immediately report any discrepancy to the invigilator. Should you need to do so, you may continue your answers on the back of pages.

Do not forget to write your ID number on each page.

ID number: ________________________________

Question 1. **(20 points)**

Given the tree shown in **Figure 1**:

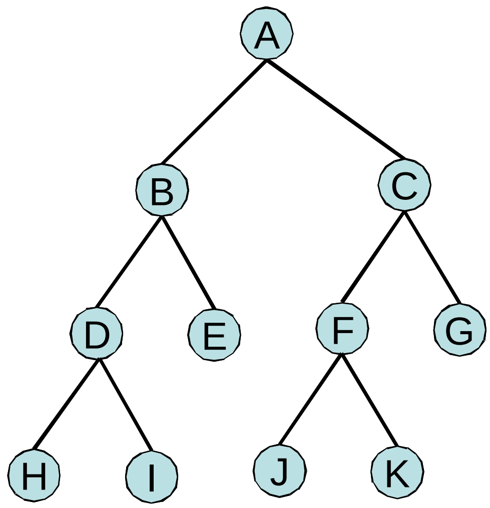


Figure 1. Tree with Root at Node with Element A

Note: The labels on the nodes represent the elements (A..K) held by the nodes

a. What is the output of the program shown on next page with the tree as input? **(7 points)**

Assume that the Node_Pointer_Stack package provides the necessary stack subprograms such as Create, Push, Pop, Empty_Stack, Full_Stack.

A
B
D
H
I
E
C
F
J
K
G

b. What is the algorithm implemented by the program? **(3 points)**

Preorder Traversal or DFS

```
-- code for question 1a and 1b
with Node_Pointer_Stack;
use Node_Pointer_Stack;

procedure Question_1_a_b (
      Root : in     Nodeptr) is
      Nodeptr_Stack : My_Stack;

begin
   -- create a temporary stack for
   My_Pointer_Stack.Create(Nodeptr_Stack);
   Push (Nodeptr_Stack, Root);

   -- loop until there are no nodes in the stack
   loop
      exit when Empty_Stack(Nodeptr_Stack);
      --get the first node from the stack
      Pop(Nodeptr_Stack, Temp);
      -- display the element
      Ada.Text_Io.Put(Temp.Element);
      Ada.Text_Io.New_Line;
      --if the right child is not null, push it
      if Temp.Right_Child /= null then
         Push(Nodeptr_Stack, Temp.Right_Child);
      end if;
      --if the left child is not null, push it
      if Temp.Left_Child /= null then
         Push(Node_Ptr_Stack, Temp.Left_Child);
      end if;
   end loop;
end Question_1_a_b;
```

ID number: ______________________________

c. What is the output of the program shown below, with the tree in **Figure 1** as input?
(10 points)

```
with Node_Pointer_Stack;
use Node_Pointer_Stack;

procedure Question_1_c (
      Root : in     Nodeptr) is
      Nodeptr_Stack : My_Stack;

begin
   -- create a temporary stack for
   My_Pointer_Stack.Create(Nodeptr_Stack);
   Push (Nodeptr_Stack, Root);

   -- loop until there are no nodes in the stack
   loop
      exit when Empty_Stack(Nodeptr_Stack);
      --get the first node from the stack
      Pop(Nodeptr_Stack, Temp);
      -- display the element
      Ada.Text_Io.Put(Temp.Element);
      Ada.Text_Io.New_Line;

      --if the left child is not null, push it
      if Temp.Left_Child /= null then
         Push(Node_Ptr_Stack, Temp.Left_Child);
      end if;

      --if the right child is not null, push it
      if Temp.Right_Child /= null then
         Push(Nodeptr_Stack, Temp.Right_Child);
      end if;

   end loop;
   null;
end Question_1_c;
```

A

C

G

F

K

J

B

E

D

I

H

ID number: ______________________________

Question 2. **(20 points)**

a. Find the Minimum weight spanning tree (MST) for the graph shown in **Figure 2**. Show all the steps in the computation of the MST. **(15 points)**

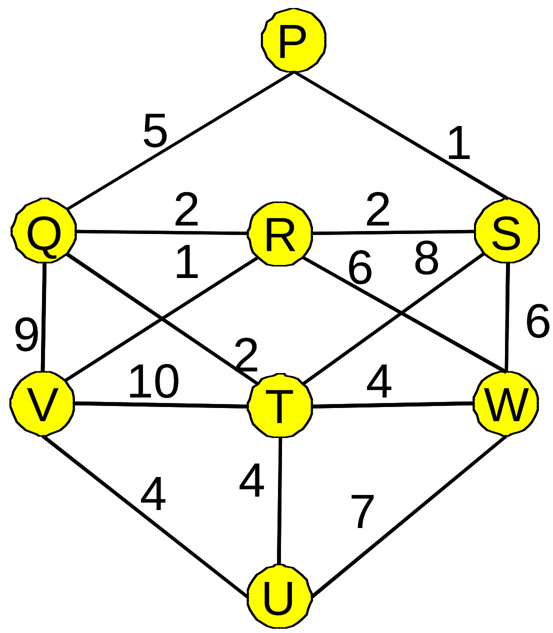
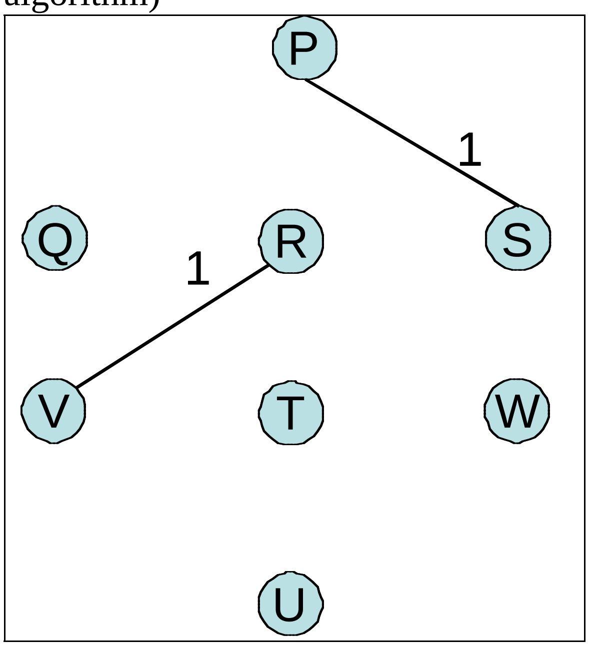
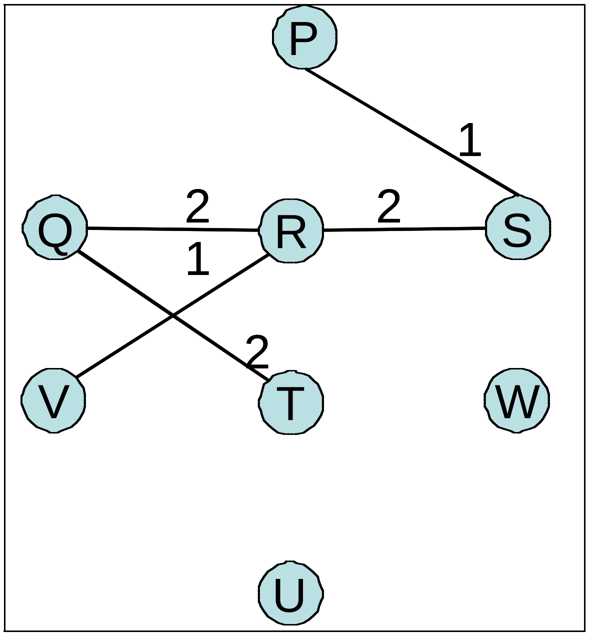
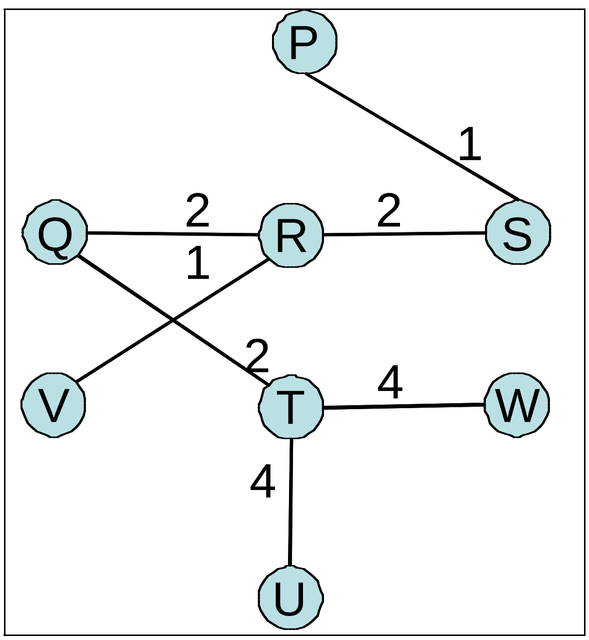


Figure 2.

Using Kruskal's algorithm (Alternatively you could also have used Prim's algorithm)







b. Is the MST unique? Justify your answer. **(5 points)**

The MST is **not** unique. For example as in the example above, choosing the edge between V and U of weight 4 instead of the edge between T and U of same weight, would have given us a different MST, but with the same total weight.

ID number: ______________________________

Question 3. **(15 points)**

Show the computation of T(n) and the Big-O complexity for the code shown below.

Statement	Work
`with Ada.Text_Io;`	
`procedure Compute_Increment (`	
`      Row       : in      Integer;`	
`      Column    : in      Integer;`	
`      Increment :     out Integer   ) is`	
`begin`	
`   Increment := 1;`	**C1**
`   for I in Row -1 .. Row + 1 loop`	**4*C2**
`      for J in Column - 2 .. Column+2 loop`	**3*6*C3**
`         if I mod 2 = 0 then`	**3*5*C4**
`            Increment := Increment + 1;`	**2*5*C5** OR(1*5*C5)
`         end if;`	
`      end loop;`	
`   end loop;`	
`   Ada.Text_Io.Put(Integer'Image(Increment));`	**C6**
`end Compute_Increment;`	

a. What is T(n)? **(10 points)**

T(n) = C1 + 4C2 + 18C3 + 15C4 + 10C5 + C6 = C

In the best case, Row is even, so I mod 2 is 0 only once. In the worst case, Row is odd, so I mod 2 is 0 twice.

ID number: ___________________________________

b. What is O(n)? **(5 points)**

O(n) = 1

ID number: ___________________________________

Question 4. **(15 points)**

a. What is the algorithm implemented by the code shown below? **(5 points)**

Note: Assume that the array is sorted in **ascending** order

```
procedure Question_4_A (
      Input_Array : in     My_Array;
      Lb          : in     Integer;
      Ub          : in     Integer;
      Element     : in     Integer;
      Location    :    out Integer) is
   Found       : Boolean;
   Left_Index,
   Right_Index : Integer;
begin
   Left_Index := Lb;
   Right_Index := Ub;
   Found := False;
   loop
      exit when Found = True or Left_Index > Right_Index;

      if Input_Array((Left_Index+Right_Index)/2) = Element then
         Location := (Left_Index + Right_Index)/2;
         Found := True;
      else
         if Input_Array((Left_Index+Right_Index)/2) < Element then
            Left_Index := ((Left_Index+Right_Index)/2) +1;
         else
            Right_Index := ((Left_Index+Right_Index)/2) -1;
         end if;
      end if;
   end loop;
   if Found = False then
      Location := -1;
   end if;
end Question_4_A;
```

Binary Search

ID number: ___________________________________

b. Write a recursive implementation (i.e., the actual Ada code) of the algorithm from 4.a **(10 points)**

```
procedure Question_4_A (
      Input_Array : in     My_Array;
      Lb          : in     Integer;
      Ub          : in     Integer;
      Element     : in     Integer;
      Location    :    out Integer) is
   Mid : Integer;

begin
   Mid := (Lb + Ub)/2;
   if (Lb > Ub) then
      Location := -1;
   else
      if Input_Array(Mid) = Element then
         Location := Mid;
      else
         if Input_Array(Mid) < Element then
            Question_4_A(Input_Array, Mid+1, Ub, Element, Location);
         else
            Question_4_A(Input_Array, Lb, Mid-1, Element, Location);
         end if;
      end if;
   end if;

end Question_4_A;
```

ID number: ______________________________

Question 5. **(20 points)**

a. What is the record declaration for a node with four fields **(5 points)**

Element	of type	character
Sibling	of type	node pointer
Left_Child	of type	node pointer
Right_Child	of type	node pointer

```
type Node;
type Nodeptr is access Node;
type Node is record
   Element : Character;
   Sibling : Nodeptr;
   Left_Child : Nodeptr;
   Right_Child : Nodeptr;
end record;
```

b. Write a program (fill out skeleton on next page) to insert a node into a binary search tree. **(15 points)**

Note: you should make siblings (nodes with the same parent) point to each other, as shown in Figure 3.

ID number: ______________________________

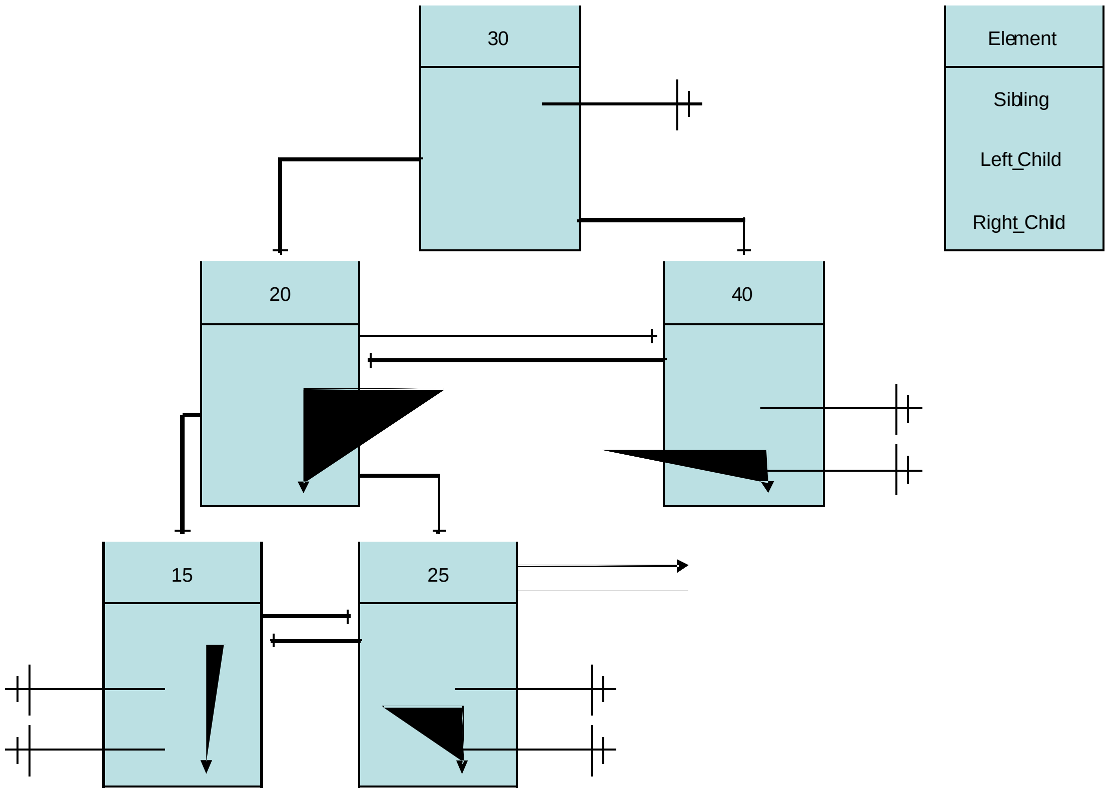


Figure 3. Sibling Connected Tree

```
procedure Question_5_B (
      Root          : in out Nodeptr;
      Input_Element : in     Element_Type) is
   Temp : Nodeptr;
   --add any local variables you want
    Inserted : Boolean;
     Tracker : Nodeptr;
begin
   Temp := new Node;
   Temp.Element     := Input_Element;
   Temp.Sibling     := null;
   Temp.Left_Child  := null;
   Temp.Right_Child := null;


  if Root = null then
      Root := Temp;
   else
      Inserted:= False;
      Tracker := Root;
      loop
         exit when Inserted = True;
         if Tracker.Element < Input_Element then
            if Tracker.Right_Child = null then
               Tracker.Right_Child := Temp;
               Temp.Sibling := Tracker.Left_Child;
               if Tracker.Left_Child /= null then
                  Tracker.Left_Child.Sibling := Temp;
               end if;
```

```
            Inserted := True;
         else
            Tracker := Tracker.Right_Child;
         end if;

      else
         if Tracker.Left_Child = null then
            Tracker.Left_Child := Temp;
            Temp.Sibling := Tracker.Right_Child;
            if Tracker.Right_Child /= null then
               Tracker.Right_Child.Sibling := Temp;
            end if;
            Inserted := True;
         else
            Tracker := Tracker.Left_Child;
         end if;
      end if;
   end loop;
  end if;
end Question_5_B;
```

ID number: ________________________________

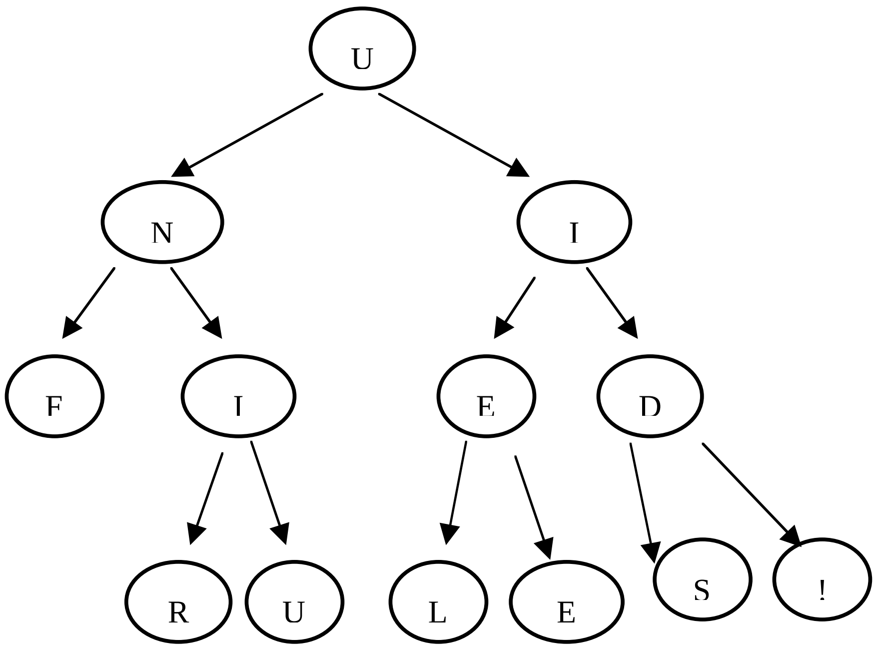
Question 6 **(10 points)**

Multiple Choice Questions. For each question, select the correct answer from the choices, and **write the chosen letter in the box provided** next to each question.

Answer

1. Traversing the tree below in depth-first order means visiting the nodes in the following order:
   a. UNFIRUIEDLES!
   b. UNIFIEDRULES!
   c. UNFIRUIELEDS!

C



2. The following prefix expression +-23*45 evaluates to:

B

   a. 21
   b. 19
   c. 9
   d. 7

ID number: ______________________________

3. Memory can be broken down into a Code, Data, Heap, and Stack portion. What types of variables are stored in the heap?

A

a. Variables created by "new"
b. Variables created after "is" and before "begin" in a subprogram
c. Independent variables - like in a scientific experiment

4. When it comes to a stack, which of the following statements is true?

   a. The process of deleting an object is called Push
   b. All insertions of elements take place at the front of the data structure and deletions of elements take place at the end of the data structure
   c. Stacks are LIFO structures

C

5. I want one of the upcoming C&P pset to be a Lego problem set

   a. Yes
   b. No

A/B