

Good luck.
1. **(60 points, 3 each) Short Answers. Write your answer in the space provided.**

(a) What is the fetch/execute cycle and where does it arise?

(b) When people bought their kids laptops for Xmas (e.g. from BestBuy), roughly how much RAM would you expect these machines to have? How much disk would you expect them to have? What would be a reasonable speed for the CPU?

(c) What is 219 in binary? In hexadecimal?

(d) Show the truth table for a 2 input AND gate

(e) If a program runs in logarithmic time and the input size is doubled, what do you expect will happen to the running time?

(f) Give an example of a branching statement in a high level programming language.

(g) Is a device driver hardware or software? Where would we expect to find a device driver?

(h) What is the difference between the syntax and the semantics of a programming language?

(i) Briefly, why do programs get larger over time?

(j) What is open source software? Give an example of an open source program.

(k) True or False: When you turn your cell phone on, you connect to a local tower and you remain connected to that tower until you turn your phone off.

(l) Briefly explain what the difference is between a LAN and a WAN.

(m) True or False: ICANN is an American institution.

(n) Who was Ada Lovelace?

(o) What is a Caesar cipher? Give an example of a Caesar cipher applied to the text “Aaron Burr Hall”.

(p) What is the difference between AES and a public key cryptosystem?

(q) Why was the second Netflix challenge cancelled?

(r) Where do we apply Zipf’s law?

(s) Give one difference between a state machine and a Turing machine?

(t) Devices that operate at higher frequency can transmit more bits in the same amount of time. What is the downside of transmitting at higher frequency?
2. (80 points) Do 4 of the following 6 problems; each problem counts for 20 points.

(a) The following code is a function in a Javascript-like language that is supposed to sort its 2 inputs and print the result in order. Sadly, the program doesn’t always return the right answer. Fix the program by explaining what is wrong with the logic and telling how you would fix it. (This is a question about correct logic, not syntax.)

```javascript
function sort2(v1, v2) {
  largest = v1
  if (v2 > largest) {
    largest = v2
    second = largest
  }
  else
    second = v2
  print largest, second
}
```

(b) Suppose that the Toy machine is augmented with a new instruction SUBTWO that subtracts two from the value in the accumulator. Here is a small program that uses the SUBTWO instruction, with reminders about what the instructions do.

```text
GET
STORE SUM
STORE SUBTWO
STORE IFNEG END
STORE MORE
STORE LOAD N
STORE ADD SUM
STORE LOAD SUM
STORE END
STORE PRINT
STORE STOP
```

What does the program do? For each of the inputs 7, 4, -1, what is the output of the program?

(c) I am playing a card game with friends. The way the game works is that I am dealt cards from a deck such that individual cards show pictures of either kings (K) or queens (Q). The game begins with my drawing a card (either a K or a Q). The game then proceeds with my turning over cards. If I see 2 more of the card I initially drew before I see any of the other card, I win. Otherwise I lose. To clarify, if the sequence of cards is KKK or QQQ, I win. Otherwise, I lose.

(1) Design a state machine to take as input a string of K's and Q's and determine whether I win or lose.

(2) State (in words) how the machine would change if the rules were changed so that I needed to draw 3 more of the card I initially drew before seeing any of the other card. In this case, if the sequence of cards is KKKK or QQQQ, I win. Otherwise, I lose. You do not need to sketch out a state machine for this, you just need to describe what additional work would need to be done.

(d) In this problem, we consider a race between 2 processes. The first process starts at a value of 128 and grows by 6% per year. The second process starts at a value of 1 and grows at the rate of Moore’s Law (which we take to be a doubling every 18 months). At what point in the future will the two processes have the same value? (Hint: you will want to use the rule of 72 here).

(e) Estimate how many pounds of food are served to undergraduates each semester on the Princeton campus. There is no precisely correct answer to this question. Rather, you are asked to explain the assumptions you would make to provide such an estimate. Based on your assumptions, you then have to work through to get an approximate answer.
(f) In this problem, you are asked various questions about running times of algorithms. In all cases, explain how you got your answer.

(1) Charles who is a bad programmer writes a program for solving a problem that runs in quadratic time. His friend Diane writes a program that solves the same problem in linear time. They notice that when their programs run on an input size of size 10, they both complete in 1 minute. How will their running times compare when they run on an input of size 20?

(2) If an algorithm runs in linear time and takes 1 minute to complete on an input of size N, how large an input can it process in 4 minutes? Describe the characteristics of an algorithm that runs in linear time and give an example of such an algorithm.

(3) If an algorithm runs in quadratic time and takes 1 minute to complete on an input of size N, how large an input can it process in 4 minutes? Describe the characteristics of an algorithm that runs in quadratic time and give an example of such an algorithm.

(4) If an algorithm runs in exponential time and takes 1 minute to complete on an input of size N, how large an input can it process in 4 minutes? Describe the characteristics of an algorithm that runs in exponential time and give an example of such an algorithm.
3. (40 points) Do 4 of these 6 questions. Each question counts for 10 points.

(a) Alice and Bob are students in COS109 who occasionally get bored during class (hard to believe) and so want to communicate across the room to one another. Alice has a Macintosh laptop and a smart phone from the 415 (San Francisco) area code. Bob has a Windows laptop and a smart phone from the 617 (Boston) area code. Both have gmail accounts.

(1) Alice sends Bob an email from her gmail account to his. How does the message get from her to Bob? In particular, does it leave the lecture room? If so, to where does it travel? You do not need to go into network specifics, you merely have to indicate to where (either in terms of a physical location or a machine with a specific function) the message travels to along its path from Alice to Bob.

(2) Bob receives Alice's email and decides to send a text message back to her. So he turns his phone on and signals to Alice that she should do the same. (NB: cell phone systems handle connections for text messaging in the same way as they handle connections for phone calls). What communications have to take place for his text message to get to Alice? Which of these communications are done over wired lines and which are done wirelessly?

(b) My wife and I are planning a trip to Timbuktu over semester break. Our trip requires a flight on FlyByNightAirlines. When I first went to FlyByNightAirlines.com to check on flights, I was quoted a fare of $250 which seems too high because the seating chart indicates that the flights have numerous free seats. So, I decided to check back every day to see if the fare would drop. I checked back daily for a few weeks and the fare was unchanged. Then, one day, I checked on my wife's computer (she had never visited the FlyByNightAirlines.com site) and was offered a fare of $200. But, when I rechecked on my computer, the fare was still $250. Be as specific as possible in answering the following questions

(1) How did FlyByNightAirlines know that I was a persistent visitor and my wife was a newcomer?

(2) After purchasing the ticket, my wife goes on Facebook and receives ads for hotels in Timbuktu. How does Facebook know to provide such ads?

(c) In this problem, you are asked to supply various details of how the internet works.

(1) To begin, briefly define the following terms

   (a) Peering points
   (b) Root servers
   (c) TCP/IP
   (d) ICANN

(2) How many root servers are there?

(3) Why are we not concerned about terrorists can take down all of the root servers since there are not so many?

(d) Explain what steganography is and how it works. In particular tell what I would use steganography for and how I would do so.

(e) When you did labs in which you developed html and other files, you could check your work and see the results of your work on your laptop. However, the TAs could not see the results of your work unless you did something else. What did you have to do to make your work visible to the TAs? Why was this necessary? Be specific about what you had to do and how inclusive the operation had to be.

(f) I have created this file called test.html to explore some of the properties of Javascript. The file is as follows

```html
<html>
<title>test</title>
<body>
<script>
  var a,b
  a = '5' + 3 - 3
  b = '5' - 3 + 3
  alert(a)
</script>
</body>
</html>
```
alert(b)

</script>
</body>
</html>

Curiously, when I run the program, the first alert returns the value 50 and the second returns the value 5. Why is this?