



Beijing-Dublin International College



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AUTUMN TRIMESTER FINAL EXAMINATION - (2024/2025)

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School of Computer Science

## COMP3014J Performance of Computer Systems

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**Time Allowed: 120 minutes**

**Instructions for Candidates:**

Answer all questions.

**BJUT Student ID:**\_\_\_\_\_

**UCD Student ID:**\_\_\_\_\_

I have read and clearly understand the Examination Rules of both Beijing University of Technology and University College Dublin. I am aware of the Punishment for Violating the Rules of Beijing University of Technology and/or University College Dublin. I hereby promise to abide by the relevant rules and regulations by not giving or receiving any help during the exam. If caught violating the rules, I accept the punishment thereof.

**Honesty Pledge:**\_\_\_\_\_ (Signature)

### Instructions for Invigilators

Open-Book. Non-programmable calculators are permitted.

No rough-work paper is to be provided for candidates.

Question 1: Fundamentals of Performance

- a. Imagine you are tasked with optimizing the performance of a real-time video streaming service. Identify and describe the key performance metrics you would consider, explain how workload characteristics affect these metrics, and propose a detailed strategy to handle variability in network conditions using a combination of simulation, measurement, and analytical modeling. Discuss potential trade-offs, including the impact of optimization decisions on both system performance and user experience. Provide recommendations for balancing these trade-offs.

(20%)

(Question Total 20%)

Question 2: Pseudo-Random Number Generation

We use a Linear-Congruential Generator (LCG) to generate random integer values for a simulation experiment. The generator is defined as:

$$X_n = (a \cdot X_{n-1} + b) \mod M$$

- a. Complete the following table with the first 13 values of the random number generator for each LCG:

	a	b	c	M	$X_0$	$X_1$	$X_2$	$X_3$	$X_4$	$X_5$	$X_6$	$X_7$	$X_8$	$X_9$	$X_{10}$	$X_{11}$	$X_{12}$	$X_{13}$
LCG1	4	5	1	18	1	9	14	7	15	11	13	3	17	1	9	14	7	15
LCG2	3	7	2	13	2	0	7	2	0	7	2	0	7	2	0	7	2	0

(10%)

- b. Determine the tail, cycle length, and period of LCG1 and LCG2. Explain which one is better in terms of efficiency and randomness.

	Tail length	Cycle Length	Period
LCG1	0	9	9
LCG2	0	3	3

(10%)

- c. Write the equation for a multiplicative LCG that achieves a period of  $2^{k-2}$ . Specify the conditions required for the multiplier  $a$  and initial seed  $X_0$ .

$$X_n = 5^n \mod 2^5, \quad X_0 = 3$$

(5%)

(Question Total 25%)

### Question 3: Queueing Theory

$s=3$

$\lambda = 15 \text{ 1/h}, \mu = 10 \text{ 1/h}$

Consider a call center with three agents answering customer calls. The time between incoming calls follows an exponential distribution with a mean of 4 minutes. The service time for each call follows an exponential distribution with a mean of 6 minutes. There can be a maximum of three calls in the system (one per agent), and any additional calls are lost.  $k=3$

- a. Draw the state-transition diagram for this system.



(5%)

- b. Write the balance equations for this birth-and-death process.

(10%)

- c. Identify the type of queueing model (e.g., M/M/C/∞, etc.) represented here.

(5%)

- d. Calculate the steady-state probabilities for the system ( $\pi_0, \pi_1, \pi_2$ , etc.).

(5%)

- e. Determine the proportion of time that all agents are busy.

(5%)

- f. Calculate the expected number of calls in the system.

(5%)

(Question Total 35%)

### Question 4: Markov Models for CPU Scheduling

To evaluate a CPU scheduling algorithm, we simulate the transitions between different process states: **Ready**, **Running**, **Blocked**, and **Exit**. The Exit state is an absorbing state, where processes no longer transition to any other state. The transition probabilities and initial state probabilities are provided below.

	Ready	Running	Blocked	Exit
Ready	0.4	0.5	0.1	0
Running	0.3	0.4	0.3	0
Blocked	0.2	0.3	0.4	0.1
Exit	0	0	0	1

Figure 1: Transition Matrix

Initial State Probabilities

	Ready	Running	Blocked	Exit
Ready	0.6			
Running	0.3			
Blocked	0.1			
Exit	0.0			

Figure 2: Initial State Probabilities

- a. Draw the state transition diagram based on the provided transition matrix and initial state probabilities.

(10%)

- b. Assume a process transitions through the following sequence of states: Ready  $\rightarrow$  Running  $\rightarrow$  Blocked  $\rightarrow$  Exit. Calculate the probability of the process following this sequence and reaching the Exit state.

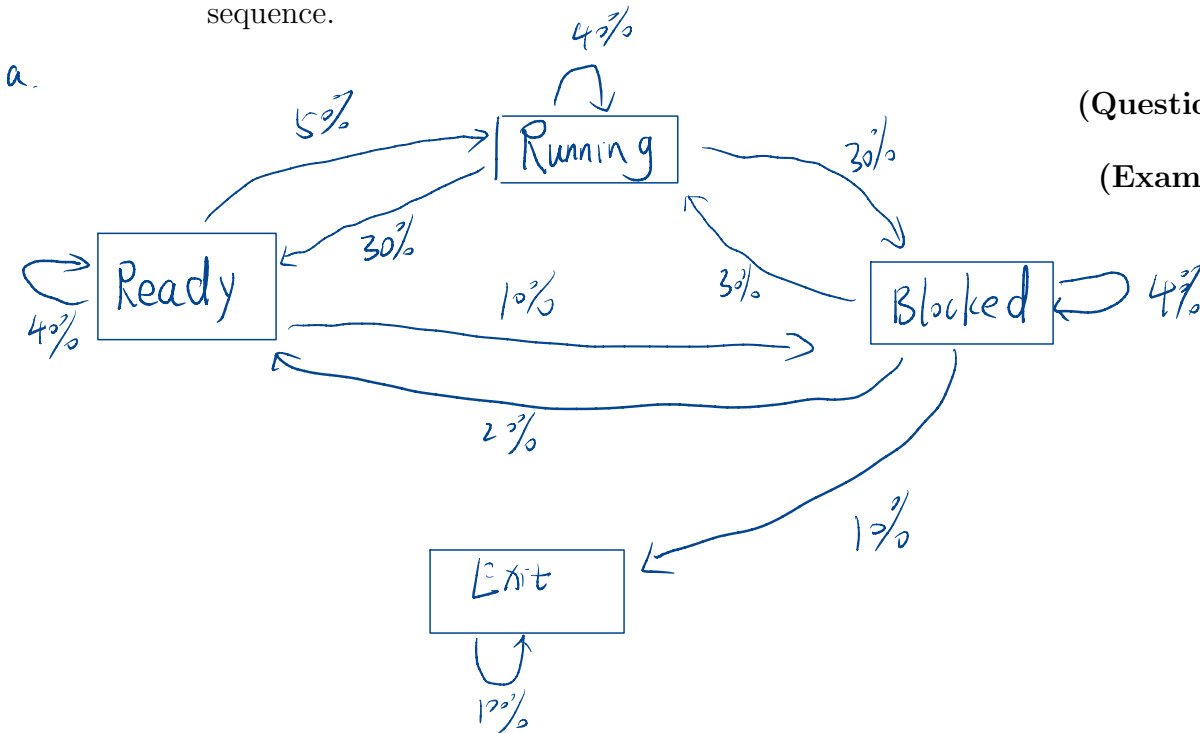
(5%)

- c. Assume a process starts in the Ready state, transitions to Running, then to Blocked, remains in Blocked again, and finally reaches Exit. Calculate the probability of this sequence.

(5%)

(Question Total 20%)

(Exam Total 100%)



$$\begin{aligned}
 \text{b. } & P(\text{Ready}) \times P(\text{Ready} \rightarrow \text{Running}) \times P(\text{Running} \rightarrow \text{Blocked}) \times P(\text{Blocked} \rightarrow \text{Exit}) \\
 &= 0.6 \times 0.5 \times 0.3 \times 0.1 = 0.009
 \end{aligned}$$

$$\begin{aligned}
 \text{c. } & P(\text{Ready}) \times P(\text{Ready} \rightarrow \text{Running}) \times P(\text{Running} \rightarrow \text{Blocked}) \times P(\text{Blocked} \rightarrow \text{Blocked}) \\
 & \times P(\text{Blocked} \rightarrow \text{Exit}) \\
 &= 0.0036
 \end{aligned}$$

Q<sub>3</sub>

$\lambda_0$



b) State 0:  $\lambda \pi_0 = \mu \pi_1$

State 1:  $\lambda \pi_0 + 2\mu \pi_2 = \lambda \pi_1 + \mu \pi_1$

State 2:  $\lambda \pi_1 + 3\mu \pi_3 = \lambda \pi_2 + 2\mu \pi_2$

State 3:  $3\mu \pi_3 = \lambda \pi_2$

c) M/M/3/3

$$\begin{aligned} \pi_2 &= \frac{\lambda_1 \lambda_0}{\mu_2 \mu_1} \pi_0 = \frac{\lambda^2}{2\mu^2} \pi_0 \\ \pi_3 &= \frac{\lambda_2 \lambda_1 \lambda_0}{\mu_3 \mu_2 \mu_1} \pi_0 = \frac{\lambda^3}{6\mu^3} \pi_0 \end{aligned}$$

d)  $\lambda = 15, \mu = 10$

$$\pi_0 + \pi_1 + \pi_2 + \pi_3 = 1$$

$$\pi_0 + 1.5\pi_0 + 1.125\pi_0 + 0.5625\pi_0 = 1$$

$$\pi_0 = \frac{16}{67} \approx 0.2388$$

$$\pi_1 = 0.3582$$

$$\pi_2 = 0.2686$$

$$\pi_3 = 0.1343$$

e)  $P(\text{busy}) = \pi_3 = 0.1343$

f)  $L = \sum_{k=1}^3 k\pi_k = \pi_1 + 2\pi_2 + 3\pi_3 = 1.2183$