

CIS MASTERS COMPREHENSIVE EXAM – SPRING 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 PART of the exam (You cannot do both areas of part 6).

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.

In addition, please indicate below which parts of the exam you are answering.

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

NAME _____

PLEASE MARK YOUR CHOICES IN EACH BOX

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

PART 2 { } Compilers

PART 3 { } Operating Systems

PART 4 { } Architecture

PART 5 { } Artificial Intelligence

PART 6 { } Theoretical CS (Pick one below)

(a) { } Formal Language Theory

(b) { } Computability Theory

PART 7 { } Database

PART 8 { } Management Information Systems **(MS STUDENTS MUST TAKE THIS EXAM)**

PART 9 { } Telecommunications and Networking

**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.

ENCLOSED IS A SELF-ADDRESSED ENVELOPE. IF IT IS NOT CORRECT, PLEASE LET US KNOW.

GOOD LUCK!!!

Analysis of Algorithms - Spring 2016

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

1. Prove the following identity:

$$\sum_{i=0}^k 3^i = \frac{3^{k+1} - 1}{2}$$

2. Order the following 10 functions such that if $f(n)$ appears before $g(n)$ then $f(n) = O(g(n))$.

$$\underline{2^n} ; \underline{n} ; \underline{\log(n)} ; \underline{\log^2(n)} ; \underline{n^2} ; \underline{3^n} ; \underline{n!} ; \underline{\sqrt{n}} ; \underline{n^{100}} ; \underline{n/\log(n)}$$

3. Let $A = A[1] < A[2] < \dots < A[n]$ and $B = B[1] < B[2] < \dots < B[m]$ be two sorted arrays containing $n + m$ distinct integers. B **separates** A if for any two entries $A[i] < A[j]$ in A there exists an entry $B[k]$ in B such that $A[i] < B[k] < A[j]$.

Describe an efficient algorithm that checks if B separates A . What is the time complexity of your algorithm as a function of n and m ? Justify your answer.

4. Let G be an undirected graph with n vertices and m edges. Let C be a coloring of the vertices of G with the k colors $1, 2, \dots, k$ (if $C(v) = j$ then the color of vertex v is j). C is a **legal** coloring of G if $C(u) \neq C(v)$ for every edge (u, v) of G .

Describe an efficient algorithm that checks if a coloring C is a legal coloring. What is the time complexity of your algorithm as a function of n and m ? Justify your answer. Specify the data structure you use to represent the graph.

5. Let P and Q be two NP-Complete problems.

- (a) Is it possible to find a polynomial time algorithm for P and at the same time prove that it is *impossible* to solve Problem Q with a polynomial time algorithm? Justify your answer.
- (b) Is it possible to prove that there is no polynomial time reduction from Problem P to Problem Q or from Problem Q to Problem P ? Justify your answer.

Comprehensive Exam on Compilers

Sprint 2016

Please answer all four questions.

Question 1

Give a regular expression for each of the following languages over $\Sigma = \{0, 1\}$.

- (a) Strings with exactly three 1s.
- (b) Strings with an even number of 0s.
- (c) Strings that do not end with 01.

Question 2

Give a DFA for each of the languages in Question 1.

Question 3

Give a context-free grammar for each of the following languages over $\Sigma = \{a, b, c\}$.

- 1. $\{a^n b^{2n} : n \geq 0\}$.
- 2. Strings of a's and b's with twice as many a's as b's.
- 3. $\{a^n b^m c^k : k = n + m\}$

Question 4

Consider the following grammar.

```
E -> E or T | T
T -> T and NF | NF
NF -> not NF | F
F -> ( E ) | x
```

- 1. Construct a parse tree for the sentence:

not (x or not x) and x

- 2. Transform the grammar into one that is suitable for top-down parsing.
- 3. Sketch a recursive descent parser based on the transformed grammar.

CIS Master Comprehensive Exam, Operating Systems Spring 2016

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

Each question is worth 25 points

1. 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**
2. 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.
3. 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) Does your solution have a bounded waiting time for the lock? 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?
4. 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: 25, 22, 110, 54, 12, 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?
5. 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?

**Computer Architecture Comprehensive Exam
Spring 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 cache 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, Spring 2016

Please Answer ALL of the four of the following FIVE questions to the best of your ability. (20 pts each)

1) Methods and People -- Match the methods below with the letter of the people's names below.

1. .Futurist and Tools for the Handicapped. ____
2. Coined the term "Artificial Intelligence" and circumscription. ____
3. Test for AI, neural models, computer chess. ____
4. Knowledge Representation, "The Human Window" ____
5. Frames, Agents, Robotics, "Society of Mind." ____
6. Neural Networks ____
7. Scripts, MARGIE, SAM, PAM, Yale University ____
8. How to Solve It , Five Steps for Problem Solving ____
9. Game of Life, Cellular Automata ____
10. General Problem Solver ____

- a. Donald Michie
- b. Marvin Minsky
- c. John Hopfield
- d. Roger Schank
- e. Raymond Kurzweil
- f. John Conway
- g. Allen Newell and Herb Simon
- h. George Polya
- i. Alan Turing
- j. John McCarthy

2. Backtracking: Four Queens Problem

Starting with a Queen on the a1 square, demonstrate how the BACKTRACKING algorithm would apply to the problem.

				4
				3
				2
				1
a	b	c	d	

3. For the 3-puzzle below, demonstrate the application of the following heuristics and branch and bound algorithm with estimates to the Goal State from the Starting State.

3	1
2	

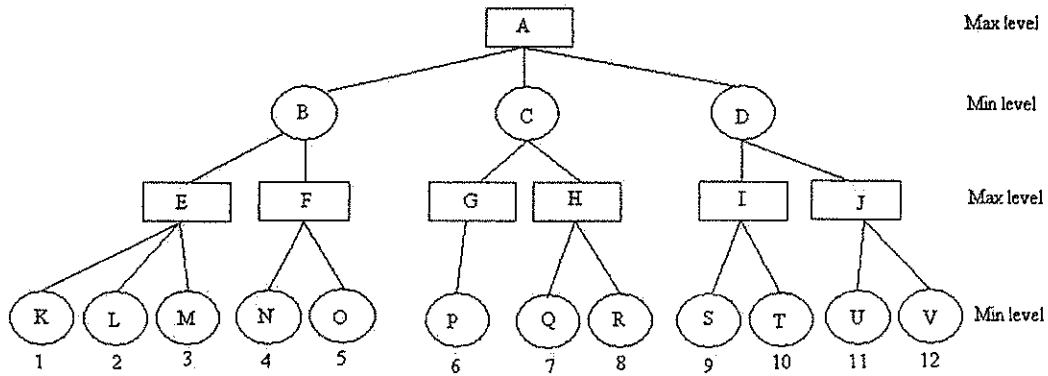
1	2
3	

 goal!

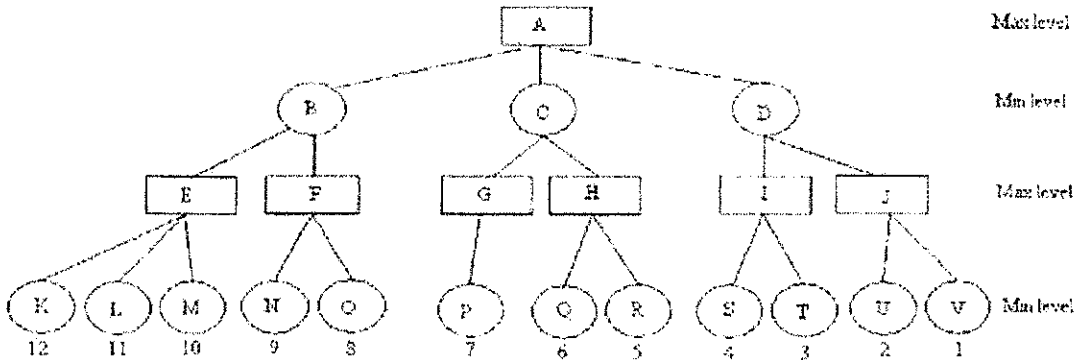
- The number of tiles out of place.
- The Manhattan Distance of each from its goal position.
- Develop and apply the combination of both heuristics to the application of the Branch and Bound Search to the problem.

4.

- a) For the tree below: Indicate what the outcome (backed up scores) of a Minimax Search with (2pts) and without the Alpha Beta algorithm (3pts) would be? Mark the cutoffs and Explain



- b) What would alpha beta cutoff for the tree below? Mark the Cutoff and Explain.



5. A new gene has been identified for people who are predisposed to being great Computer Scientists. It has been found in 0.1% of the population. A test for this gene has also been developed, which is 99% accurate at both identifying people who have the gene and at identifying people who do not. You go to the doctor to have the test performed.

- a) Write down the following probabilities based on the above problem specification:

$$p(\text{have gene}) =$$

$$p(\text{do not have gene}) =$$

$$p(\text{test positive} \mid \text{have gene}) =$$

$$p(\text{test negative} \mid \text{have gene}) =$$

$$p(\text{test positive} \mid \text{do not have gene}) =$$

$$p(\text{test negative} \mid \text{do not have gene}) =$$

- b) Your test comes back positive. Use Bayes rule to compute the probability that you have the gene given that your test result was positive. Bayes rule states that for two events, X and Y, $p(Y \mid X) = p(X \mid Y) p(Y) / p(X)$.

Theoretical Computer Science
Spring 2016

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

Part I: Formal Language Theory

Question I. a) (12 points.) Give a context-free grammar that generates odd length palindromes in the alphabet $\{x,y,z\}$.

b) (13 points.) Give a pushdown automata that recognizes odd length palindromes in the alphabet $\{x,y,z\}$.

Question II. (25 points.) Prove that the class of regular languages is closed under the Kleene + operation. That is, show that if L is regular, then so is L^+ .

Part II: Computability Theory

Question III. (25 points.) Prove that Turing Recognizable languages are not closed under complement.

Question IV. (25 points.) Describe a Turing machine that accepts exactly those words that are of the form $a^n b^m c^n$ where m, n are non-negative integers. Assume that the alphabet is $\{a,b,c\}$. The description should be clear but does not have to be a listing of every move that the Turing machine should make.

Part III: Complexity Theory

Question V. a) (15 points.) Give three examples of problems in **NP**.

b) (10 points.) What is a polynomial time verifier?

Question VI. a) (15 points.) Prove that if A is polynomial time reducible to B and B is in **P**, then A is in **P**.

b) (10 points.) State the Cook-Levin Theorem.

ANSWER ALL THREE QUESTIONS.**Question I. Answer ALL parts. 35 points total.**

1. 10 points 2 points each.

You are given table $T(A,B,C,D)$. The primary key is the concatenation of A and B. The table is in 2NF but not 3NF.

For each of the 5 statements below, state whether it is True or False and explain why.

a. $C \rightarrow D$ b. $A \rightarrow C$ c. $A \rightarrow D$ d. $A \rightarrow B$ e. $C \rightarrow A$

2. 5 points

Given: $T(A,B,C,D,E,F)$ $A,B \rightarrow C$ $C \rightarrow D$ $A \rightarrow E$ $B \rightarrow F$

What is the correct decomposition into 3NF?

Be sure to show each table used and the fields within each table. Clearly indicate the primary key(s) of each table.

3. 5 points

Given: $T(A,B,C,D)$ in which $A \rightarrow B$, $A \rightarrow C$, $A \rightarrow D$, $B \rightarrow C$, and $C \rightarrow D$

What is the correct decomposition into 3NF?

Be sure to show each table used and the fields within each table. Clearly indicate the primary key(s) of each table.

4. 15 points

Each actor/actress in the actor/actress union has a unique number (example: A1234, B1235). Each movie in the movie database has a unique number (example: M08A, M08B). We want to store for each actor, their name, date of birth, sex, and amount of money earned per movie. We want to store for each movie, its title, time in minutes, rating (The possible choices for the field rating are: G,PG,PG13,R,X,NR), and the amount of money paid to each actor/actress.

Be sure to clearly define what each field refers to.

What is the correct decomposition into 3NF? Be sure to clearly indicate the primary key(s) of each table.

Comment [kh1]: fix wording You are given a table ... The primary key is the concat of ... The table is in ...

Comment [kh2]: change are to must be? or may be? or both

Comment [kh3]: save space - put these on the same line here and increase the margins elsewhere

Comment [kh4]: are these the only func dependencies?

Comment [kh5]: be sure to show each table used and the fields within each table

Comment [kh6]: say the possible choices for this field are

Comment [kh7]: variable is a funny word to use - field, attribute, column?

Question II. Answer ALL parts. 37 points total.

You are given the following tables:

HOTEL (HOTEL#, HotelName, HotelAddress, HotelCity)

ROOM (HOTEL#, ROOM#, Type, Price)

BOOKING (HOTEL#, GUEST#, FROMDATE, ROOM#)

GUEST (GUEST#, GuestName, GuestAddress, GuestCity)

Table HOTEL contains hotel details, and HOTEL# is the primary key.

ROOM contains room details for each hotel, and (HOTEL#, ROOM#) form the primary key.

BOOKING contains details for each booking, and the primary key is (HOTEL#, GUEST#, FROMDATE).

Comment [kh8]: now tables are all caps, but some fields are and some are not - this bothers me . not sure if it bothers anyone else

Comment [kh9]: I would prefer all caps for the table names, not the way you have it

GUEST contains guest details, and GUEST# is the primary key.

Write one or more SQL statements for each of the following:

- List the name and address of each guest staying in a hotel where the city is LONDON. The results should be ordered alphabetically by the name of the guest.
- What is the total number of rooms for all hotels that are located in London and for which the price is more than \$300?
- What is the total income from bookings at the PLAZA HOTEL in NEW YORK for May 5, 2016?
- For each hotel in BOOKING, give the hotel's name and the total number of rooms in that hotel.
- Add the record(s) necessary to show that Bob Jones (id# 123) living at 444 Ave B in BROOKLYN stayed in room 212 at Hotel# 17 on 4/23/2008.. Bob Jones has not yet been entered into the GUEST table..
- For any hotel in LAS VEGAS, replace the price of every room with a 10% increase if the current price is under \$500; replace it with a 3% increase if it is currently \$500 or more.
- List the name of the hotel and room number for every room that has NEVER been rented.
- List the name of the hotel and room number for the room that has been rented the largest number of times.

Comment [kh10]: new sentence The results should be ...

Comment [kh11]: What is the total number of rooms for all hotels that are located in London and for which ...

Comment [kh12]: from which table? it is easier from Booking than from Hotel

Comment [kh13]: is he a new guest or not?

Comment [kh14]: replace it by the price

Comment [kh15]: the largest number of times

QUESTION III (28 pts) Answer any four (4) parts of this question.
Each answer should be at least 2-3 sentences, not just a few words.

Comment [kh16]: cut this severely make it 4 out of 7 instead of 7 out of 11

- Assume you have two tables:

EMP (EMP#, EMPNAME, DEPT#) EMP# is the primary key

DEPT (DEPT#, DEPTNAME) DEPT# is the primary key

There are many records in EMP for each row in DEPT. At the moment, the tables enjoy referential integrity. A user deleted the record in DEPT for DEPT#12. How does this affect referential integrity? If this damages referential integrity, explain what options the DBA and the DBMS have in order to maintain referential integrity?

Comment [kh17]: are or may be?

Comment [kh18]: if you keep DEPT, then say for each row in DEPT

- User 17 is transferring \$10 from JOHN to MARY. User 17 updates JOHN's record and releases the LOCK on JOHN's record. Before updating MARY's record, user 17 decides to abort the transaction. Because user 17 released JOHN's record too early, 2 bad things could possibly happen. What are the two?
- Assume you have a log containing preimages and post-images. The DBMS crashes. The data on the hard disk is safe. What do you need to do to recover from this DBMS crash?

Comment [kh19]: replace two by a number then ask for at least two

4. Assume you have a distributed database that has some replicated data. You need to update some of the replicated data. How does the DBMS accomplish this update without creating inconsistent data?
5. How can a client-server system increase throughput? Explain what tasks are performed by the client and by the server?
6. Give an example for how deadlock can occur with 3 users?
7. User 17 is updating record 12. User 99 is updating record 13. How is it possible for user 99's update to overwrite user 17's update?
8. Assume you have a distributed database that has some non-replicated fragmented data. The data contains customer balances. You need to determine the name of customer with the largest balance. How does the DBMS accomplish this task?

Comment [kh20]: I don't get his one at all

Comment [kh21]: same here ? 3 different?

Comment [kh22]: huh????

MIS Comp Exam, Spring 2016

Answer questions 1-3 and then any 7 from 4 through 15:

Each Question is worth 10 points (partial credit is awarded)

Answer all of the following 3 questions (10 points each):

1. Given the following project data, estimate payback period and nominal cost-benefit ratio (disregarding the time value of money).

<u>Time</u>	<u>Outflow</u>	<u>Inflow</u>
Begin year 1	\$15,000	\$ 0
End year 1	10,000	12,000
End year 2	3,000	10,000
End year 3	1,000	8,000

2. Draw the PERT chart for the tasks shown on the right side. Show both the early and late start and finish times for each task.

<u>Task</u>	<u>Predecessors</u>	<u>Time</u>
A	-	3
B	-	5
C	-	7
D	A	8
E	B	5
F	C	5
G	E	4
H	F	5
I	D	6
J	G, H	4
K	I, J	1

3. Develop an activity diagram in UML which represents the process of ordering a product online, including the checkout process, etc. The ordering process should include:
- What is the product number of the item being ordered?
 - Is the product in stock?
 - How is the order verified? (Address and debit/credit card information)
 - What is the final checkout cost with Product cost, Tax, and Shipping cost.

Answer any 7 of the following 12 questions (10 points each):

4. Critique the following analysis (include specific examples in your critique): It would cost us \$800,000 to build this system, but we can purchase an equivalent package for \$125,000. Therefore, we can save the organization \$675,000 by purchasing the software package.
5. Define and describe the differences between CPM, Gantt charts, and PERT. Give one disadvantage of each model.
6. Contrast the strengths of bottom-up and top-down approaches to project budgeting.
7. Compare the Acceleration and Containment strategies for supporting user computing and provide a rationale for why a firm might choose one or the other.
8. What are the main categories of feasibility tests (texts divide them into four to six categories) and what is the criteria each of them uses to measure feasibility?
9. What are the primary differences between operational planning, tactical planning, and strategic planning?
10. What are the relative advantages and disadvantages of open-source software versus proprietary application packages?
11. What are some of the major business risks associated with user applications development?
12. Explain the meaning of "requirements" and why they are so important in the development of software. Explain the differences between Validation and Verification.
13. How has the development of UML coupled with USE CASE diagrams facilitated the process of developing requirements?
14. Explain the general message behind the Mythical Man-Month and why it is such a unique and important book.
15. Explain three distinct important ideas that you have obtained from the Mythical Man-Month.

Comprehensive Examination in Telecommunications Spring 2016

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

1.
 - (a) Suppose the data are stored on 16 Gig SD cards (assume exacty 16,000,000,000 bytes) that weigh 2 grams each. Suppose that an airliner carries 10^4 kg of these SD at a speed of 1000 km/h over a distance of 5000 km. What is the data transmission rate in bits per second of this system? What is the latency?
 - (b) Consider a baseband bus with a number of equally spaced stations with a data rate of 10 Mbps and a bus length of 1 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/ μ s (meters per microsecond).
 - (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?
2.
 - (a) You are sending an email to `user@brooklyn.cuny.edu`. Answer the following:
 - i. When looking up `brooklyn.cuny.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.
 - (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?
3.
 - (a) We are transmitting data at a rate of 1000 bits per second. During transmission, the noise introduces errors so that, on average, 5% 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 20 Mbps, the bandwidth of the channel is 3 MHz. Assuming white thermal noise, what signal to noise ratio is required to achieve this capacity?
 - (c) The spectrum of a channel is between 3 MHz and 4 MHz, and SNR_{dB} is 24 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?
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?

Computer & Information Science
Programming Languages Comprehensive
Fall 2017

PREVIOUS COMPILERS

1. (20) A rational number is a number that can be represented by a pair of integers—a numerator and a denominator. Write a class `Rational` that represents rational numbers. The class should support the following behavior:
 - A constructor that accepts a numerator and a denominator
 - A constructor that accepts a single integer representing a whole number (i.e., with a denominator of 1).
 - A default constructor that initializes the `Rational` to 1 (1/1).
 - (Java) A `toString` method that returns the string representation *num / denom*.
(C++) A `<<` operator that prints *num / denom*
 - A `multiply` method/member function that returns a new `Rational` consisting of the product of the receiver and (`Rational`) parameter.
 - An `inverse` method that returns a new `Rational` representing the inverse (reciprocal) of the receiver.
 - A `divide` method that returns the quotient of the receiver and (`Rational`) parameter. Remember --to divide two rationals, you multiply the first by the inverse of the second.
 - An `equals` method that returns whether two `Rational`s are the same. Assume $2 / 4$ is not equal to $1 / 2$ (i.e., you don't have to deal with reducing the rationals to lowest form).

2. Suppose you had the following Shape interface:

```
interface Shape {  
    int area();  
    int perimeter();           // sum of the lengths of all sides  
    int numberOfSides();  
};
```

and you wanted to code Rectangle and Square classes, both implementing Shape.

Here are some design choices.

- | | | |
|-----|--|---------------------------------|
| i | class Rectangle implements Shape
class Square implements Shape | <i>totally independent</i> |
| ii | class Rectangle implements Shape
class Square extends Rectangle | <i>Square extends Rectangle</i> |
| iii | class Square implements Shape
class Rectangle extends Square | <i>Rectangle extends Square</i> |

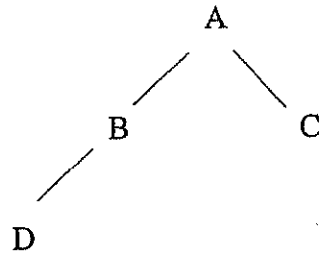
- a) Implement each of the above (i.e., for each implementation, code the Rectangle and Square classes) — try to take advantage of as much OOP as possible. If you find yourself unhappy with one or more of the implementations, all that counts is that the methods work properly
- b) Compare the implementations—which was best? worst? Justify your answers.

3.

- a. What is the difference between overloading and overriding? Give an example of each.
- b. What is the difference between an interface and a class in Java?
- c. What does overriding have to do with polymorphism?
- d. Explain how the toString method of Java is a classic example of polymorphism.
- e. Explain why C++ cannot for all practical purposes have a toString method.
- f. What are the two things required to make have a function act polymorphically in C++?

4. This question should be answered using Java.

- a. What is an upcast? What is a downcast?
- b. Given the hierarchy



Give a least two examples of an upcast and two examples of a downcast (declare/create any variables/objects you want).

- c. Are upcasts always legal? If not, under what circumstances would the upcast be legal? Illegal?
- d. Are downcasts always legal? If not, under what circumstances would the downcast be legal? Illegal?
- e. Using the above hierarchy, give an example of two classes that can NEVER be cast to each other.
- f. Explain why no cast is required when placing items into a collection object (e.g. a Vector, or Set) but a cast is usually required when removing the item in order to invoke the object's methods.