1. (total 20 points) Short answers: multiple choice and fill-in-the-blank.

(a) (4 points) There are many different criteria for evaluating programming languages, including readability, writability, reliability, cost, and so on. Among these, the most important criterion for judging a programming language is ______________. Justify your answer by stating the reason.

(b) (2 points) A language is said to be ______________ if it has a relatively small set of primitive constructs that can be combined in a relatively small number of ways to build the control and data structures of the language. Such a language is easy to learn and read because every possible combination is legal without an exception and the meaning is context independent.

(c) (2 points) Programming languages can be implemented by three general methods. Which method does Java use?
   i. Programs are translated into machine languages, which are executed directly on the computer.
   ii. Programs are interpreted by another program called an interpreter, with no translation whatever.
   iii. Programs are translated to an intermediate language designed to allow easy interpretation.
(d) (2 points) An attribute grammar is a BNF with three additions: attributes, attribute computation functions, and predicate functions. Among the three additions, the role of ________________ is to state the semantic rules or constraints of a grammar rule.

(e) (2 points) The address of a variable (l-value) is the machine memory address with which it is associated. Which of the following statements is incorrect about the address of a variable?

   i. A variable may have different addresses at different times during execution.
   ii. The same name may have different addresses at different places in a program.
   iii. If two variable names can be used to access the same memory location, they are called aliases.
   iv. Aliases are harmful to program efficiency.

(f) (2 points) Which storage binding scheme is described below? Storage bindings are created for variables when their declaration statements are elaborated. It allows recursion and conserves storage, however, it incurs overhead of allocation and deallocation and doesn’t support history sensitive variables for subprograms.

   i. Static
   ii. Stack-dynamic
   iii. Explicit heap-dynamic
   iv. Implicit heap-dynamic

(g) (2 points) There are five different subscript and storage bindings possible for arrays. Which one does Java use?

   i. Static array
   ii. Fixed stack-dynamic array
   iii. Stack-dynamic array
   iv. Fixed heap-dynamic array
   v. Heap-dynamic array

(h) (2 points) PHP supports several different types of values including Booleans, integers, floating-point numbers, strings, objects, and resources. Every PHP value regardless its type is either true or false value.

   i. True
   ii. False

(i) (2 points) Which of the following statements are incorrect about PHP strings?

   i. A string can be expressed by enclosing it in a pair of single or double quotes, e.g., ‘Hello’ and “Hello”.
   ii. There is no semantic difference between the use of single and double quotes in expressing a string.
   iii. A special character can be contained in a string by preceding it with a escape character.
   iv. Two strings can be concatenated with the dot (.) operator.
2. (5 points) In the history of computing, there are hundreds of notable computer programming languages, some evolving over time or influencing the designs of new languages. Name one particular language that became the most popular at some point in the history of computing. Why do you think it gained its popularity?

3. (4 points) The web platform is one of the most popular computing platforms of today. Name one or two programming languages that are most suitable for developing web applications.

   - Front-end web development:
   - Back-end web development:

4. (5 points) PHP provides two different equality operators, == and ===. State the difference between the two operators and show an example, i.e., two values that are == but not ===.

5. (6 points) State the difference between static binding and dynamic binding, and give an example of each in terms of bindings of variable attributes occurring in the following Java local variable declaration.

   ```java
   if (...) {
       int x = 10;
   ...
   }
   ```
6. (7 points) This question is about the ambiguity of a grammar.

- When a grammar is said to be ambiguous? I.e., give the definition of the ambiguity of a grammar.
- Prove or disprove the ambiguity of the following grammar.

\[ <E> \rightarrow <E> \ast <E> \]

7. (8 points) Write a BNF grammar for declaring the formal parameters of Java methods. Assume a nonterminal \(<ident>\) is defined to specify a parameter name. You may also assume that two parameter types, say \(\text{boolean}\) and \(\text{int}\), are allowed. Example sentences include:

- \(()\)
- \((\text{int} \ x)\)
- \((\text{int} \ x, \text{int} \ y, \text{boolean} \ z)\)
8. (15 points) Consider the following PHP code snippet.

```php
$name = "A";
$closure = function() {
    use ($name) {
        return sprintf("Hello,%s", $name);
    }
};
function callClosure() {
    global $closure;
    $name = "B";
    return $closure();
}
$name = "C";
echo callClosure();
```

(a) Define the referencing environments of lines 4 and 9, respectively.

(b) What value will be printed when the above code is executed, and why?

(c) What would be the referencing environment of line 4 with dynamic scoping?

(d) What value will be printed if the above code is Dart code, and why?
9. (15 points) Suppose a programming language PL\textsubscript{m} that supports multi-dimensional arrays. Your program written in PL\textsubscript{m} contains a two-dimensional array, say \(A[100, 50]\) (100 rows \(\times\) 50 columns). You learned that (i) each element of the array requires 2 bytes of memory, and (ii) \(A[0, 0]\) and \(A[10, 1]\) are stored at memory addresses 1000 and 2002, respectively, on a byte-addressable machine.

(a) Does PL\textsubscript{m} use row major order or column major order? Justify your answer by stating the reason.

(b) Write a formula that, given valid indices \(i\) and \(j\), gives the memory address where \(A[i, j]\) is stored.

(c) Calculate the memory address of \(A[10, 10]\).

10. (15 points) Consider the following PHP function.

```php
function f($n = 100) {
    for ($i = 0; $i < $n; $i++) {
        yield $i;
    }
}
```

(a) Describe the meaning of the `yield` statement.

(b) Write equivalent (but less efficient) Java code. You may assume that the above function is defined in some class. Hint: how do you use the function?
11. (10 points) Write a PHP function, named `deep_sum`, that takes an array and returns the sum of all its elements. An element of an (argument) array may be a numeric value or another array. If the element is an array, it should also be summed to calculate the return value. For example, `deep_sum([10, [10, 20]])` should return 40. Hint: use `is_array()` to determine if a variable is an array. Do not use any other array function except for `is_array()`.