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page 1 page 2 page 3 page 4 page 5 Total / 54

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No books ; No calculator ; No computer ; No email ; No internet ; No notes ; No phone. Neatness counts ! Do your scratch work elsewhere and enter only your final answer into the spaces provided.

1. Given the grammar presented here, and using the style from the LALR(1) handout :
   (a) Construct the characteristic finite state machine (CFSM), sets of items and transition diagram, showing shifts, reductions, and acceptance. **[6✔]**
   (b) Construct the FOLLOW sets. Show the first pass with rule symbols in the Follow sets. Then show the revised follow sets with only terminal symbols. (See chart at the bottom of the page.) **[3✔]**
   (c) Answer ***yes*** or ***no*** to each of the following questions : **[1✔]**

   Is the grammar LR(0) ? _____ Is the grammar SLR(1) ? _____

0.	**S → $ G $**
1.	**G → G R x**
2.	**G → G o x**
3.	**G → G x**
4.	**G →**
5.	**R → s =**
6.	**R → R s**

Follow sets with rule symbols:

Follow(C) :
Follow(A) :

Follow sets with only V_T symbols :

Follow(C) :
Follow(A) :

2. Outline, using C-like pseudocode, the mark algorithm used in the mark and sweep collection algorithm. Assume a variable `rootset`. **[3✔]**

3. Assuming a compacting or copying collector, write the `malloc` algorithm, assuming that memory is always allocated on a 16-byte boundary. **[3✔]**

4. Write an unambiguous grammar for the following language : An `E` is a sequence of one or more `T`s connected by a right associative `/` operator. A `T` is an `F` optionally preceded by a `+` or a `-` operator. An `F` is an `x` or an `E` in parentheses. Use the same syntax as is used on the first page. **[2✔]**

5. Draw the CFSM for the following grammar. Is the grammar LR(0) ? **[2✔]**

   `T` → `x T`
   `T` →

6. Code the function **abs**, which takes the absolute value of an integer. ***Do not use any control transfer instructions.*** Assume that an `int` is 32 bits and that the operator `>>` does an arithmetic right shift. **[1✔]**

```
int abs (int n) {



}
```

7. Given the declaration of a class at the left, draw a picture of a `foo* p` pointing at an object, label the contens of each field, and show the contents of the virtual function table. **[2✔]**

```
class foo {
   int a;
   int b;
   virtual void f();
   virtual void g();
}
```

8. Given the function at the left, translate it into `oil` statements using the specification for project 5. Each statement of your answer should be put in the box corresponding to the original source statement. **[4✔]**

`int prod (int[] a, int[] b, int n) {`	
`   int s = 0;`	
`   int i = 0;`	
`   while (i < n) {`	
`      s = s + a[i] * b[i];`	
`      i = i + 1;`	
`   }`	
`   return s;`	
`}`	

9. Draw the abstract syntax tree for the above function, using the specifications for project 3. **[3✔]**

Multiple choice. To the ***left*** of each question, write the letter that indicates your answer. Write ***Z*** if you don't want to risk a wrong answer. Wrong answers are worth negative points. **[12✔]**

number of correct answers		× 1 =	$= a$
number of wrong answers		× ½ =	$= b$
number of missing answers		× 0 =	0
column total $c = \max(a - b, 0)$	12		$= c$

1. Which of the following items in a state was added during the closure computation ?
   (A) $E \to \bullet\ E + T$
   (B) $E \to E \bullet + T$
   (C) $E \to E + \bullet\ T$
   (D) $E \to E + T \bullet$

2. The number of registers on the x86-64 architecture is :
   (A) 8
   (B) 16
   (C) 32
   (D) 64

3. If a function is nested inside another, what does the inner function use to access the local variables of the outer function ?
   (A) dynamic link
   (B) frame pointer
   (C) stack pointer
   (D) static link

4. If an NFA is constructed from a regular expression whose length is $|r|$ and is used to scan a string whose length is $|s|$, then it will run at speed :
   (A) $O(|r|)$
   (B) $O(|r| + |s|)$
   (C) $O(|r| \times |s|)$
   (D) $O(|s|)$

5. What is used to identify the natural loops of a function ?
   (A) basic block
   (B) dominator tree
   (C) flow graph
   (D) tail call

6. Given a grammar $G = \langle V_N, V_T, P, S \rangle$, where $V = V_N \cup V_T$. The set of productions P consists of rules of the form $(A \to \alpha)$, where :
   (A) $A \in V$ and $\alpha \in V^*$.
   (B) $A \in V_N$ and $\alpha \in V^*$.
   (C) $A \in V_T$ and $\alpha \in V_N^*$.
   (D) $A \in V^+$ and $\alpha \in V^+$.

7. Which of the following items will cause a shift transition to be added to the current state ?
   (A) $E \to \bullet\ E + T$
   (B) $E \to E \bullet + T$
   (C) $E \to E + \bullet\ T$
   (D) $E \to E + T \bullet$

8. The number of bits in `%rax` on the x86-64 architecture is :
   (A) 8
   (B) 16
   (C) 32
   (D) 64

9. If an NFA is constructed from a regular expression whose length is $|r|$ and is used to scan a string whose length is $|s|$, then it will run at speed :
   (A) $O(|r|)$
   (B) $O(|r| + |s|)$
   (C) $O(|r| \times |s|)$
   (D) $O(|s|)$

10. The first instruction in a function will usually push what register onto the function call stack ?
    (A) argument pointer
    (B) frame pointer
    (C) return address
    (D) stack pointer

11. In C++, what data structure implements a hash table that allows a key lookup to find an associated value ?
    (A) `map`
    (B) `set`
    (C) `unordered_map`
    (D) `unordered_set`

12. The executable binary name of the C/C++ preprocessor is :
    (A) `/usr/bin/cccp`
    (B) `/usr/bin/cpp`
    (C) `/usr/bin/g++`
    (D) `/usr/bin/gcc`

Multiple choice. To the ***left*** of each question, write the letter that indicates your answer. Write ***Z*** if you don't want to risk a wrong answer. Wrong answers are worth negative points. **[12✔]**

number of correct answers		× 1 =	$= a$
number of wrong answers		× ½ =	$= b$
number of missing answers		× 0 =	0
column total $c = \max(a - b, 0)$	12		$= c$

1. Which of the following items will cause a reduction action to be added to the current state ?
   (A) $E \rightarrow \bullet\ E + T$
   (B) $E \rightarrow E \bullet + T$
   (C) $E \rightarrow E + \bullet\ T$
   (D) $E \rightarrow E + T \bullet$

2. The grammar :
   $A \rightarrow Ax$
   $A \rightarrow y$
   (A) is LR(0) but not SLR(1)
   (B) is SLR(1) but not LR(0)
   (C) is both LR(0) and SLR(1)
   (D) is neither LR(0) nor SLR(1)

3. What parsing action pops some number of items from the parsing stack and then pushes a nonterminal onto that stack ?
   (A) accept
   (B) error
   (C) reduce
   (D) shift

4. The address of a variable local to a function is determined at _____ time.
   (A) compile
   (B) exec
   (C) function call
   (D) link

5. Given an NFA constructed via Thompson's construction, which is then converted into a DFA using the subset construction, but not mimimized, the NFA will likely be [x] than the DFA, and when used in scanning, the NFA will likely run more [y] than the DFA.
   (A) [x] = larger, [y] = quickly
   (B) [x] = larger, [y] = slowly
   (C) [x] = smaller, [y] = quickly
   (D) [x] = smaller, [y] = slowly

6. On the x86-64, what is the alignment requirement for `%rbp` and `%rsp` ?
   (A) `0x10`
   (B) `0x100`
   (C) `0x1000`
   (D) `0x10000`

7. The Java virtual machine (JVM) interprets what kind of language ?
   (A) abstract syntax tree
   (B) stack machine code
   (C) three address code
   (D) two address code

8. Which of the following items has a transition which will be taken during a reduction operation ?
   (A) $E \rightarrow \bullet\ E + T$
   (B) $E \rightarrow E \bullet + T$
   (C) $E \rightarrow E + \bullet\ T$
   (D) $E \rightarrow E + T \bullet$

9. Which statement is true ?
   (A) All LR(k) languages are unambiguous.
   (B) All context free languages are LR(k).
   (C) Some LR(k) languages are ambiguous.
   (D) Some regular languages are not LR(k).

10. Which of the following problems can be solved using a context-free grammar but not a regular grammar ?
    (A) Detecting C++ double-slash (`//`) comments.
    (B) Detecting a plus or minus sign followed by one or more digits.
    (C) Detecting a sequence of one or more letters and digits, beginning with a letter.
    (D) Detecting balanced parentheses.

11. Which grammar is ambiguous ?
    (A) $A \rightarrow A\ x$
        $A \rightarrow x$
    (B) $A \rightarrow x\ A$
        $A \rightarrow x$
    (C) $A \rightarrow A\ A$
        $A \rightarrow x$
    (D) $A \rightarrow x\ x$
        $A \rightarrow x$

12. Which `(flex)` pattern will recognize a double-slash (`//`) comment as in Java or C++ ?
    (A) `/\/\[^/n]*`
    (B) `/\/\[^\n]*`
    (C) `\/\/[^/n]*`
    (D) `\/\/[^\n]*`