Computer Science Department

CS-350: Fundamentals of Computing Systems

Final

Fall 2017

Name: ______________________________

Login: ____________________ BU Id: ____________________

You can use the back of any page to answer the question <u>on the front</u> of that page

Problem #1:	*/36*
Problem #2:	*/16*
Problem #3:	*/14*
Problem #4:	*/16*
Problem #5:	*/16*
Problem #6:	*/12*
Total Grade:	*/100*

Note:

- This is a closed-book/notes exam
- Basic calculators are allowed
- Time allowed is 120 minutes
- There are 110 total points
- Problems are weighted as shown
- Sub-problems are weighted as reported
- Explain your assumptions clearly

I give credit to students who can accurately assess their performance. Thus, after you finish the exam answer the following for up to five bonus points!

What do you guess your score will be? _________

Bonus = *max*(0 , 5 - | *GuessedGrade* – *ActualGrade* |)

1) Label each of the statements below with either **True** or **False**:

	Question	**Answer**
a.	In a discrete event simulator, the best way to compute the average size of queues is to sample the status of the queues at regular and deterministic time intervals.	
b.	The probability of rejection in a M/M/1/K system is always strictly greater than zero regardless of the value of K.	
c.	An average for total number of requests in a M/M/1 system can be computed as the average number of requests in the queue plus 1. Thus: .	
d.	Linearly increasing the arrival rate at a M/M/1 system can cause a more-than-linear increase in the average number of queued requests.	
e.	Assume that a confidence interval [-E, +E] on the mean of a normally distributed random variable has been derived. Then every additional experimental sample will fall within the range [-E, +E].	
f.	There exist instances of systems where Little's law applies while the Jackson's theorem does not.	
g.	A real-time task with very low utilization can be considered as an I/O bound task.	
h.	Assume that a specific real-time task-set is schedulable under algorithm A. Then no task-set can suffer starvation under A.	
i.	RM is never able to schedule a real-time task-set on single-processor if the utilization of the task-set is only slightly below 100%.	
g.	Complete Fair Queuing (CFQ) admits requests from tasks using a RR scheme. Hence, no knowledge of the disk geometry is required to implement CFQ.	
k.	At least (N+1) semaphores are required to perform N-party rendezvous.	
l.	Consider a semaphore called "mutex" and initialized to 4. The semaphore can be safely used to serialize N processes over a shared data structure.	
m.	The Banker algorithm may deem as unsafe and deny a request even if granting the request does not always lead to a deadlock.	
n.	Consider a group of processes synchronizing over a shared resource using a semaphore in a deadlock-free system. Starvation may still occur depending on the semaphore's queuing policy.	
o.	S is a single-processor system where SJN is used to schedule processes. In S, processes use semaphores to synchronize over shared resources. S is a deadlock-free system.	
p.	It is always preferable to use a semaphore to achieve mutual exclusion rather than a spinlock.	
q.	Consider a resource-to-process assignment graph. The order in which processes acquire shared resources impact the possibility of the graph to develop a loop.	
r.	In the typical implementation of a Message Queue middleware, a sender may remain blocked if the receiver is not ready to process the message being sent.	

Note: There are 18 questions. A correct answer will get you +2 points. An incorrect answer will get you -1 points. A blank answer will get you 0 points.

2) A two-tier data center is composed by 4 nodes. Node A and B compose the first tier, while Node C and D compose the second tier. Requests arrive with a rate at A. With probability a request needs pre-processing and it is sent to B. Otherwise, it is sent to C or to D directly from A with probability and respectively. Once a request has completed pre-processing at B, it will be routed to C or D with probability and respectively. The values for all the probabilities are reported in Table 1. A, B, and C are M/M/1 systems. D is a M/M/1/4 system. All the node parameters reported in Table 2.

Route	Probability
	0.6
	0.1
	0.3
	0.7
	0.3

Table 1: Routing probabilities in the two-tier data center.

Node	Service Time ( )	System Type
A	2 ms	M/M/1
B	5 ms	M/M/1
C	3 ms	M/M/1
D	8 ms	M/M/1/4

Table 2: Service time parameters for nodes A, B, C, and D.

a) **(2 points)** Compute the Utilization of Node C as a function of R.

b) **(4 points)** Assume that R = 200 req/s. What is the probability that a request will be rejected by Node D?

c) **(4 points)** What is the maximum value for the arrival rate R that the system can handle without buckling? ***Hint***: *an M/M/1/K system can never buckle.*

d) **(6 points)** With R = 200 req/s, what is the average number of requests in the system at steady state?

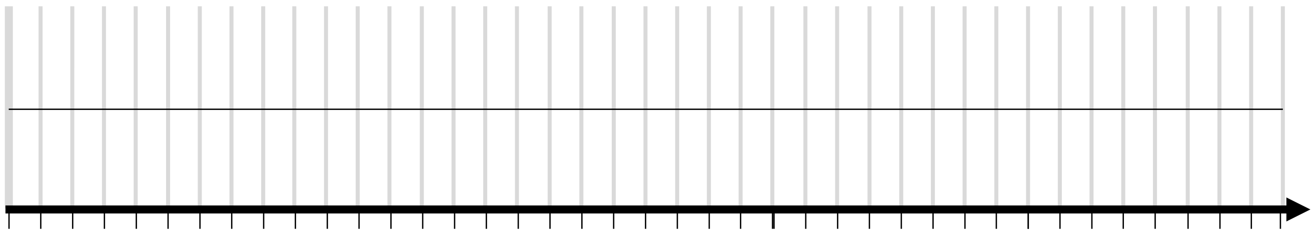
3) A car production plant consists of two sub-plants in sequence: painting and assembly. Assembly for a car can start only once the painting process for the same car has been completed. The plant produces cars in batches. Each batch has the following composition: 2 cars of type A, 1 car of type B, 1 car of type C, 1 car of type D. For the different types, painting and assembly times are reported in Table 3. A new batch cannot start processing until the last car of the previous batch has been fully assembled.

Car Type	Painting	Assembly	Quantity in Batch
A	8 min	14 min	2x
B	14 min	8 min	1x
C	6 min	12 min	1x
D	10 min	6 min	1x

Table 3: Production parameters for car types at assembly and painting sub-plants.

a) **(8 points)** If we want to minimize the completion time for a batch, what is the order in which each car type should be scheduled within a batch? Motivate your answer.

b) (4 points) Assuming that a new batch can start processing immediately after the previous batch has been completed, how many cars per 8-hours day the plant will be able to produce?
Note: *the grid below is provided only for your convenience. You do not have to use it if you do not need it to answer this question.*



c) (2 points) What is the utilization of the assembly sub-plant? Motivate your answer.

4) The new Airbuzz Nightmareliner is being designed using a **dual-processor** computing platform. The engineers have produced a flight control system comprised of 7 real-time tasks, namely T1, …, T7. The parameters for these tasks are reported in Table 4. Answer the following questions:

Task	WCET	Period	Utilization
T1	5 ms	25 ms	
T2	8 ms	25 ms	
T3	9 ms	25 ms	
T4	3 ms	10 ms	
T5	3 ms	20 ms	
T6	10 ms	40 ms	
T7	11 ms	50 ms	

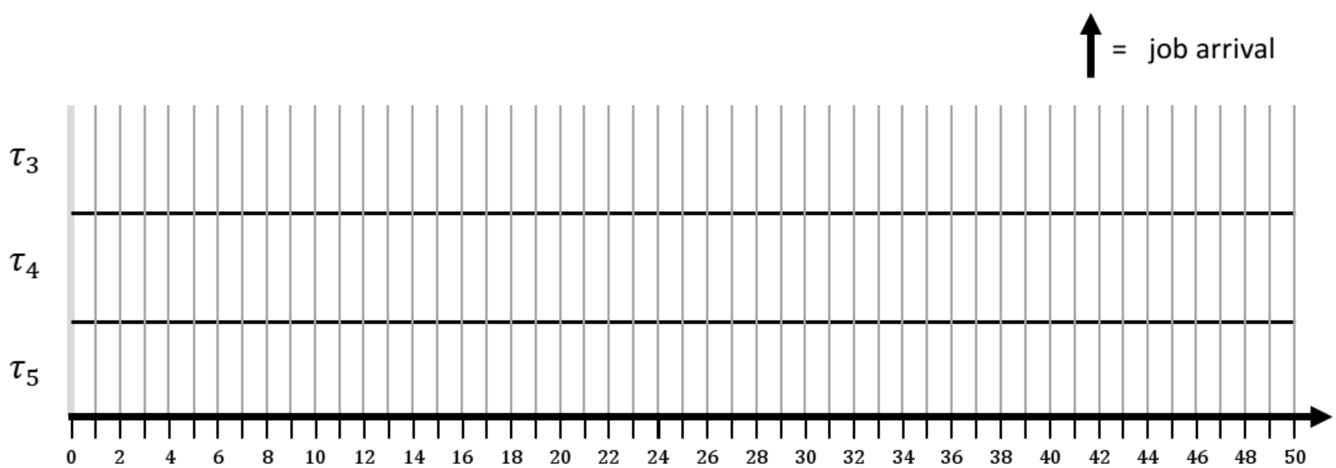
Table 4: Parameters of Airbuzz Nightmareliner flight control tasks.

a) **(2 points)** Compute the utilization of each task in Table 4.

b) **(4 points)** Is the task-set schedulable under EDF-FF on the considered computing platform? Motivate your answer.

c) (6 points) If possible, produce a task-to-processor assignment using EDF-FF and the following ordering of tasks: T2, T1, T6, T4, T3, T7, T5.

d) (2 points) Assume that T3, T4 and T5 are scheduled according to EDF on Processor 1. Produce the corresponding schedule up to time . Use the grid provided below.



e) (2 points) Using the setup and time frame considered for Part d), what is the average response time for a job of T3?

5) A group of 4 friends has decided to go watch a movie. Being Italian, they are all expected to show up at the movie theater at unpredictable times (hopefully before the end of the movie). They agree on the following protocol: (a) if less than 3 people have arrived at the movie theater, they block, waiting for more friends to arrive; (b) once at least 3 friends have arrived, they go in together, even if the fourth friend has not arrived yet; (c) when the 4th friend shows up, he realizes that his friends have already arrived and joins them inside the theater.
Note: *this protocol does not repeat. Consider each friend as a one-shot process.*

a) **(6 points)** Produce a pseudo-code for the process of a generic "friend" that uses semaphores and that follows the described protocol. Clearly state how your variables are being initialized.

b) (10 points) After the movie is over, all the friends want to share a single cab. Only one of them can stop a cab by the curb. After the cab has been stopped, everyone waits for everyone else to be in the cab. Lastly, once everyone is in the cab, only one of the friends instructs the driver toward their destination (home?). Modify the code written at the previous step to incorporate the additional synchronization logic. Once again, provide the initialization of all the used variables. ***Note:*** *if you are reusing the code from the previous step, use it here as:* ENTRY_PROTOCOL()

6) Consider a system with 4 Processes and 3 shared resources . For these resources, the static parameters are reported in Table 5.

		Parameter	Resources		
			8	5	8
Processes			6	2	4
			3	4	3
			2	1	1
			4	0	4

Table 5: Static parameters of considered system.

a) **(4 points)** Considering what reported in Table 5, complete Table 6 with the amount of allocated resources to all the processes , and with the availability of all the resources .

		Parameter	Resources			Parameter	Resources		
Processes							5	0	2
							0	4	1
							1	1	1
							3	0	2

Table 6: System state for considered system.

b) (8 points) Would the state in Table 6 be deemed safe by the Banker algorithm? If so, produce a possible sequence in which all the processes can come to completion.

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Equations for some queuing systems:

- M/G/1 system $q = \dfrac{\rho^2 A}{1-\rho} + \rho$ and $w = \dfrac{\rho^2 A}{1-\rho}$, where $A = \dfrac{1}{2}\left[1 + \left(\dfrac{\sigma_{Ts}}{Ts}\right)^2\right]$

- M/D/1 system $q = \dfrac{\rho^2}{2(1-\rho)} + \rho$ and $w = \dfrac{\rho^2}{2(1-\rho)}$

- M/M/1/K system $q = \begin{cases} \dfrac{\rho}{(1-\rho)} - \dfrac{(K+1)\rho^{K+1}}{(1-\rho^{K+1})} & \text{for } \rho \neq 1 \\ \dfrac{K}{2} & \text{for } \rho = 1 \end{cases}$, and

$$\Pr(\text{"Rejection"}) = \Pr(S_K) = \begin{cases} \dfrac{(1-\rho)\rho^K}{(1-\rho^{K+1})} & \text{for } \rho \neq 1 \\ \dfrac{1}{K+1} & \text{for } \rho = 1 \end{cases}$$

- M/M/N system $q = C\dfrac{\rho}{1-\rho} + N\rho$ and $w = C\dfrac{\rho}{1-\rho}$,

$$\text{where } \rho = \frac{\lambda}{N\mu} = \frac{\lambda T_s}{N},\ C = \frac{1-K}{1-\rho K} \text{ and } K = \frac{\sum_{i=0}^{N-1} \frac{(N\rho)^i}{i!}}{\sum_{i=0}^{N} \frac{(N\rho)^i}{i!}}$$

Tasks and Schedulability Results:

- Minimum Slowdown for job at time :
- Single-processor RM: tasks schedulable *if*
- Single-processor EDF: tasks schedulable *if and only if*
- RM-FF: -tasks schedulable on processors *if*
- EDF-FF: -tasks schedulable on processors *if*
  - With