**October 25, 1999** **Fall Term, 1999**

# CSC 470F: Computer System Modelling and Analysis
# Mid-Term Test

**NAME** _____ **STUDENT #** _____

| #1 | #2 | #3 | #4 | #5 | #6 | #7 | TOTAL |
|---|---|---|---|---|---|---|---|
| /12 | /12 | /20 | /12 | /10 | /18 | /16 | /100 |

**[HINT: Try to answer all questions before spending too much time on any one.**
**Open Book; open notes; calculators allowed.]**

1. [12 marks]
A terminal type system consists of a set of terminals, a processor, and a disk. The service demands at the two centers are $D_{proc} = 4$ and $D_{disk} = 6$, and the average think time is $Z = 10$. The general form of optimistic asymptotic bounds on throughput and response time is illustrated on the axes below, in terms of six critical parameters: **A**, **B**, **C**, **D**, **E**, and **F**.

$$D_{proc} = 4 \qquad D_{disk} = 6 \qquad Z = 10$$

In the table below, give the value **(as a number or fraction)** of each of the six parameters under each of the four cases indicated.

| Case | **A** | **B** | **C** | **D** | **E** | **F** |
|---|---|---|---|---|---|---|
| Original Case (defined above) | | | | | | |
| Processor Speed Doubled ($D_{cpu} = 2$) | | | | | | |
| Add Disk and Balance ($D_{disk} = D_{disk\,2} = 3$) | | | | | | |
| Upgrade Original Disk by 50% ($D_{disk} = 4$) | | | | | | |

2. [12 marks]
Performance prediction studies can be carried out by:

- experimentation
- simulation modelling
- analytic modelling

For each of the four situations below, indicate **which** of the approaches would be the most appropriate one to use, and briefly (in a few words) indicate **why**.

(a). In designing a new client-server system to handle a database processing load, you know the characteristics of various servers, workstations, and disks that might be used in the system, and you wish to estimate how great a workload could be supported by various combinations of components.

(b). In implementing a brand new type of database application on an existing system that has two types of database systems already running on it, you wish you determine which database system to use for the new application.

(c). In the context of an organization with a complex network with many processing nodes, knowing the typical pattern of communication rates among various nodes, you wish to evaluate several possible algorithms for routing messages through the network.

(d). Given a set of files and measured access rates of how many reads and writes are done to each one, determine how they should be assigned to a set of disks *all of the same speed* with the objective of minimizing the average response time to users of the system.

3. [20 marks]
Simulation models may be:
- static or dynamic
- deterministic or stochastic

For each of the system simulation tasks described below, circle one descriptor from each pair to indicate the *most appropriate* type of simulation to use.

a. Simulation of a rocket's trajectory in space flight, knowing its initial position, its speed and acceleration, and the gravitational forces exerted upon it by nearby objects.

STATIC or DYNAMIC DETERMINISTIC or STOCHASTIC

b. Simulation of messages passing through a local area network between workstations and a server, knowing the rate at which messages are sent and the required processing times for messages at various components of the network.

STATIC or DYNAMIC DETERMINISTIC or STOCHASTIC

c. Simulation of the execution of a computer program during debugging, knowing the sequence of instructions in the program and the meaning of each one.

STATIC or DYNAMIC DETERMINISTIC or STOCHASTIC

d. Simulation of the inventory of products in a store, knowing customer purchase patterns, supplier delivery responsiveness, and appropriate order quantities for each product.

STATIC or DYNAMIC DETERMINISTIC or STOCHASTIC

e. Simulation of a gambling strategy for the game of roulette to determine the likelihood of turning an initial $100 stake into $10,000, knowing the rules of the game.

STATIC or DYNAMIC DETERMINISTIC or STOCHASTIC

4. [12 marks]
In a single-class system of terminal type, there are **10 online users**, with an average **think time of 20** seconds. At one particular **center k**, where the **service demand is 2** seconds, a **utilization of 50%** is observed, and the average **residence time is 4** seconds per customer (in all its visits). Use the fundamental laws of computer system analysis to answer the following questions **showing in each case the equations that you use**.

(a). What is the *system throughput*, $X(N)$ ?

(b). What is the average *queue length* at center $k$, $Q_k(N)$ ?

(c). What is the average *response time* of the system, $R(N)$ ?

(d). What is the average number of customers who are *thinking* at any time?

5. [10 marks]
In a system that serves both a *transaction* class and a *batch* class, the following measurements were taken over a one hour interval:

| | |
|---|---|
| Observation interval: | 3600 seconds |
| Number of transactions processed: | 600 |
| CPU service per transaction: | 3 seconds |
| CPU service per batch job: | 20 seconds |
| Total CPU utilization: | 75% |

(a). What is the CPU utilization due to the transaction class?

(b). What was the throughput of batch jobs in the one hour interval?

(c). Assuming that the transaction workload remains unchanged and that the CPU is the bottleneck center in the system, what is the greatest possible increase in batch throughput that this system can support?

6. [18 marks]

A large, complex CSim program consisting of many different processes is used to model a wide-area computer network. The network is highly complex, involving dynamic routing, priority scheduling, limited buffer sizes, etc. One process in the simulation system (the pseudo-code for which is shown below) is dedicated to evaluating the time required to send a short message from one designated site to another and receive an acknowledgement (measuring round-trip time). Examine the pseudo-code below (which is based on CSim-like operations), and then answer the questions that follow.

```
for i = 1 to N
    for j = 1 to K
        start = clock        /* keep current simulated time */
        send(dest, msg)      /* send message to fixed destination */
        wait(response_rcvd)  /* await receipt of response */
        record(clock-start, first_tbl)     /* record round-trip time */
        hold(inner_pause)    /* delay for time inner_pause */
    endfor
    record(table_mean(first_tbl), second_tbl)  /* record summary result */
    reset_table(first_tbl)   /* empty first_tbl */
    hold(outer_pause)        /* delay for time outer_pause */
endfor
M = table_mean(second_tbl)   /* extract mean of table entries */
V = table_var(second_tbl)    /* extract variance of table entries */
```

Answer the questions below using the variables $N$, $K$, $M$, $V$, and $T_\alpha$ where appropriate.

(a). What is the best estimate based on the execution of this process for the "true" mean round-trip time?

(b). Assuming that **inner_pause and outer_pause are both zero**, give expressions for the end points of the $(1-\alpha)\%$ confidence interval on the "true" mean?

(c). What method of confidence interval analysis is represented in part (b)?

(d). Assuming that **inner_pause is zero and outer_pause is very large**, give expressions for the end points of the $(1-\alpha)\%$ confidence interval on the "true" mean?

(e). What method of confidence interval analysis is approximated in part (d)?

7. [16 marks]
An image processing system consists of a processor and a memory buffer. Images arrive by a Poisson process at rate $\lambda$ (i.e., the average interarrival time is $1/\lambda$). Images are processed at rate $\mu$, and processing times are exponentially distributed (i.e., the average processing time is $1/\mu$). The memory buffer is only large enough to contain two images at once, one that is currently being processed and one more that is awaiting processing. Any images that arrive when the memory buffer is full are simply lost and are never processed (and hence they do not contribute to the system *throughput*).

(a). Draw the *state transition diagram* of this system, showing all distinguishable system states, and the rates of movement among them.

(b). Write the set of *global balance equations* sufficient to solve for $P_S$ the proportion of time spent in state $S$, for each system state $S$.

(c). Solve the set of equations in (b) for $P_0$, the proportion of time that the system is idle.

(d). Assume that $\mu = 1$ (one image per minute), and give the *system throughput* for each of the three values of $\lambda$ indicated below.

| Value of $\lambda$ | $P_0$ | $X(\lambda,\mu)$ |
|---|---|---|
| $\lambda = 0.5$ *min.* (one image per 2 minutes) | | |
| $\lambda = 1.0$ *min.* (one image per minute) | | |
| $\lambda = 2.0$ *min.* (two images per minute) | | |

(e). Briefly indicate why it is critical to the analysis done above that both processing times and interarrival times by assumed to be *exponentially* distributed.