

University of Mississippi  
Department of Computer and Information Science  
Programming Languages Comprehensive Examination  
SAMPLE QUESTIONS

## INSTRUCTIONS

- Answer the questions on the paper provided. Clearly label your answer to each question. Staple your pages to the back of the examination paper when you have completed your work and submit the package to the exam proctor.
- You have up to **four hours** to complete your work on this examination.
- This exam has three parts. Carefully read the instructions for each part and answer the questions as indicated.

## PART I

Answer **ANY TWO** of the questions 1 through 6.

1. Omitted.
2. Omitted.
3. Suppose you are working with a lexically scoped, block structured language such as Pascal. Further suppose that the runtime system is stack-based and uses conventional activation records to maintain procedure invocation information.

Suppose we wish to extend the language design to allow a function to *return* a function name as its value. (It should be possible to call the function that is returned.)

- (a) In terms of compile-time (static) typing and type checking, what additional issues, if any, does this introduce?
- (b) What major runtime issues must be addressed?
- (c) How would the runtime system need to be modified to accommodate such a feature?

4. Omitted.
5. Java and C++ are similar languages, yet they have a few significant differences.
  - (a) Java uses garbage collection for its storage management; C++ does not. What is meant by garbage collection? What are the advantages and disadvantages of using garbage collection?
  - (b) Java has a single inheritance hierarchy for classes; C++ has multiple inheritance. What is meant by single and multiple inheritance? What are the advantages and disadvantages of the single inheritance approach as in Java?
  - (c) In Java's inheritance hierarchy, each class inherits directly or indirectly from the root class `Object`. If no other inheritance is declared, then a Java class derives from `Object` by default. In C++'s inheritance hierarchy, there is no root class from which all other classes inherit. If no inheritance is declared, then a C++ class does not derive from any other class. (Although not precise from a graph theoretical standpoint, it is sometimes said that Java's inheritance hierarchy is a tree and C++'s is a forest.) What are the advantages and disadvantages of the approach taken by Java?
6. Although the C language does not support the class construct, it is possible to simulate classes using other C constructs, the C preprocessor, separate source code files, programming conventions, etc.

Explain in some detail how you can "implement" a "class" in C. (It must be possible to create and destroy instances of classes dynamically.)

## PART II

Answer ANY TWO of the questions 7 through 12.

7. Omitted question about a paper on the reading list.

8. In the paper “Logic Programming and Prolog: A Tutorial,” Davis states:

Logic programming has much to recommend it, whether it is used as an executable specification language or an implementation language. Separation of the logic and control aspects of a program allow a very high level description of the desired relationships without the over-specification that results from prescribing how they are to be computed. The declarative semantics of logical implication, the locality of reference, and the unification-driven computation scheme ensure that there can be no side effects and that each clause can be understood without reference to its position in a set of clauses. The specification of relationships rather than computations allows the same definition to be used in different ways, depending on what is supplied as input and what is expected as result. Unification, as the procedure-calling mechanism, obviates the need for selector functions and allows computation with partially defined objects.

Consider the programming language Prolog, an implementation language according to Davis. Explain how it accomplishes each of the issues in logic programming mentioned in the above quotation. Where necessary give brief examples to illustrate your ideas. (Exact syntax is not an issue here.)

9. Omitted question about a paper on the reading list.

10. Omitted question about a paper on the reading list.

11. Consider the article “Concepts, Evolution, and Application of Functional Programming Languages” by Paul Hudak.

(a) What are the primary differences between imperative and declarative languages?

(b) One of the primary concepts of purely functional languages and other declarative languages is the concept of *referential transparency*. What is meant by referential transparency? Why is referential transparency important in reasoning about programs? in enabling programs to be executed in parallel?

12. Omitted.

## PART III

Answer ANY ONE of the questions 13 through 18.

13. Specify a finite automaton (transition graph preferred) that accepts the language  $L = \{ wcc : w \in \{a, b\}^*, w \text{ has an even number of } a\text{'s and an odd number of } b\text{'s} \}$ . Note that the alphabet is  $\{ a, b, c \}$ . Be sure to indicate the initial and final states.
14. Construct a regular expression for the language  $L = \{ w : (n_a(w) - n_b(w)) \bmod 3 = 2 \}$ . Here  $(n_a(w))$  means the number of occurrence of symbol  $a$  in string  $w$ .
15. Construct a regular grammar for the language  $L = \{ w : w \in \{0, 1\}^*, \text{ where the sum of the values of the digits of } w \text{ is even} \}$ . Use  $S$  for the start symbol.
16. Consider the language  $L = \{ a^n b^l : 2n < l \}$ . Using the Pumping Lemma, prove that  $L$  is not regular.
17. Specify a pushdown automaton (transition graph preferred) for the language  $L = \{ a^n b^m : n \geq 0, n \neq m \}$ . Be sure to indicate the initial and final states.
18. Let language  $L = \{ a^n b^m c^k : n = m \text{ or } m = k \}$ . Construct a context-free grammar for  $L$ . Use  $S$  as the start symbol.

Complete ANY ONE of the questions 19 through 23.

19. Using the Pumping Lemma, prove that the language  $L = \{ a^n b^{2n} c^n : n > 0 \}$  is not regular.
20. Let  $L = \{ ww^R : w \in \{a, b\}^+ \}$ . Specify a Turing Machine (transition graph preferred) that halts in state  $q_f$  if its input is in  $L$  and halts in  $q_n$  otherwise.
21. Specify a Turing machine (transition graph preferred) to compute the function

$$f(x) = 3x - 1$$

where the number  $x$  is in **unary** notation. (That is,  $x$  is a string of 1's where the integer value of  $x$  is the length of the string.)

22. Construct a context-sensitive grammar the language  $L = \{ a^n b^{2n} c^n : n > 0 \}$ . Show the productions using  $S$  for the start symbol.
23. Omitted.