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ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

Department of Computer Science and Engineering (CSE)

SEMESTER FINAL EXAMINATION **WINTER SEMESTER, 2022-2023**

DURATION: 3 HOURS **FULL MARKS: 150**

CSE 4309: Theory of Computing

Programmable calculators are not allowed. Do not write anything on the question paper.

Answer **all 6 (six)** questions. Figures in the right margin indicate full marks of questions whereas corresponding CO and PO are written within parentheses.

1. a) Provide a comparative analysis of Finite Automata, Pushdown Automata, and Turing Machine. 6 (CO1) (PO1)

   b) Finite Automata are good models for computer with an extremely limited amount of memory. The controller for an automatic door is one such example. Design and explain the informal picture of this Finite Automata with the required states and input conditions. 7 (CO2) (PO2)

   c) Assume the password policy for creating a student account is set as follows: 12 (CO2) (PO2)

   - Password should start with symbols like !, #, $, @.
   - Password should contain at least one upper case letter or at least one digit as substring.
   - Password can contain zero or more number of lower case letters.

   Derive the regular expression that generates the passwords based on the policies mentioned above and design a Finite Automata that accepts the strings generated by the regular expression.

2. a) Explain δ for DFA, NFA, and ϵ-NFA. 3 (CO1) (PO1)

   b) The World Health Organization (WHO) has designated COVID-19 as an airborne disease, prompting a reconsideration of human-to-human testing due to potential risks. Consequently, a robotic testing system has been devised with the following operational procedure: The individual being tested exhales in proximity to the robot's sensor. If the pressure is insufficient, they are instructed to exhale again. Subsequently, a viral presence assessment is conducted. If positive, the individual is instructed to place their forehead near the temperature sensor of the robot. If an elevated temperature is detected, an alarm is triggered, and appropriate authorities facilitate the individual's transportation to a medical facility. Conversely, if the temperature is within the normal range, the robot provides guidance for the individual to observe a 14-day home quarantine.
   Design a Finite Automaton to represent the sequence of operations of the robotic system. 12 (CO2) (PO3)

   c) Considering the ϵ-NFA shown in Table 1, compute the ϵ-closure of each state and convert it to an equivalent DFA. 10 (CO5) (PO1)

Table 1: Transition table for Question 2.c)

	ϵ	a	b	c
$\rightarrow p$	$\{q,r\}$	$\emptyset$	$\{q\}$	$\{r\}$
q	$\emptyset$	$\{p\}$	$\{r\}$	$\{p,q\}$
$* r$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$

3. a) What are the closure properties of Regular Languages? Using Pumping lemma of Regular Languages, show that language $L = \{0^n 1^{2n} | n \geq 1\}$ is not regular. $2+5$ (CO1) (PO1)

b) You are given an NFA, $N1 = (Q1, \sum, \delta1, q1, F1)$ that accepts the language A, and an NFA, $N2 = (Q2, \sum, \delta2, q2, F2)$ that accepts the language B. Show that there exists an NFA, N that recognizes the language $A \cup B$. 8 (CO1) (PO1)

c) What is Chomsky Normal Form (CNF)? Simplify the following grammar and put the resulting grammar into CNF. 10 (CO2) (PO2)

$$S \rightarrow aAa \mid bBb \mid \epsilon$$
$$A \rightarrow C \mid a$$
$$B \rightarrow C \mid b$$
$$C \rightarrow CDE \mid \epsilon$$
$$D \rightarrow A \mid B \mid ab$$

4. a) Explain ambiguous grammar. How can you remove ambiguity from a grammar? 5 (CO1) (PO1)

b) Design a Pushdown Automata which accepts the if/else errors by empty stack and show the moves for the input string w = *iieee*. 12 (CO1) (PO1)

c) Show that the following grammar is ambiguous on the string *aabbccdd*. 8 (CO2) (PO3)

$$S \rightarrow AB \mid C$$
$$A \rightarrow aAb \mid ab$$
$$B \rightarrow cBd \mid cd$$
$$C \rightarrow aCd \mid aDd$$
$$D \rightarrow bDc \mid bc$$

5. a) Explain Decidability, Undecidability, and Intractability. 3 (CO1) (PO1)

b) Construct a PDA equivalent to the following CFG and simulate it on the input string *010000*. 12 (CO5) (PO1)

$$S \rightarrow 0BB$$
$$B \rightarrow 0S \mid 1S \mid 0$$

c) If $L = N(P_N)$ for some PDA $P_N = (Q, \sum, \Gamma, \delta_N, q_0, Z_0)$, then prove that there is a PDA, P_F such that $L = L(P_F)$. 10 (CO2) (PO3)

6. a) Why Turing Machines are Deterministic? What are the 7 tuples of a Turing Machine? $3+3$ (CO1) (PO1)

b) How can you simulate a Turing Machine by using a computer? 7 (CO1) (PO1)

c) Design a Turing machine for the language $L = a^n b^n c^n | n \geq 1$ with transition diagram and show the tape movements for the string $w = aabbcc$. 12 (CO2) (PO3)