DUBLIN CITY UNIVERSITY

AUGUST/REPEAT EXAMINATIONS 2017/2018

MODULE: CA4003 - Compiler Construction

PROGRAMME(S):

CASE	BSc in Computer Applications (Sft.Eng.)
CPSSD	BSc in ComputationalProblem Solv&SW Dev.

YEAR OF STUDY: 4

EXAMINERS:

Dr. David Sinclair	(Ph:5510)
Dr. Hitesh Tewari	External
Prof. Brendan Tangney	External

TIME ALLOWED: 3 hours

INSTRUCTIONS: Answer 10 questions. All questions carry equal marks.

PLEASE DO NOT TURN OVER THIS PAGE UNTIL INSTRUCTED TO DO SO

The use of programmable or text storing calculators is expressly forbidden.
Please note that where a candidate answers more than the required number of questions, the examiner will mark all questions attempted and then select the highest scoring ones.

There are no additional requirements for this paper.

Note: In the following questions, non-terminal symbols are represented by strings starting with an upper case letter, e.g. A, Aa, Name, and terminal symbols are represented by either individual symbols (e.g. $+$) or sequence of symbols (e.g. $>=$), or by strings starting with a lower case letter, e.g. a, xyz. The ϵ symbol represents an empty symbol or null string as appropriate. The $ symbol represents the end-of-file.

QUESTION 1 ***[Total marks: 10]***

1(a) [4 Marks]

Given a binary alphabet {0,1}, write a regular expression that recognises all words that have an odd number of '1's.

1(b) [6 Marks]

Use the subset construction method to derive a deterministic finite state automaton that recognises the language from part (a).

[End Question 1]

QUESTION 2 ***[Total marks: 10]***

[10 Marks]

Calculate the FIRST and FOLLOW sets for the following grammar.

$S \rightarrow u\ B\ D\ z$
$B \rightarrow B\ v$
$B \rightarrow w$
$D \rightarrow E\ F$
$E \rightarrow y$
$E \rightarrow \epsilon$
$F \rightarrow x$
$F \rightarrow \epsilon$

[End Question 2]

QUESTION 3 **[Total marks: 10]**

[10 Marks]

Convert the following grammar into an LL(1) grammar which recognises the same language (you may assume that the grammar is unambiguous).

E → T + E | T
T → int | int * T | (E)

[End Question 3]

QUESTION 4 **[Total marks: 10]**

[10 Marks]

Construct the LL(1) parse table for the following grammar and using this table determine whether or not it is a LL(1) grammar.

$S \rightarrow Bc$
$S \rightarrow DB$
$B \rightarrow ab$
$B \rightarrow cS$
$D \rightarrow d$
$D \rightarrow \epsilon$

[End Question 4]

QUESTION 5 **[Total marks: 10]**

[10 Marks]

Construct the LR(1) parse table for the following grammar and use it to determine whether or not the following grammar is LR(1).

$S' \rightarrow S\$$
$S \rightarrow a\ E\ a$
$S \rightarrow b\ E\ b$
$S \rightarrow a\ F\ b$
$S \rightarrow b\ F\ a$
$E \rightarrow e$
$F \rightarrow e$

[End Question 5]

QUESTION 6 **[Total marks: 10]**

[10 Marks]

Determine whether or not the grammar in question 5 is an LALR(1) grammar.

[End Question 6]

QUESTION 7 **[Total marks: 10]**

7(a) [6 Marks]

Convert the following source code into 3-address intermediate code using the syntax-directed approach given in the appendix. Assume that all variables are stored in 4 bytes.

```
min = a[0];
i = 1;
while (i < 10)
{
  if (a[i] < min)
  {
    min = a[i];
  }
  i = i+ 1;
}
```

7(b) [4 Marks]

Generate a *Control Flow Graph* from the intermediate code generated in part (a) of this question. Clearly describe the rules used to generate the *Control Flow Graph*.

[End Question 7]

QUESTION 8 **[Total marks: 10]**

8(a) [4 Marks]

Describe how *Data Flow Analysis* is used to calculate the liveness of variables.

8(b) [6 Marks]

For the following intermediate code, assuming variable d, k and j are live on exit from this code, calculate which variables are live on entry.

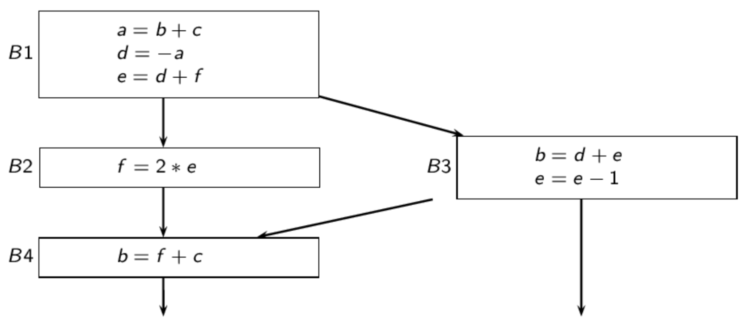
$$
\begin{aligned}
&t_1 = j + 4\\
&g = a[t_1]\\
&h = k - 1\\
&f = g * h\\
&t_2 = j + 12\\
&e = a[t_2]\\
&t_3 = j + 8\\
&m = a[t_3]\\
&b = a[f]\\
&c = e + 24\\
&d = c\\
&k = m + 4\\
&j = b
\end{aligned}
$$

[End Question 8]

QUESTION 9 ***[Total marks: 10]***

9(a) [7 Marks]

Calculate the live variables at each point of the following control flow graph assuming that variable b is live on the exit from Block B4 and variables b and e are live on exit from block B3.



9(b) [3 Marks]

Draw the interference graph for the control flow graph in part (a) of this question.

[End Question 9]

QUESTION 10 ***[Total marks: 10]***

10(a) [5 Marks]

What is a *Runtime Environment* ? What does the use of a *Runtime Environment* enable?

10(b) [5 Marks]

Using a piece of code as an example, describe how the stack frame in procedure A is modified when another procedure, procedure B, with arguments, is invoked from within procedure A.

[End Question 10]

[APPENDICES]

Syntax-directed definition approach to build the 3-address code

Production	Semantic Rule
$S \rightarrow \mathbf{id} = E;$	$gen(get(\mathbf{id}.lexeme)$ '=' $E.addr)$;
$S \rightarrow L = E;$	$gen(L.addr.base$ '[' $L.addr$ ']' '=' $E.addr);$
$E \rightarrow E_1 + E_2$	$E.addr = \mathbf{new}Temp();$ $gen(E.addr$ '=' $E_1.addr$ '+' $E_2.addr);$
$E \rightarrow \mathbf{id}$	$E.addr = get(\mathbf{id}.lexeme);$
$E \rightarrow L$	$E.addr = \mathbf{new}Temp();$ $gen(E.addr$ '=' $L.array.base$ '[' $L.addr$ ']'$);$
$L \rightarrow \mathbf{id}[E]$	$L.array = get(\mathbf{id}.lexeme);$ $L.type = L.array.type.elem;$ $L.addr = \mathbf{new}Temp();$ $gen(L.addr$ '=' $E.addr$ '*' $L.type.width);$
$L \rightarrow L_1[E]$	$L.array = L_1.array;$ $L.type = L_1.type.elem$ $t = \mathbf{new}Temp();$ $L.addr = \mathbf{new}Temp();$ $gen(t$ '=' $E.addr$ '*' $L.type.width);$ $gen(L.addr$ '=' $L_1.addr$ '+' $t);$
$B \rightarrow B_1 \| \| B_2$	$B_1.true = B.true$ $B_1.false = newlabel()$ $B_2.true = B.true$ $B_2.false = B.false$ $B_1.code \| label(B_1.false) \| B_2.code$
$B \rightarrow B_1 \&\& B_2$	$B_1.true = newlabel()$ $B_1.false = B.false$ $B_2.true = B.true$ $B_2.false = B.false$ $B_1.code \| label(B_1.true) \| B_2.code$
$B \rightarrow !B_1$	$B_1.true = B.false$ $B_1.false = B.true$ $B.code = B_1.code$
$B \rightarrow E_1\ \mathbf{rel}\ E_2$	$B.code = E_1.code \| E_2.code$ $\| gen($'if' $E_1.addr\ \mathbf{rel}\ E_2.addr$ 'goto' $B.true)$ $\| gen($'goto' $B.false)$
$B \rightarrow\ \mathbf{true}$	$B.code = gen($'goto' $B.true)$
$B \rightarrow\ \mathbf{false}$	$B.code = gen($'goto' $B.false)$

Production	Semantic Rule
$P \to S$	$S.next = newlabel()$ $P.code = S.code \| label(S.next)$
$S \to \textbf{assign}$	$S.code = \textbf{assign}.code$
$S \to \textbf{if}\ (\ B\ )\ S_1$	$B.true = newlabel()$ $B.false = S_1.next = S.next$ $S.code = B.code \| label(B.true) \| S_1.code$
$S \to \textbf{if}\ (\ B\ )\ S_1\ \textbf{else}\ S_2$	$B.true = newlabel()$ $B.false = newlabel()$ $S_1.next = S_2.next = S.next$ $S.code = B.code \| label(B.true) \| S_1.code$ $gen(\text{'goto'}\ S.next) \| label(B.false) \| S_2.code$
$S \to \textbf{while}\ (\ B\ )\ S_1$	$begin = newlabel()$ $B.true = newlabel()$ $B.false = S.next$ $S_1.next = begin$ $S.code = label(begin) \| B.code$ $\| label(B.true) \| S_1.code \| gen(\text{'goto'}\ begin)$
$S \to S_1\ S_2$	$S_1.next = newlabel$ $S_2.next = S.next$ $S_1.code \| label(S_1.next) \| S_2.code$

[END OF APPENDICES]

[END OF EXAM]