Sample Exam Questions

1. (5 points) There are three major syntactic components of an Ada procedure. The first one is the list of declarations. What are the other two components? Write a (simple!) procedure that contains all three components.

2. (a) (10 points) In Scheme, write a function called \texttt{mapfun}, that takes two lists and applies each element of the first list to the corresponding element of the second list. A list of the results is returned. For example,

   \begin{verbatim}
   (mapfun (list add1 sub1 car) '(1 2 (3 4)))
   \end{verbatim}

   should return the list \((2 \ 1 \ 3)\), resulting from applying \texttt{add1} to \(1\), \texttt{sub1} to \(2\) and \texttt{car} to the list \((3 \ 4)\).

   (b) (10 points) In Scheme, define a function \texttt{create-fun-list} that takes an argument \(n\) and returns a list of functions \((f_1 \ldots f_n)\) such that each \(f_i\) is a function taking a single argument \(x\) and returning the value of \(x + i\). For example,

   \begin{verbatim}
   (mapfun (create-fun-list 4) '(1 1 1 1))
   \end{verbatim}

   returns the list \((2 \ 3 \ 4 \ 5)\). If you need to, you may define an auxiliary function to assist \texttt{create-fun-list}.

3. Consider the Ada procedure on the following page.

   (a) (5 points) In \texttt{add}, why did I introduce the variable \texttt{num}? That is, why not perform the addition on \texttt{sum} and the call to \texttt{another_procedure} using \texttt{x}, inside the accept statement?

   (b) (15 points) If \texttt{some_procedure} is a short procedure and \texttt{another_procedure} is a long procedure, \texttt{produce} will spend alot of time waiting for the rendezvous to occur each time through the loop.

   Suppose I want \texttt{produce} to execute \texttt{lotsa_work} as soon as possible after the 100 numbers are sent to \texttt{add}. To do this, I don’t want \texttt{produce} to wait until \texttt{add} has received all of those numbers. Modify the program so that, after sending a number, \texttt{produce} can continue executing (and sending more numbers), even though \texttt{add} was not yet ready to receive it. (hint: You will need another task or protected type to serve as an intermediary).
procedure foo is

    task produce;
task add is
        entry input(x:integer);
    end add;

    task body produce is
    begin
        for i in 1..100 loop
            add.input(i);
            some_procedure(i);
        end loop;
        add.input(-1);
        lotsa_work;
    end produce;

    task body add is
        num: integer;
        sum: integer := 0;
        done: boolean := false;
    begin
        while not done loop
            accept input(x:integer) do
                num := x;
            end input;
            if (num >= 0) then
                sum := sum+num;
                another_procedure(num);
            else
                done := true;
            end if;
        end loop;
        put(sum);
    end add;

begin
    null;
end foo;

4. (a) Define the term *abstraction*, as it is used in computer science.

(b) The type systems of several of the languages we studied support abstract data types. In Ada and in either Java or C++, write the definition of an abstract data type called *ant* with the following components:

Visible components:

- An operation *crawl* that allows the user to specify the direction, speed, and duration (all integers) of the ant’s crawl.
- A function *position* that indicates the current position as x and y coordinates (also integers) of the ant.
Hidden components:

- An integer variable `x`, position
- An integer variable `y`, position

You do not have to provide the code for the body of the procedures crawl and position.

(c) Although ADT’s are not supported directly by Scheme’s type system, write a scheme procedure `make-ant` that returns an object that has similar characteristics, in terms of the visibility of its components, to the ADT’s you defined in part c.

5. (a) In C++, what does it mean for a class B to be considered a subtype of a class A?
(b) If a C++ class B is publicly derived from a class A, why is it safe to consider B a subtype of A? Why doesn’t C++ allow A to be treated as a subtype of B?
(c) Write a C++ template procedure `sum` that will work for any class for which `operator+` is defined, such that `sum` takes an array of objects of the class and the size of the array as parameters, and returns the sum of the elements of the array.

6. (a) What is concurrency? Be sure to include in your answer the case in which there is only a single processor.
(b) Given the function `dfac` defined as

\[
\text{dfac}(x,y) = \begin{cases} 
  x = y & \text{then } x \\
  \text{else } \text{dfac}(x,(x+y)/2) \times \text{dfac}((x+y)/2+1,y)
\end{cases}
\]

notice that `factorial(n) = \text{dfac}(1,n)`, assuming that integer division truncates. Here is the Ada code for `dfac`:

```ada
function dfac(low,high:integer) return integer is
  mid : integer;
begin
  if low = high then return low;
  else
    mid := (low + high)/2;
    return dfac(low,mid) \times dfac(mid+1,high);
  end if;
end dfac;
```

The nice thing about this method for computing factorial is that it can be parallelized by performing the two recursive calls in parallel. Write in Ada the parallel version of `dfac`.

7. I’m having trouble getting my C++ program, below, to compile and run correctly.

```cpp
#include <iostream.h>

class A {
  A(): y(7) {}
  void f(int x) { cout << "x = " << x << " y = " << y << endl; }
  int y;
};

class B: public A {
  B(int w): z(w), A(4) {}
  void f(int x) { cout << "x = " << x << " y = " << y << " z = " << z << endl; }
  int z;
```
void g(A c)
{
    c.f(7);
}

I want my main() procedure,

int main()
{
    B b(13);
    g(b);
}

to print out

x = 7, y = 4, z = 13

Without modifying main(), fix the code above (on the exam sheet, if you like) so that the program will compile and run as I expect. Be sure that, in good object oriented style, no class member is more widely visible than it needs to be.

8. (a) Novice Java programmers often write code similar to,

    class C { public int x; ... }

    C[] a = new C[10];
    for(int i = 0; i < a.length; i++)
        a[i].x = i;

What is the problem with this code? Fix it.

(b) Other novice Java programmers might write,

    class C {
        int f() {
            return System.in.read();
        }
    }

and get a compiler error that says something about System.in.read() throwing an exception. What is the problem? Fix it.

9. The Java API defines the Comparable interface as

    interface Comparable {
        int compareTo(Object);    
    }

where x.compareTo(y) should return -1 if x is less than y, 0 if they are equal, and 1 otherwise.

Define a class MyArray that implements Comparable and whose objects behave like integer arrays. MyArrays should be compared based on the sum of their elements. For example,

    int[] a = new int[] {1,2,3,4};  //create an array and initialize the elements
    int[] b = new int[] {-1,2,-3,4,-5};
    MyArray m1 = new MyArray(a);  //the elements of m1 are those of a
    MyArray m2 = new MyArray(b);  //the elements of m1 are those of b
    System.out.println(m1.compareTo(m2));  //prints 1, since 1+2+3+4 > -1+2-3+4-5
Define just enough of the MyArray class for the above code to work.

10. What is the type of the ML procedure f defined by

   \texttt{fun f a \ (b::bs) = if a = b then [bs] else []}

11. (a) Assume the following procedure is defined in a language that uses pass-by-value-result.

\begin{verbatim}
procedure f(x,y :integer);
begin
  x := x + 1;
  y := y * 2;
end;
\end{verbatim}

Write a procedure in C that simulates this procedure.

(b) The language Algol uses the pass-by-name parameter passing mechanism. What would the following Algol program print?

\begin{verbatim}
begin
  integer array A[10];
  integer n;

  procedure F(x,y)
    value y; integer x, y;
    begin
      y := y + 1;
      x := 5;
    end;

  n := 1;
  A[1] := 1;
  F(A[n], n);
  print(A[1],A[2]);
end
\end{verbatim}