ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
Department of Computer Science and Engineering (CSE)

SEMESTER FINAL EXAMINATION **WINTER SEMESTER, 2017-2018**

DURATION: 3 Hours **FULL MARKS: 150**

CSE 4703: Theory of Computing

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

There are **8 (eight)** questions. Answer any **6 (six)** of them.

Figures in the right margin indicate marks.

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1. a) State the differences between a DFA and an NFA. 4

   b) What is the language recognized by the NFA of Figure 1? Show the computation of the NFA that makes the input 1011 be accepted. 3+6

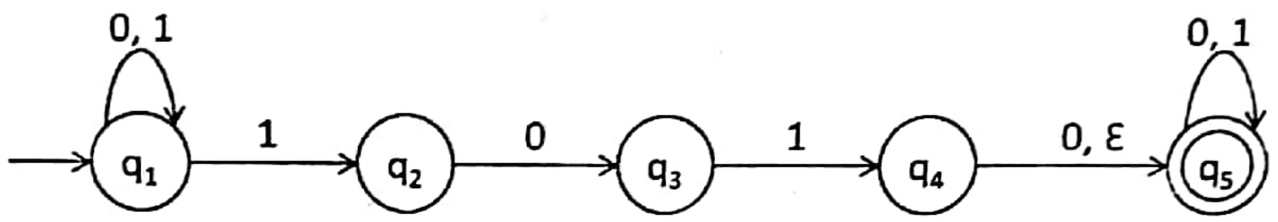

Figure 1: State diagram of an NFA for Question 1.b)

c) *Design NFA's for the following languages. Try to use ϵ-transitions to simplify your design.* 2×6

   i. *The set of strings consisting of zero or more a's, followed by zero or more b's, followed by zero or more c's over the alphabet $\{a, b, c\}$.*

   ii. *The set of all strings that consist of either 01 repeated one or more times or 010 repeated one or more times over the alphabet $\{0, 1\}$.*

2. a) What is the difference between empty string and empty language? 2

   b) Explain the differences among Σ, Σ^0 and Σ^1. 3

   c) Consider the following ϵ-NFA. 3+3

Table 1: Transition table of an ϵ-NFA for Question 2.c)

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

   i. Compute the ϵ-closure of each state

   ii. Give all the strings of length three or less accepted by the automaton

   d) **Write the regular expressions for the following languages:** 2×7

   i. $L = \{ w \mid w \in \{0, 1\}$ and $|w|$ is multiples of $3\}$

   ii. $L = \{ w \mid w \in \{0, 1\}$ and no two consecutive 0's$\}$

3. a) Convert the regular expression $(0 + 10)^*010(0 + 1)^*$ to NFA. 6

b) Consider the following transition table for a DFA. 3×4

Table 2: Transition table of a DFA for Question 3.b)

	0	1
$\rightarrow q_1$	q_2	q_1
q_2	q_3	q_1
$^*q_3$	q_3	q_2

Give all the regular expressions of $R_{ij}^{(0)}$, $R_{ij}^{(1)}$, $R_{ij}^{(2)}$.

(Note: $R_{ij}^{(k)} = R_{ij}^{(k-1)} + R_{ik}^{(k-1)}\left(R_{kk}^{(k-1)}\right)^* R_{ij}^{(k)}$. Think of state q_i as if it were the state with integer number i.)

c) Construct the transition diagram for the DFA of Table 2 and give a regular expression for its language using state elimination technique. 7

4. a) What are the operators of regular expression? Mention the order of precedence followed by the operators. 3+2

b) Using pumping lemma for regular language, show that the language $L = \{0^n 10^n \mid n \geq 1\}$ is not regular. 10

c) Suppose h is the homomorphism from the alphabet $\{a, b, c, d\}$ to the alphabet $\{0, 1\}$ defined by: 10

$h(a) = 0 = h(b)$

$h(c) = 00$

$h(d) = 11$

Now consider the following language:

$L = \{11, 011, 110, 111, 0011\}$

What is $h^{-1}(L)$?

5. a) Consider the set of all strings of balanced parentheses of two types, round and square. An example of where these strings come from is as follows. If we take expressions in C, which use round parentheses for grouping and for arguments of function calls, and use square brackets for array indexes, and drop out everything but the parentheses, we get all strings of balanced parentheses of these two types. For example, 10

```
f(a[i]*(b[i][j], c[g(x)]), d[i])
```

Figure 2: Example code for Question 5.a)

The code of Figure 2 becomes the balanced-parentheses string `([](][][()])[])`. Design a grammar for all and only the strings of round and square parentheses that are balanced.

b) Consider the grammar: 3×3

$E \rightarrow +EE \mid *EE \mid -EE \mid x \mid y$

Find the following from the grammar for the string "$+ * -xyxy$":

i. Left most derivation

ii. Right most derivation

iii. Parse tree

c) Show that the following grammar is ambiguous on the string "ibtibtaea" 6

$S \rightarrow iCtS \mid iCtSeS \mid a$

$C \rightarrow b$

6. a) Explain the 6 tuple definition of Pushdown Automata (PDA). When can we define a PDA with 6 tuple? 7

b) Describe the languages accepted by PDA. 4

c) Design a PDA to accept the following languages. Draw the transition diagram for the constructed PDA. 2×7

i. $L = \{ w \mid w \in \{0,1\}$ and w has equal number of 0's and 1's $\}$

ii. $L = \{ a^n b^{2n} \mid n \geq 1 \}$

7. a) Explain the working of a PDA with diagram. 5

b) Suppose the PDA $P = (\{q, p\}, \{0,1\}, \{Z_0, X\}, \delta, q, Z_0, \{p\})$ has the following transition function: 8

1. $\delta(q, 0, Z_0) = \{(q, XZ_0)\}$
2. $\delta(q, 0, X) = \{(q, XX)\}$
3. $\delta(q, 1, X) = \{(q, X)\}$
4. $\delta(q, \epsilon, X) = \{(p, \epsilon)\}$
5. $\delta(p, \epsilon, X) = \{(p, \epsilon)\}$
6. $\delta(p, 1, X) = \{(p, XX)\}$
7. $\delta(p, 1, Z_0) = \{(p, \epsilon)\}$

Starting from the initial ID (q, w, Z_0), show all the reachable ID's when the input is 0011

c) Obtain PDA equivalent to the following grammar: 2×6

i. $E \rightarrow E + E \mid E * E \mid id$

ii. $S \rightarrow aABC$
$A \rightarrow aB \mid a$
$B \rightarrow bA \mid b$
$C \rightarrow a$

8. a) What is ambiguous grammar? Explain with example. 3

b) Begin with the grammar: 3×4

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

i. Eliminate ϵ productions

ii. Eliminate any unit productions in the resulting grammar

iii. Eliminate any useless symbols in the resulting grammar

c) What is Chomsky Normal Form (CNF)? Convert the following CFG to CNF: 10

$S \rightarrow aSb \mid ab \mid Aa$
$A \rightarrow aab$