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UNIVERSITY OF MORATUWA

FACULTY OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

BSc Engineering Honours Degree
Semester 4 Examination (2021 Intake)

CS 3063 THEORY OF COMPUTING

Time allowed: 2 Hours July 2024

ADDITIONAL MATERIAL: *None*

INSTRUCTIONS TO CANDIDATES:

1. This paper consists of **5** questions in **4** pages, including this page.
2. Answer **ALL** questions.
3. The maximum attainable mark for each question/part is given in brackets.
4. This examination accounts for 70% of the module assessment.
5. This is a closed book examination.

   NB: It is an offence to be in possession of unauthorized material during the examination.
6. Only calculators approved and labeled by the Faculty of Engineering are permitted.
7. Assume reasonable values for any data not given in or with the examination paper. Clearly state such assumptions made on the script.
8. In case of any doubt as to the interpretation of the wording of a question, make suitable assumptions and clearly state them on the script.
9. This paper should be answered only in English.
10. Abbreviations and Notations
    - DFA – Deterministic Finite Automaton
    - NFA – Non-deterministic Finite Automaton
    - NFA-Λ – Non-deterministic Finite Automaton with Λ-transitions
    - CFG – Context-free Grammar
    - CFL – Context-free Language
    - PDA – Push-Down Automaton
    - TM – Turing Machine
    - In a CFG, non-terminals are denoted by upper-case letters and terminals are denoted by lower-case letters and/or digits; non-terminal S is usually the start symbol and Λ represents the null string
    - A DFA or NFA is defined as a 5-tuple (Q, Σ, q_0, A, δ), where each component has the usual meaning.
    - A PDA is expressed as a 7-tuple (Q, Σ, Γ, q_0, Z_0, A, δ) where each component has the usual meaning.

Question 1 [20 marks]

In this question, there are 10 statements, (a) – (j); for each, you have to state whether it is either **True** or **False**. A correct choice will result in 2 marks and an incorrect choice will have a penalty of -1 mark. If not answered, it will result in 0 marks (no penalty). The minimum total marks possible for Q1 is 0.

(a) A string w is not accepted by an NFA if every path corresponding to w ends up at a non-accepting state.

(b) A finite automaton can accept the null string Λ only if it is an NFA-Λ.

(c) If M is a DFA that accepts a language L, then there is a DFA accepting L with more states than M.

(d) The regular expressions $(aa^*bb^*)^*$ and $\Lambda \mid a(a|b)^*b$ are not equivalent.

(e) A Mealy machine can have fewer states than a Moore machine for the same input-output behavior.

(f) The pumping lemma can be used to prove that a language is context-free.

(g) If a CFG is ambiguous, then we can make it unambiguous by eliminating unit productions from it.

(h) We can construct a PDA to accept the language $\{ a^i b^i c^i \mid i \geq 1\}$.

(i) If we can construct a Turing machine T to compute the characteristic function of a language L, then T will halt for a string not in L.

(j) There exist computational problems that a Universal Turing machine cannot solve.

Question 2 [20 marks]

(a) Construct a Mealy machine whose input alphabet is $\{a, b\}$ and which outputs 1 when it detects the substring *abba* in input and outputs 0 otherwise. [6 marks]

(b) (i) State the pumping lemma for regular languages. [2 marks]

(ii) Use the pumping lemma to show that $L = \{ww \mid w \in \{0,1\}^*\}$ is not regular. [6 marks]

(c) Consider the language of all strings that do not end with 01, where the alphabet is $\{0,1\}$

(i) Find a regular expression corresponding to the language above. [2 marks]

(ii) Show the transition diagram of a DFA that recognizes the language. [4 marks]

Question 3 [20 marks]

(a) Consider the DFA, M_1=({0,1, 2, 3, 4, 5, 6,7}, {a, b}, 0, {2}, δ), whose δ is specified below.

Current State	Next State			Current State	Next State	
	Input a	Input b			Input a	Input b
0	1	5		4	7	5
1	6	2		5	2	6
2	0	2		6	6	4
3	2	6		7	6	2

(i) Identify the *equivalence classes* of the given set of states. Show your work.

[7 marks]

(ii) Show the transition diagram of the equivalent *minimum-state* DFA.

[3 marks]

(b) Suppose the NFA-Λ, M_2 = ({A,B,C,D,E}, {0, 1}, A, {E}, δ) is given, where the transitions are specified as follows.

Current State	Next State(s)		
	Input 0	Input 1	Input Λ
A	A		B, D
B	C	E	
C		B	
D	E	D	
E			

(i) Find Λ(A).

[2 marks]

(ii) Construct an equivalent NFA and show its transition diagram. Show your work.

[3 marks]

(iii) Construct an equivalent DFA and show its transition diagram. Show your work.

[5 marks]

Question 4 [20 marks]

(a) Construct a CFG that generates the language of odd-length strings in {a, b}* with middle symbol a.

[4 marks]

(b) Describe what language is generated by each of the CFGs indicated by the following productions:

(i). S → aSa | bSb | Λ

(ii). S → aSb | bSa | Λ

[2×2=4 marks]

(c) Describe what is meant by the *dangling else ambiguity* in programming languages, using a suitable example.

[5 marks]

(d) Suppose M_1 and M_2 are PDAs accepting languages L_1 and L_2, respectively.

Describe how to construct a PDA accepting the language L_1L_2. Note that nondeterminism would be necessary and that the stack alphabets of M_1 and M_2 are independent. State clearly how the new machine works.

[7 marks]

Question 5 [20 marks]

(a) Construct a Turing machine (TM) to accept the language of *balanced strings of parentheses*. For example, "(()(())())" is balanced and ")(()(())" is not balanced.

[10 marks]

(b) Describe the terms "Turing complete" and "Turing equivalent".

[5 marks]

(c) State whether each statement below is True or False. (TM = Turing Machine).
- (i) A linear bounded automaton is a non-deterministic TM with limited abilities.
- (ii) If L is a recursive language, then there is a TM which will halt even when a string not in L is input.
- (iii) The set of real numbers is countable because it can be put into one-to-one correspondence with the natural numbers.
- (iv) There are languages that cannot be accepted by any Turing Machine.
- (v) PCP was initially thought to be unsolvable but later proved to be intractable.

[5 marks]

------ End of Paper ------