CIS MASTERS COMPREHENSIVE EXAM – FALL 2016

ANSWER EACH PART OF THE EXAM IN A SEPARATE TEST BOOKLET.

IF YOU DO NOT, YOU MAY LOSE PARTIAL CREDIT.

You must answer 3 PARTS of the exam

Be sure to indicate on the outside of each test booklet which part is being answered. On some exams, you must answer each question; on some exams there is a choice. Within each particular question, there may be further choices as well.

ONCE AGAIN BE SURE TO ANSWER EACH PART IN A SEPARATE BOOK.
BE SURE TO PUT YOUR NAME ON EACH BOOKLET.

PART 1 { } Analysis of Algorithms **(MA STUDENTS MUST TAKE THIS EXAM)**

PART 2 { } Architecture

PART 3 { } Artificial Intelligence

PART 4 { } Compilers

PART 5 { } Database

PART 6 { } Management Information Systems **(MS STUDENTS MUST TAKE THIS EXAM)**

PART 7 { } Operating Systems

PART 8 { } Telecommunications and Networking

PART 9 { } Theoretical

DO NOT LEAVE THE ROOM WITH ANY PORTION OF THE EXAMINATION.
IF PART OF THE EXAM IS MISSING, YOU WILL FAIL THE EXAM.

DO NOT CALL THE CIS DEPARTMENT FOR YOUR GRADE. IT WILL BE MAILED TO YOU.

GOOD LUCK!!!

Analysis of Algorithms - Fall 2016

Do any (4) out of the following (5) problems

1. Prove by induction:

$$\sum_{i=1}^{n} i^3 = \left(\frac{n(n+1)}{2}\right)^2$$

2. For each of the following questions, give an example of a function that satisfies the criteria, or state that none exist. There is no need to justify your answers.

   (a) A function that is $O(\log n)$.

   (b) A function that is both $\Omega(n \log n)$ and $O(n^2)$.

   (c) A function that is both $O(2^n)$ and $\Omega(3^n)$.

   (d) A function that is $O(n)$ but not $\Theta(n)$.

3. Let $A = A[1] < A[2] < \cdots A[n]$ be a sorted array of n distinct integers. Describe a $\theta(\log n)$ algorithm that determines if there exists an index $1 \leq i \leq n$ such that $A[i] = i$. If such an index exists, the algorithm should return it. If not, it should return the number -1.

   What is the time complexity of your algorithm as a function of n?

   You will earn a partial credit for a correct but non-efficient algorithm.

4. The *reverse* of a directed graph $G = (V, E)$ is another directed graph, $G^R = (V, E^R)$ where $E^R = \{(v \to u) | (u \to v) \in E\}$. That is, the set of vertices is the same but the edges are reversed.

   Describe an efficient algorithm that, given a representation of G with adjacency lists, outputs the adjacency list representation of G^R. Your algorithm should run in time linear of n and m, where n denotes the number of vertices and m denotes the number of edges. Be precise in your answer.

5. (a) Circle all that we know to be true about the Traveling Salesman problem.

   in P in NP NP-complete

   (b) Suppose that someone give you a polynomial-time (correct) algorithm for the SAT problem. What do we now know about the Traveling Salesman problem? Circle all that apply.

   in P in NP NP-complete

   (c) Suppose that (instead) someone gives you a polynomial-time (correct) algorithm for the Minimum Spanning Tree problem. What do we now know about the Traveling Salesman problem? Circle all that apply.

   in P in NP NP-complete

   Justify your answers.

Computer Architecture Comprehensive Exam
Fall 2016

Answer 3 of the 4 questions.
Show all your work. State any assumptions you make.
Explain your answers.
The questions are weighted equally
(33 points each plus 1 point for submitting the exam)
Within a question, sub-questions are weighted equally.

1. Assume the following floating point representation using a 14-bit format. There are 5 bits for the exponent with a bias of 16. A normalized mantissa of 8 bits, and a single sign bit for the number.
   a. Show the representation of the number 100.0.
   b. Show the representation of the number 0.25.
2. Suppose a computer using direct mapped cache has 2^{20} words of main memory and a cache of 32 blocks, where each cahce block contains 16 words.
   a. How many blocks of main memory are there?
   b. What is the format of a memory address as seen by the cache, that is what are the sizes of the tag, block, and word fields?
   c. To which cache block will the memory reference $0DB63_{16}$ map?
3. Explain why exceptions and interrupts are difficult to handle in a pipelined processor.
4. In many computers the cache block size is in the range of 32 to 128 bytes. What would be the main advantages and disadvantages of making the size of the cache blocks larger or smaller within this range?

Artificial Intelligence
Comprehensive Exam – Fall 2016

Please answer **three** of the following five questions
to the best of your ability

1. Use resolution in the propositional logic to prove the following argument is valid. Explain your work.

$$\begin{array}{l} p \vee q \\ p \Rightarrow r \\ q \Rightarrow \neg s \\ s \\ \hline \therefore \ \neg q \end{array}$$

2. Fuzzy logic.
   a) Draw a membership function for the set of tall people
   b) On the same diagram, draw the membership function for very tall people
   c) Also on the same diagram, draw the membership function for the set of people who are **not** tall.

   d) Classify a person who is 6 feet tall in each of the previous three sets

3. You are given the following production system

   1. $Y \wedge D \rightarrow Z$
   2. $X \wedge B \wedge E \rightarrow Y$
   3. $A \rightarrow X$
   4. $C \rightarrow L$
   5. $L \wedge M \rightarrow N$

   The initial contents of working memory is $\{A, B, C, D, E\}$ and the goal is Z . When there are conflicts, the lowest numbered rule should fire.

   Apply a) forward chaining (data-driven) and b) Backward chaining (goal-driven) to this system

   a) Forward chaining

   b) Backward chaining

4. You are given two biased coins that are indistinguishable from one another. Coin 1 is biased so that heads has a probability of 1/3 and coin 2 is biased so that heads has a probability of 2/3.

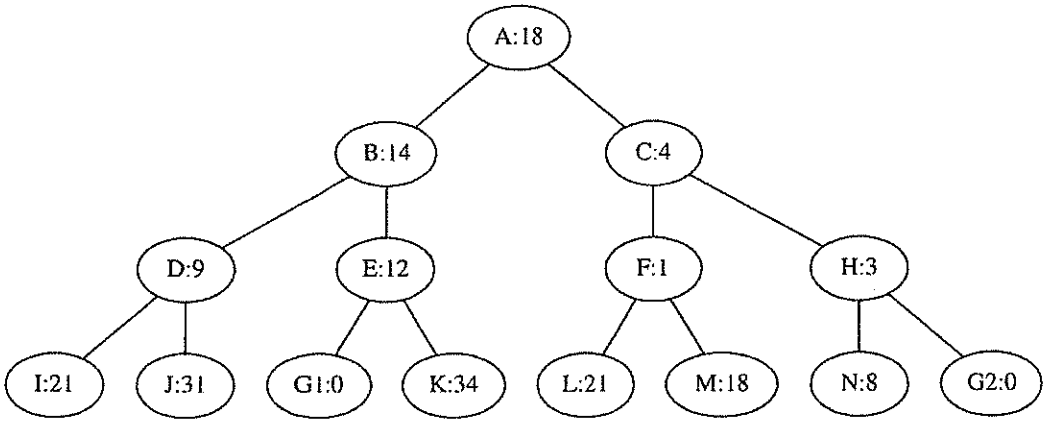
   a) You choose one of the coins uniformly at random and flip it once. What is the probability that it will come up heads? Show your work.

   b) It does come up heads. What is the probability that you have selected coin 2, which has a probability of heads of 2/3? Show your work.

   c) You flip the same coin again. What is the probability that it comes up heads again? Show your work.

5. Best first search.
   a) Describe the best first search in a paragraph or so.

   b) Perform a best first search on the following tree to reach a path to either G1 or G2. Show the contents of the Open and Closed lists after each step.



   c) Is best first search i) Complete ii) Optimal? Explain your answers.

CIS Comprehensive Examination in Compilers
Fall 2016

Answer 3 of the following 4 questions.

1. A floating point constant is defined as having an optional sign, followed by one or more decimal digits, followed by an optional fractional part, followed by an optional exponent. A fractional part consists of a decimal point followed by 0 or more digits. An exponent consists of an 'E' or 'e' followed by an optional sign followed by 1 or more decimal digits.

   a. Write a regular expression for a floating point constant.

   b. Produce a deterministic finite automata that recognizes floating point constants.

2. a. Construct an SLR parsing table for the following grammar:

```
S ::= A S | c
A ::= a A | b
```

   b. Parse the string **abc** showing each successive snapshot during the parse.

3. Given the following grammar:

```
S ::= Q q | R s
Q ::= p Q | ε
R ::= r R | ε
```

   a. Construct the FIRST and FOLLOW sets for this grammar.

   b. Use the information derived in *part a* to create an LL(1) parsing table for the grammar.

   c. Use the table of *part b* to parse the string ppq

4. a. Why is it impossible to use the following grammar for recursive descent parsing?

```
E ::= E a | a C q
C ::= a E E | a E C | d
```

   b. Give a modified grammar for the same language which is parseable using recursive descent.

DATABASE COMPREHENSIVE EXAM Fall 2016

Answer all three parts. In Parts I and II, you must do all questions. In Part III, you have a choice.

Part I (45 pts) You must answer all of the following questions

1. You want to have a table called **J** (for JellyBeans) with fields for the name of a person, the age of the person, the name of a color, and the number of jelly beans of that color the person ate. The fields are called **P** (for the person's name), **A** (for the person's age), **C** (for the color's name), and **N** (for the number eaten). A person can eat more than one color jelly bean, and a color can be eaten by more than one person.

For each part, give one or more **SQL commands** which will:

a. create the table (include the primary key constraint)

b. insert a row saying Mary ate 15 blue jelly beans and she is 19 years old

c. find the name and age of each person who ate one or more black jelly beans but did not eat any white jelly beans, order by the name of the person

d. delete all rows containing the color red

e. add 3 to the number eaten for all rows in which the person has an age that is 30 or above

f. find the total number of jelly beans eaten of each color; give the name of the color and the total number of jelly beans of that color; order by total number

g. determine how many different colors were eaten by Melissa; print Melissa's name and the number of different colors

h. create a view consisting of all the rows in the table for which the person ate green jelly beans; print the view, ordered by the person's name and descending age.

i. using the view from step h, find how many of these rows have an age less than 15.

Assume you have a second table, called **W** (for Workers) with fields for the name of a worker (**N**) and the occupation of a worker (**O**). This table has already been created and filled with values.

Use both tables (**J** and **W**) to give SQL for the following:

j. find the name, age, and occupation of each person who ate one of more red jelly beans

k. find the name of each person who ate one or more blue jelly beans and one or more pink jelly beans, and whose occupation is lawyer or doctor

Part II (35 pts) You must answer all of the following questions

There is a single table called CANDYJOBS which has the following fields: the name of a person, the age of the person, the person's occupation, the name of a color, the number of calories in each jelly bean of that color, and the number of jelly beans of that color this person ate.

For example, there can be a row in the table which says Mary, who is 28 and a lawyer, ate 15 yellow jelly beans, and each of the yellow jelly beans has 7 calories.

The fields in table CANDYJOBS are called **P** (for the person's name), **A** (for the person's age), **O** (for the person's occupation), **CN** (for the color's name), **CL** (for the number of calories in that color), and **N** (for the number of jelly beans of that color eaten by that person). A person can eat more than one color jelly bean, and a color can be eaten by more than one person. Each person has one occupation; each color has one value for the number of calories.

a. Draw the functional dependency diagram of CANDYJOBS, or indicate a complete set of functional dependencies in some other way.

b. What is the primary key of this table?

Give a complete explanation of why that is the primary key and nothing else can be the primary key.

c. Is the table in 1NF? Give a 1-2 sentence explanation of your answer.

d. Is the table in 2NF? Give a 1-2 sentence explanation of your answer.

e. Is the table in 3NF? Give a 1-2 sentence explanation of your answer.

f. Give **two** potential problems (sometimes called update anomalies) that might result from leaving the table in the original form (from part a).

Be very specific in describing each potential problem.

g. Normalize the above table completely, showing all steps.

In your final design, be sure to show all the fields in each table and the primary key for each table.

h. Explain how your normalized table(s) solve the two problems mentioned in step f.

Part III (20 pts) Answer **four** (4) of the following **six** (6) questions

Do <u>not</u> answer all six questions. Indicate which ones you are omitting.

Your answer to each subpart of each question should be 1-2 sentences, not just a word or two (and not a complete paragraph for each subpart). You will lose points for writing too much or too little.

1. When was the relational model of databases first developed?
What is the most important characteristic of the relational model?
Why is the relational model so widely used today?

2. What is query optimization?
Who is responsible for it?
When is query optimization done?

3. You just executed a transaction which updated two records. Unfortunately, you now want to undo the effects of the transaction. What does the DBMS have to do in order to undo the effects of this transaction? (Hint: there are several cases to consider.)

4. What is the relational algebra?
What are some examples of things that can be done in the relational algebra?
Why is it important in the field of databases?

5. What is a distributed database system?
Give two possible advantages of a distributed system (as compared to what?).
Give a brief explanation for each advantage.

6. The ER model divides the world into two things.
Give the names of these two things.
Give a one-two sentence explanation of each thing.

MIS Comprehensive Exam – Fall 2016

You Must Complete Both Parts A and B

A. Case Study (30%) – Troubleshooting Information Systems at the Royal Hotel – attached - Answer all three questions at the end of the case (10% each)

B. Short Answer Questions (70%) – Answer any seven of the following ten questions (10% each)

1. Why is making a lot of modifications to a packaged system sometimes a risky approach? What are the alternatives?

2. Define the four strategies for implementing a new system – Parallel, Pilot, Phasing, and Cutover – and describe a distinct advantage of each strategy.

3. Describe the similarity and the difference between the bus and the ring topology; then describe the similarity and the difference between the star and the tree topology.

4. List and define the four primary categories of actors utilized in Use Cases.

5. Explain the notion of multiplicity in UML. Describe each of the following in multiplicity notation:

    a. A person can work for one to three employers
    b. An employee has either one or no spouse
    c. A customer can make zero to many payments

6. List and define the five groups of UML diagrams.

7. According to Brooks, how should the distribution of effort for each of the primary phases (as fractions of the total) be scheduled in a software development project? How does this differ from conventional scheduling?

8. According to Brooks, are flowcharts or tables better documentation tools? Why? Does Brooks believe in democracy in software systems project management? If not, then what does he believe in?

9. Trying to decide between three alternatives, a company employed a weighted scoring model.

Three criteria were chosen. Criterion A was believed to be the most important and so was given a weight of 50%. The other two criteria, B and C, were deemed to be equal to each other in importance.

A relative scoring range of 0 to 10 was used. The table below shows each alternative and their scores.

Criteria	Alternative 1	Alternative 2	Alternative 3
A	5	6	7
B	8	7	7
C	8	8	5

Which alternative should the company choose? Show how you determined your answer.

10. The Scott Corey accounting firm is installing a new computer system. The following table provides information about the tasks that must be completed for successful implementation.

Task	Immediate Predecessor(s)	Time (weeks)
A		3
B		4
C	A	6
D	B	2
E	A	5
F	C	2
G	D, E	4
H	F, G	5

How long will it take to install the system? What is (are) the critical path(s)? Show how you determined your answers.

CASE STUDY: TROUBLESHOOTING INFORMATION SYSTEMS AT THE ROYAL HOTEL

INTRODUCTION

In early May 2006, after his first year in the master's program at the Very Famous University (VFU), Blake Cantera landed a summer internship with Fancy Consultants & Company (FC). Upon receiving FC's call, Blake was thrilled. FC was a highly regarded local IT consulting firm serving the needs of clients ranging from independent midsized hotels to large multinational grocery chains.

While small and nimble, FC afforded the opportunity to work with large clients on cutting-edge projects. It also offered significant potential for personal growth and, with

CASE STUDY (*continued*)

its flat organizational structure, FC prided itself on picking independent and self-reliant young consultants who'd work immediately on projects rather than toil in the "analysts limbo" for years. This was the most appealing aspect of FC for Blake, who knew that he would be able to do some real work over the summer.

After a brief introduction to FC systems and culture and a two-week orientation discussing the FC approach to consulting, Blake was assigned to his first account. As expected, this was a relatively small account. On the bright side, Blake was sent alone to manage the whole project, from start to finish. He was thrilled: July had not even started and he was already doing some real work!

THE ROYAL HOTEL

The Royal Hotel in New York City was a luxury all-suite hotel primarily serving an executive clientele visiting Manhattan on business. Typically, these business guests stayed for three to six days, during which time they used their suite as a temporary office. Thus, Royal Hotel's management had positioned the property to cater to the many needs of this busy and demanding audience. Amenities included in-suite plain paper fax, printer, and copier; three two-line telephones with voice mail and remote message alert; high-speed Internet access; and plasma TVs and entertainment centers in each of the 482 guest suites. The Royal Hotel also provided three restaurants and a coffee shop on the premises, a 24-hour business center, a fitness center, suite dining, laundry service, complimentary shoe shine, and dedicated high-speed elevators. While business fluctuated in relation to the economic cycle, the Royal welcomed over 150 thousand guest per year bringing in total revenues of upward of $30M.

This made for a fairly complex operation that needed to run smoothly and consistently. Given the high percentage of repeat guests it was important that guest rooms be spotless and consistently in working order.

THE TASK

As he arrived at the property for a one-week assignment, all expenses paid, Blake thought to himself with a smile, "I can get used to this..." But, with just enough time to take a shower, he had to get ready for a dinner meeting with the general manager (GM).

The Royal Hotel's GM was a no-nonsense, old-school hotelier with a distinctive German accent. He quickly zeroed in on the task, in response to Blake's comment about the "very good" quality of service provided by the Royal Hotel:

> Our level of service is unacceptable! We are very good by most hotels' standard, but we are not "most hotels." Our guests are extremely discerning; it is completely unacceptable to have a light bulb out in the bathroom when the guest checks in, particularly if she is a returning guest. And that's not as bad as a stain on the carpet or a clogged toilet. I had one of my best customers call down to report a clogged toilet last week; can you imagine? Unacceptable! I need you to make sure this never happens again.

As he sat listening to the GM, Blake briefly questioned the wisdom of taking on so much responsibility so quickly; he had not even finished his master's! But this was a brief moment of doubt, and he remembered one of his father's famous sayings: "Did you want the bicycle? Now you have to pedal!" Blake silently chuckled to himself and tuned back into the GM's tirades with a confident smile. He already had the answer to the problem.

THE SOLUTION

After examining the property and interviewing a number of people, including the directors of housekeeping, maintenance, and IT, Blake recommended that the Royal Hotel purchase and install M-Tech's Espresso! Rapid Response Solution (see Case Appendix for a description of the product). In his presentation to the executive team, highlighting the main advantages of the proposed information system, he mentioned the following:

- *Rapid response:* The Espresso! application enabled the use of a phone interface, allowing housekeepers to report problems with the room (e.g., light bulb out) as soon as the problem was identified rather than having to wait until the housekeeper ended the shift and verbally communicated the problem to the maintenance department.
- *Quality control:* Since the new information system allowed immediate reporting of problems, it reduced the chance of "slippage through the cracks" occurring when housekeepers at the end of the shift forgot to communicate the problem. It also eliminated the risk that maintenance would forget or claim it did not receive the request.
- *Preventive maintenance:* The maintenance department would be able to identify recurrent problems and stop them before they occurred again.
- *Reporting:* Management would be able to extract a number of extremely valuable reports from the system (see Case Appendix for details). This would allow managers to reward best performers and motivate employees.

Upon receiving the go-ahead from the executive team, Blake negotiated with the vendor for the application license, configuration and start-up costs, ongoing maintenance and support, and a week of onsite training. But as he was preparing for the upcoming roll-out and implementation, he was called to a new account. This unexpected call was

continued

bittersweet. Yes, he would not be able to see his very first project through, but the partner at FC must have noticed his performance since he was being reassigned to a project with a regional credit union in Cortland, New York. Not quite New York City, but the project was larger and more high profile. This was a good move for a summer intern!

As Blake handed the Royal Hotel project to his replacement and classmate at VFU, Jack Scarso, he was a bit nervous. Having been on a couple of teams with Jack back at school, Blake did not hold him in the highest esteem. Yet, telling himself that Jack deserved a fair shake, Blake turned over all the paperwork and his draft information system design, adding a word of caution:

> Jack, the GM is very impatient about this project. Make sure you don't let his anxiety for an operational system rush you into a half-baked design. This is a complex operation, there is a heck-of-a-lot going on here. Good luck!

SIC TRANSIT GLORIA MUNDI[9]

A month and a half had gone by since Blake left the Royal Hotel. While he heard from Jack a couple of times regarding minor questions, he assumed everything had gone well. He felt good about the quality of the material he had left with Jack, as well as the quality of the Espresso! application and the contract he had negotiated.

He had missed staying at the Royal Hotel, having traded down to a Ramada Inn across the street from the bank headquarters. But he felt good about the project as he wrapped up the documentation. A full-time offer was a sure bet!

"Here it comes," Blake smiled as he recognized the cell phone ring tone associated with his boss's personal cell phone. As he picked up, Blake quickly realized he was in for a surprise. Blake's boss sounded quite unhappy as he said.

> What happened at the Royal Hotel? I just got a call from the GM over there. He said that they did what you and Jack proposed and they wasted a bunch of money on a system nobody is using! I had my doubts about Jack, but I thought you'd have no problem with this project. You don't start school for another two weeks, right? My assistant just booked you on a flight back to NYC; you should have confirmation in your inbox.

Blake realized that this was not the time to voice his own doubts about Jack. Rather, he simply took ownership of solving the problem and began modifying his plans on the fly. Out were the pre-class barbeques and trading summer internship stories with classmates. Two weeks was probably just enough to attempt to straighten out the mess made by Jack. Blake's attempts to get in touch with Jack were futile. Jack's internship had ended and he was backpacking through the woods of Utah to, as he put it, relieve stress and recharge his batteries before school started again.

Upon returning to the Royal Hotel, Blake found that the machine running Espresso! was sitting in a corner collecting dust. It looked like it was abandoned soon after roll-out, a suspicion confirmed by the director of IT, who mentioned that the installation and training session had been smooth sailing. Employees had been very eager to learn about the system but seemed to lose that interest rapidly afterward.

The director of housekeeping and the director of maintenance did not have much to add, simply noting that employees found the old manual system to work much better for their needs. The GM, on the other hand, had much to say, his German accent more pronounced than ever. The words were still ringing in Blake's ears as he left the meeting: "I invested a lot of money in this software. You better deliver all the results you promised in your presentation."

As Blake prepared to troubleshoot this failed information system and to devise a solution to make it work, he remembered the words of his information systems professor at VFU: "Focus on the information system design, not the technology investment!" "Therein lay the solution," Blake thought with a tinge of hope.

DISCUSSION QUESTIONS

1. Despite having relatively little specific information about why the system failed, what do you think are the main reasons for such failure?
2. How could you fix these problems?
3. Reflecting on this experience, what do you think where the main mistakes, if any, that Blake made in handling the engagement?

[9] A phrase meaning "*thus passes away the glory of the world*" used to remind us that nothing is permanent and that we must stay humble. As Blake found out, so fleeting can be the fortunes of a summer internship.

CIS Master Comprehensive Exam, Operating Systems Fall 2016
Answer four (4) of the following five (5) questions.
Each question is worth 25 points

1. a) (5 pts) How does a multicore computer with shared memory differ from a distributed or a clustered system with respect to the OS? Make specific reference to the OS kernel.
   b) (5 pts) Briefly explain the difference between processes and threads.
   c) (10 pts) Threads on a single core system are often handled in user mode. Explain why this is not acceptable on a multicore computer.
   d) (5 pts) Explain at least 2 ways that the OS can handle threads on a multicore computer.

2. a) (5 pts) Implement a **mutex lock** using **TestAndSet**, i.e. write pseudocode to implement each of the functions **lock()** and **unlock()** on a boolean variable **m** (the **mutex lock**.)
   b) (5 pts) Why is **TestAndSet** necessary?
   c) (5 pts) Assuming that no task possesses the lock indefinitely, does your solution avoid starvation? Why or why not?
   d) (5 pts) How can a **semaphore** (with operations **Signal** and **Wait** or **P** and **V**) be implemented to guarantee fairness?
   e) (5 pts) When is a **spin-lock** (or **busy waiting**) acceptable?

3. a) (5 pts) Explain how a **demand paging system** works with **virtual memory**. Describe what is stored in the **page table** and how a **virtual address** gets translated into an **actual memory address**.
   b) (5 pts) If the number of **page frames** is very large this can create a problem. Explain what a **TLB** is and how it helps with this problem.
   c) (5 pts) What causes a **page fault**? What does the **operating system** do in this case?
   d) (10 pts) Briefly explain how each of the following page replacement algorithms work:
      I) **FIFO**
      II) **Clock**
      III) **NRU**

4. Consider the Dining Philosopher's problem with 4 philosophers. The philosophers are each holding a shared chopstick and the system is in deadlock.
   a) (5 pts) Draw a resource allocation graph representing the deadlock. Explain the nodes and arcs in the graph.
   b) (5 pts) Explain how this deadlock can be broken.
   c) (5 pts) Explain two ways (OS policies) that this deadlock could have been prevented: include an explanation of how each method works.
   d) (5 pts) Describe a situation in a computer system that is similar to the Dining Philosophers' problem.
   e) (5 pts) In the real world, most operating systems ignore the problem of deadlock. Why?

5. a) (5 pts) Explain seek time and rotational latency. Which can be controlled by disk scheduling algorithms, and why?
   b) (5 pts) **SSTF, C-SCAN**, and **LOOK** are three different algorithms for accessing information stored on a disk. Explain the advantages and disadvantages of each.
   c) (10 pts) For each algorithm, show the order in which each of the following disk I/O requests (listed by track number) will be handled: 29, 22, 108, 53, 16, 132, 60. Assume that the **read/write head** is currently servicing **track 56** and has recently finished servicing **track 65**, and that the tracks are numbered **1 to 150**.
   d) (5 pts) Based on your answer to part b, which of the three algorithms is best? Why?

Comprehensive Examination in Telecommunications
Fall 2016

Answer any *four* (4) of the following *five* (5) questions.

1. (a) You are sending an email to `user@brooklyn.edu`. Answer the following:
   i. When looking up `brooklyn.edu`, what is the difference between *recursive* and *iterative* queries?
   ii. What are `MX` records, and how do they differ from `A` records.
   iii. What is the *minimum* number of network round trips to send a small email message using SMTP? (include DNS lookup) Explain each step.

   (b) IP packet with a payload of 4480 octets is to be transmitted through an Ethernet with a maximum payload of 1500 octets. Show the Total Length, More Flag, and Fragment Offset values in each of the resulting fragments. Use 20 octets for IP header.

   (c) What are RAW sockets, and why is there a need for them?

2. (a) We are transmitting data at a rate of 1000 bits per second. During transmission, the noise introduces errors so that, on average, 2% of bits are received incorrectly (i.e.: a 0 as 1, or 1 as 0). What is the maximum error free capacity of this channel?

   (b) Given a channel with an intended capacity of 10 Mbps, the bandwidth of the channel is 5 MHz. Assuming white thermal noise, what signal to noise ratio is required to achieve this capacity?

   (c) The spectrum of a channel is between 5 MHz and 10 MHz, and SNR_{dB} is 8096 dB.
   i. What is the maximum error free capacity of this channel?
   ii. Assuming we can reach that capacity, how many signaling levels are required?

3. (a) Consider a baseband bus with a number of equally spaced stations with a data rate of 10 Mbps and a bus length of 2 km. What is the mean time to send a frame of 1000 bits to another station, measured from beginning of transmission to the end of reception? Assume propagation speed of 200 m/μs (meters per microsecond).

   (b) Suppose the data are stored on 32 Gig SD cards (assume exacty 32,000,000,000 bytes) that weigh 2 grams each. Suppose that a truck carries 10^3 kg of these SD cards at a speed of 100 km/h over a distance of 500 km. What is the data transmission rate in bits per second of this system? What is the latency?

   (c) Consider the use of 1000 bit frames on a 1 Mbps satellite channel with a 270 ms delay. What is the maximum link utilization for:
   i. Stop-and-wait flow control?
   ii. Continuous flow control with a window size of 7?
   iii. Continuous flow control with a window size of 127?
   iv. Continuous flow control with a window size of 255?

4. (a) Explain primary differences between Unipolar, Polar, Bipolar encoding.

   (b) Explain primary differences between NRZ and RZ. What are the benefits/trade-offs?

   (c) One positive side effect of bipolar encoding is that a bipolar violation (two consecutive + pulses or two consecutive − pulses separated by any number of zeros) indicates to the receiver that an error has occurred in transmission. Unfortunately, upon the receipt of such a violation, the receiver does not know which bit is in error (only that an error has occurred). For the received bipolar sequence: $+ - 0 + -0 - +$ which has one bipolar violation, construct two scenarios (each of which involves a different transmitted bit stream with one transmitted bit being converted via an error) that will produce this same received bit pattern.

5. For pure-ALOHA, slotted-ALOHA, CSMA/CD, CSMA/CA, and Token Ring protocols, answer the following:

   (a) When should the station access the medium?

   (b) What should be done if the medium is busy?

   (c) How should the station determine the success or failure of the transmission?

   (d) What should the station do if there's an access conflict?

Theoretical Computer Science
Fall 2016

Do any four (4) of the following six (6) Questions.

Part I: Formal Language Theory

Question I. Consider the language described by the regular expression$((a \cup b)^*b)^*$.
a) (12 points.) Give a non-deterministic finite automaton that recognizes this language.

b) (13 points.) Give a regular (linear) grammar that generates this language.

Question II. (25 points.) Consider the operation that takes two languages K and L and returns the langue (K*UL)*. Show that the class of context-free languages is closed under this operation.

Part II: Computability Theory

Question III. (25 points.) Formally define a Turing machine with an infinite 2-dimensional tape. What type of moves can the Turing machine make? Show that it is equivalent to a Turing machine with an infinite 1-dimensional tape.

Question IV. (25 points.) Give a high-level description of a Turing machine that accepts words of the form $a^nb^nc^n$ for $n > 0$.

Part III: Complexity Theory

Question V. a) (15 points.) Give three examples of problems in NP which are not known to be part of P.

b) (10 points.) What does it mean for one problem to be polynomial-time reducible to another problem?

Question VI. a) (15 points.) Explain why P is a subclass of PSPACE.

b) (10 points.) State Savitch's Theorem.