Module 1: Cairn

Question 1 — 0.5 pts

Suppose that you had a program written in Java that maintains a list of courses that a student was taking, and that program was exhibiting issues from reference types. Which of the following would most likely indicate that issue?

1- The program crashes immediately with a null pointer exception.
2- The program prompts the user for input, but instead of waiting, instantly reads a null string and continues.
3- The program crashes immediately with an error message about allocating memory for a new Student object.
4- Even after adding ten unique classes, when displaying everything, it shows the same ten classes.

Answer: 4

Question 2 — 1.5 pts

Which of the following statements are true of the concepts listed below?
A) Defines operations.
B) Defines state.
C) Not concerned with internal implementations.

1- A) is true of ADTs.
2- B) is true of ADTs.
3- C) is true of ADTs.
4- A) is true of Classes.
5- B) is true of Classes.
6- C) is true of Classes.
7- A) is true of Interfaces.
8- B) is true of Interfaces.
9- C) is true of Interfaces.

Answer: 1,3,4,5,7,9

Question 3 — 2 pts

Given the following API for a mutable `Employee` ADT, determine if each of the operations is an extraction, or transformation.

```
int    getId();                      [Extraction / Transformation]
void   logWorkHours(double hours);   [Extraction / Transformation]
double calculatePayCheck();          [Extraction / Transformation]
void   logVacationTime(int days);    [Extraction / Transformation]
int    vacationTimeAvailable();      [Extraction / Transformation]
void   logSickDays(int days);        [Extraction / Transformation]
int    paidSickDaysAvailable();      [Extraction / Transformation]
```

Answer:

1- Extraction
2- Transformation
3- Extraction
4- Transformation
5- Extraction
6- Transformation
7- Extraction

Question 4 **2 pts**

The following class represents a 3d shape using an array of 3dPoints. It is intended to be immutable. Assume the 3dPoint class is immutable.

Some of these functions, by their nature, make the class mutable and should be removed completely to make it immutable.

Some others might make the class mutable, but it is possible to make them safe by implementing them carefully.

Others are mostly safe in an immutable class.

Determine which functions should be removed, which must be carefully implemented, and which are safe.

```
class 3dShape {
    private 3dPoint points;
    public 3dShape(3dPoint[] points);

    // Sets the point array member to the given point array
    public void setPoints(3dPoint[] points);

    // Returns the point array member
    public 3dPoint[] getPoints();

    // Returns the volume of the shape represented by the point
    public double getVolume();

    // Stretches the shape by the percent specified in each direction
    public void stretch(double x, double y, double z);
}
```

Choices are:

- needs to be removed.
- needs to be carefully implemented.
- does not need special attention.

function 1:
function 2:
function 3:
function 4:

Answer:

function 1: needs to be removed.
function 2: needs to be carefully implemented.
function 3: does not need special attention.
function 4: needs to be removed.

Question 5 **1 pts**

Select the functions from the following list that could belong to an ADT. Remember that not all ADTs are immutable. (Hint: ask yourself if these methods belong in an idealistic ADT, i.e. one truly meeting the ADT design rule.)

```
1- Account ADT
   // Accepts an int and sets the account's opening year to that
   setYear(int year)
2- Bag ADT
   // Sets the max capacity of the bag to the given integer
   setMax(int capacity)
3- Queue ADT
   // Sets the queues internal ArrayList to the given ArrayList
   setMaxCapacity(int capacity)
4- Queue ADT
   // Removes the least recently added item
   dequeue() throws ArrayOutOfBoundsException
```

Answer:

1,2

Module 2: Cairn

Question 1 — 0.5 pts

Consider the following implementation of a 1D vector class:

```
class IntVector {
  private final int[] data;
  public IntVector(int[] vector) {
      if (vector == null)
          throw new IllegalArgumentException();
      data[y] = vector[y];
  }
  // ...
}
```

Is this class immutable? Answer yes/no, and justify.

1- Yes - the constructor validates that there is no outside refeference to the data and throws an exception if there is.
2- Yes - the member variable is set to final and the constructor makes a deep copy.
3- No - although the member variable is set to final, the constructor does not make a deep copy.
4- No - the constructor always throws an exception before it is able to copy the data.
5- No - this would not even compile since there is an assignment to a final variable in the constructor.
6- Yes - the member variable is set to final and that is sufficient.

Answer: 5.

Question 2 — 1 pts

Select the functions from the following list that could belong to an ADT. (Hint: ask yourself if these methods belong in an idealistic ADT, i.e. one truly meeting the ADT design rule.)

1- Stack ADT
   // add an item
   `push(Item item)`
2- Stack ADT
   // Sets the stack's internal `ArrayList` to the given `ArrayList`
   `setContents(ArrayList contents)`
3- Stack ADT
   // Sets resize factor for the internal array
   `setResizeFactor(float rsf)`

4- Stack ADT
   // remove the most recently added item
   `pop() throws EmptyStackException`
5- Stack ADT
   // remove the most recently added item
   `pop() throws ArrayOutOfBoundsException`

Answer: 1,4.

Question 3 **1 pts**

It is correct to say that the nodes in a linked list are... (select all that apply)

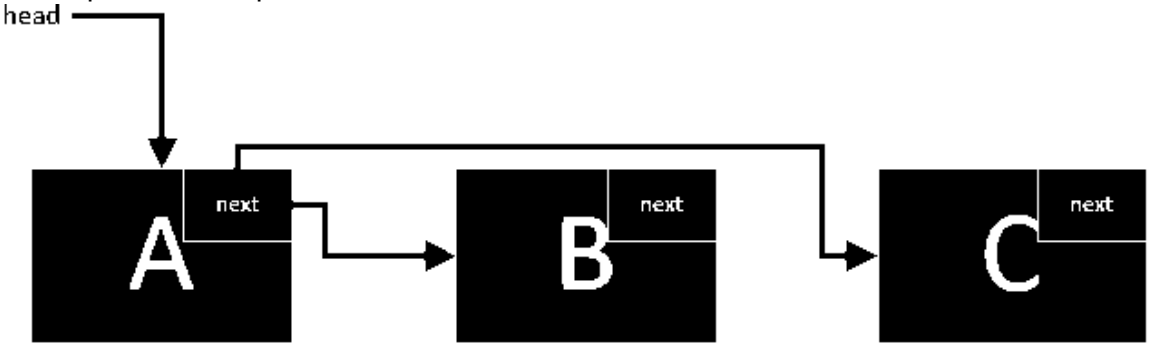
1- statically allocated.
2- recursive data.
3- dynamically allocated.
4- contiguously allocated next to each other in main memory

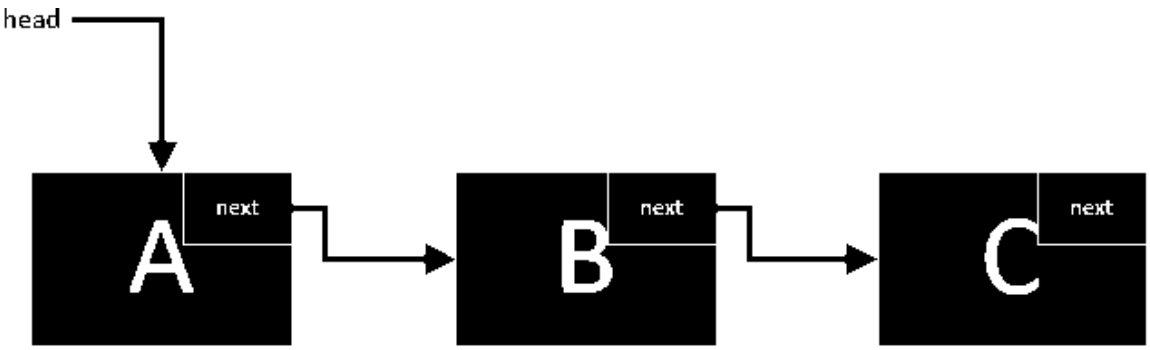
Answer: 2,3.

Question 4 **0.5 pts**

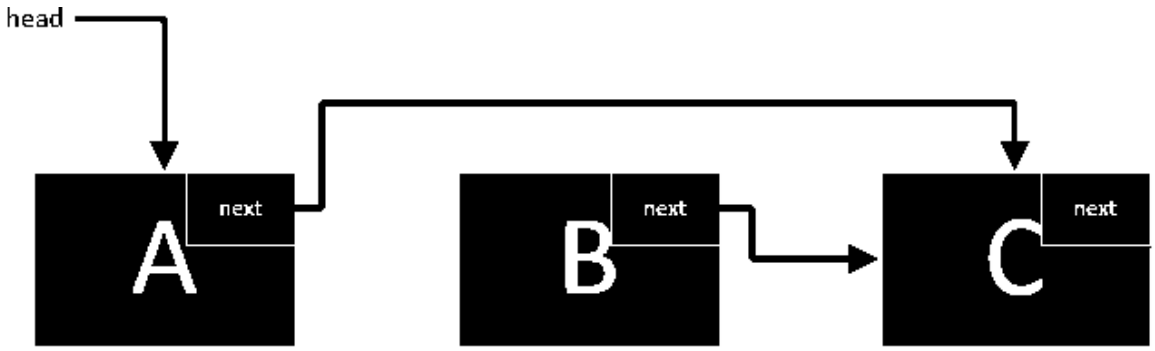
Assume that `head` is the head node of a singly-linked list containing the nodes A, B, and C. What would the result of executing the following code be? Indicate the resulting list using box and arrow notation.

```
head.setNext(head.getNext().getNext());
```

1- A null pointer exception will be thrown.
2-


3-


4- None of these.

5- 

Answer: 5.

Question 5 **0.5 pts**

Consider the code below. Assume head points to the beginning of a list and is a class variable

```
public void methodA(Node newNode) {
    if(head == null)
        head = newNode;
    else {
        newNode.next = head;
        head = newNode;
    }
}

public void methodB(Node newNode) {
    Node iter = head;
     if(head == null)
        head = newNode;
    else {
        while(iter.next != null)
            iter = iter.next;
        Iter.next = newNode;
    }
}
```

Suppose the list already has five elements. What code would be faster in terms of adding an element to the list?

1- Both are the same because they both add a node to a linked list.
2- Method A because you don't have to traverse through the list.
3- Method B because it checks null before spending time to do anything else.
4- Method A because it has fewer lines of code.
5- Method B because it safely adds a new node to the list using an iterator node.

Answer: 2.

Question 6 **2 pts**

Assume we have an array with contents 1, 5, 3, 7, 8. Those contents could also be stored with a singly linked list (with 1 at the head, no tail variable). When considering performance:

It is faster to access 8 in a [array].

It is faster to access 1 in a [array].

Resizing a linked list would typically be [faster] as compared to an array because a linked list is [dynamically allocated].

Question 7 **0.5 pts**

Compare the amount of memory needed to store an array of 100 integers and a linked list containing 100 integers. Which requires less? Or are they the same? Justify.

1- List - it will be exactly the number of elements until the array.
2- Array - since that will allow the use of bracket notation.
3- Array - it will only store the integers, no other references.
4- List - they are always smaller than arrays.
5- Same - they store the same number of elements.

Answer: 3.

Question 8 **1 pts**

Which of the following statements are true about generics? Select all that apply.

1- They allow for different data types in the code without specifying one at the beginning.
2- They are limited to object types but can still use primitives through wrapper classes.
3- They make compiled files smaller.
4- They make code reusable.

Answer: 2.

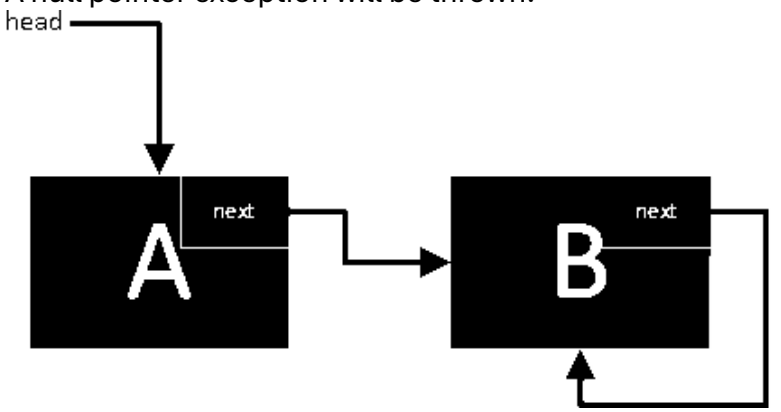
Module 3: Cairn

Question 1 **1 pts**

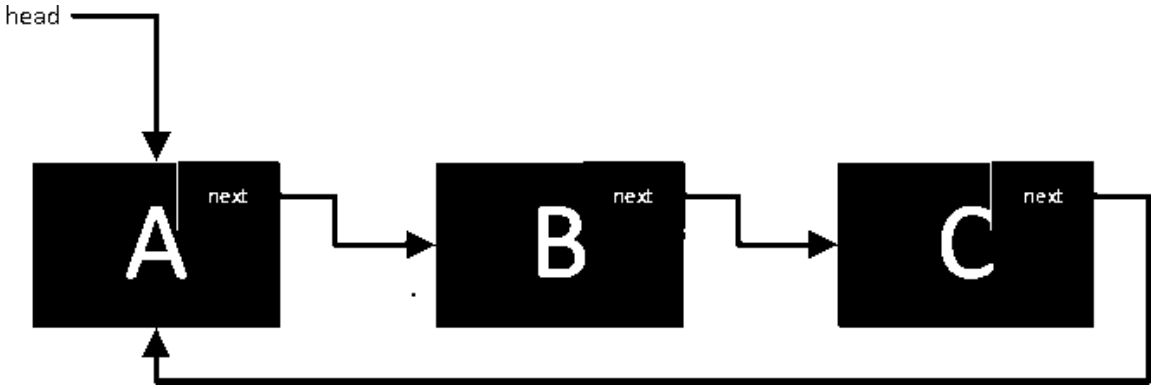
[Acuña] Assume that head is the head node of a singly linked list containing the nodes A, B, and C. What would the result of executing the following code be? Indicate the resulting list using box and arrow notation.

```
head.getNext().setNext(head.getNext());
```

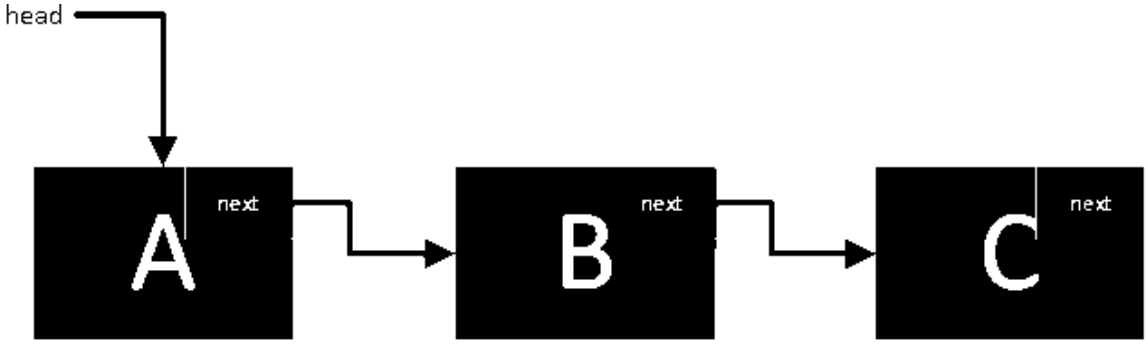
1- None of these.
2- A null pointer exception will be thrown.
3-



4-



5-



Answer: 3.

Question 2 **1 pts**

Suppose that you are asked to analyze the Big-Oh of the following method `pop()`. What pieces of additional information which need to give a perfectly accurate answer? Select all that apply.

```
public ItemType pop() {
    if(isEmpty())
     throw new NoSuchElementException();

   ItemType element = top.getElement();
   top = top.getNext();
   n--;

   return element;
}
```

1- The Big-Oh of the constructor of the `NoSuchElementException` class.
2- The number of times `pop()` will be called.
3- The type that will be used in place of ItemType.
4- The Big-Oh of `isEmpty()`.

Answer

2,4

Question 3 **1 pts**

Assuming there is a growth function $f(n)$, what does the value of $f(0)$ represent in terms of an algorithm?

Answer

$f(0)$ helps us understand the baseline or "fixed" cost of an algorithm when the input size is minimal or zero.

Question 4 **0.5 pts**

What is the Big-Oh order of the following growth expression?

$$f(n) = 24n + 2nlg(n) + 280$$

1- $O(24n)$
2- $O(2nlg(n))$
3- $O(n)$
4- $O(280)$
5- $O\big(nlg(n)\big)$

Answer

$$O\big(nlg(n)\big)$$

Question 5 **0.5 pts**

Is it *correct* to say that the expression in the previous question is $O(2^n)$? Explain.

Answer

No; because:

- $nlog(n)$ is **polynomial growth** with a logarithmic factor.
- 2^n is **exponential growth**, which increases much faster than any polynomial or logarithmic function.

Question 6 **0.5 pts**

What is the Big-Oh order of the following code fragment? The size of the problem is expressed as n.

```
for (int i = 1; i <= n; i++)
  for (int j = 1; j <= n; j += 2)
   System.out.println("Nested loops!");  //f(n) counts these
```

1- $O(n^2)$
2- $O(n + lg(n))$
3- $O(nlg(n))$
4- $O(lg(n)lg(n))$

Answer

$O(n^2)$

Question 7 **0.5 pts**

What is the Big-Oh order of the following code fragment? The size of the problem is expressed as n.

```
for (int i = 0; i < (int)Math.pow(2, n); i++)
   System.out.println("what could could go wrong?");  //f(n) counts these
```

1- $O(2^n)$
2- $O(n^2)$
3- $O(lg(n))$
4- $O(1)$
5- $O(n)$

Answer

$O(2^n)$

Question 8 **0.5 pts**

What is the tilde approximation of the following growth function?

$$f(n) = n + 5n^4 + nlg(n)$$

1- n^4
2- Does not exist.
3- 5
4- ~ 5
5- $5n^4$
6- $\sim n^4$
7- $\sim 5n^4$
8- $\sim nlg(n)$

Answer

$\sim 5n^4$

Question 9 **0.5 pts**

You are in the process of choosing between two 3rd party libraries that implement some algorithm and have found two solutions, A and B, that are advertised as $O(n)$ and $\sim n$, respectively. Which of these solutions would you prefer in terms of performance? Explain. (Hint: think about which one gives a more "stable" result).

Answer

In terms of **performance**, you would prefer **Solution B** $(\sim \boldsymbol{n})$, as it provides more precise and predictable performance characteristics. The tilde notation suggests that the algorithm's behavior is well-analyzed and predictable, which often translates to better and more stable real-world performance.

Module 5: Cairn

Question 1 — 1 pts

Consider the following problem, and categorize according to the different axis of problem complexity: create an algorithm to determine which song from a collection to recommend to a user, based on what they have listened to in the past.

It is **[Select]** ["open-ended", "close-ended"] and **[Select]** ["ill-defined", "well-defined"].

Answer:

Open-ended and ill-defined.

Question 2 — 1 pts

Understanding the data format and ordering requirements for an algorithm that needs to (as a sub-problem) sort data would take place during **[Select]** ["Analysis", "Design", "Justification"] , while analyzing the sorting algorithm's ability to meet those requirements would happen during **[Select]** ["Analysis", "Justification", "Design"] .

Answer:

Design, analysis.

Question 3 — 1.5 pts

Consider the following array: `21,16,3,7,23,12`. Show a trace of execution for **selection sort.** The trace begins with the provided initial state of the array, followed by the array's state after each **swap** is made.

Enter each subsequent state as a comma separated list (as shown by the initial state). Do not include any spaces. If you follow these directions exactly and are marked off by the auto-grader on the second submission, reach out to the instructional staff.

```
initial: 21,16,3,7,23,12
i  =  0: 3,16,21,7,23,12
i  =  1:
i  =  2:
i  =  3:
i  =  4:
i  =  5:
```

Answer

```
i  =  1: 3,7,21,16,23,12
i  =  2: 3,7,12,16,23,21
i  =  3: 3,7,12,16,23,21
i  =  4: 3,7,12,16,21,23
i  =  5: 3,7,12,16,21,23
```

Question 4 — 1.5 pts

Consider the following array: `21,16,3,7,23,12`. Show a trace of execution for **insertion sort**. The trace begins with the provided initial state of the array, followed by the array's state after each **pass** is made.

Enter each subsequent state as a comma separated list (as shown by the initial state). Do not include any spaces in your answer. If you follow these directions exactly and are marked off by the auto-grader on the second submission, reach out to the instructional staff.

```
initial: 21,16,3,7,23,12
i  =  1: 16,21,3,7,23,12
i  =  2:
i  =  3:
i  =  4:
i  =  5:
```

Answer

```
i  =  2: 3,16,21,7,23,12
i  =  3: 3,7,16,21,23,12
i  =  4: 3,7,16,21,23,12
i  =  5: 3,7,12,16,21,23
```

Question 5 — 1 pts

Selection sort assumes there is a region of [Select] ["unsorted elements at the front", "sorted elements at the front", "sorted elements at the back", "unsorted elements at the back"] of a collection, picks the first unsorted element and places it [Select] ["in the middle of", "at the beginning", "at the end"] of the sorted region, until the entire list is sorted.

Answer:

sorted elements at the front, at the end.

Question 6 **0.5 pts**

What is the Big-Oh order of the following code fragment? The fragment is parametrized on the variable `N`. Assume that you are measuring the number of assignments to min.

```
int N = a.length;
for (int i = 0; i < N; i++) {
    int min = i;                  //assignment to min
    for (int j = i+1; j < N; j++)
        if (less(a[j], a[min]))
            min = j;              //assignment to min
    exch(a, i, min);
}
```

Group of answer choices

1- $O(logn)$
2- Does not exist, or cannot be determined with information given.
3- $O(n^2)$
4- $O(n)$
5- $O(nlogn)$
6- $O(1)$

Answer

$O(n^2)$

Question 7 **0.5 pts**

What is the most efficient sorting algorithm to use for the data set `1,3,5,7,9` assuming you want to sort the numbers in ascending order.

Group of answer choices

1- Bogo Sort.
2- Shell Sort.
3- Selection Sort.
4- Insertion Sort.

Answer

Insertion Sort

Module 6: Cairn

Question 1 — 1 pts

Consider the following array: `3,8,23,18,15,16`. Show a trace of execution for **insertion sort**. The trace begins with the provided initial state of the array, followed by the array's state after each **pass** is made.

Enter each subsequent state as a comma separated list (as shown by the initial state). Do not include any spaces in your answer. If you follow these directions exactly and are marked off by the auto-grader on the second submission, reach out to the instructional staff.

```
initial: 3,8,23,18,15,16
i  =  1: 3,8,23,18,15,16
i  =  2:
i  =  3:
i  =  4:
i  =  5:
```

Answer

```
i  =  2: 3,8,23,18,15,16
i  =  3: 3,8,18,23,15,16
i  =  4: 3,8,15,18,23,16
i  =  5: 3,8,15,16,18,23
```

Question 2 — 0.5 pts

Match the following scenarios with which sorting algorithm is potentially most appropriate. (Find the best matching, with using each algorithm exactly once.)

1- Datasets that are already almost sorted.
[Choose] Shellsort Selection Sort Mergesort Insertion Sort

2- Datasets being analyzed on system with a limited number of writes.
[Choose] Shellsort Selection Sort Mergesort Insertion Sort

3- Large datasets where memory is not a limitation.
[Choose] Shellsort Selection Sort Mergesort Insertion Sort

4- Datasets where elements are very far away from where they need to be.
[Choose] Shellsort Selection Sort Mergesort Insertion Sort

Answer

1- Insertion Sort
2- Selection Sort
3- Mergesort
4- Shellsort

Question 3 — 3 pts

Consider the following array: 2, 13, 16, 3, 7, 23, 12, 25. Show a trace of execution for top-down mergesort using the method shown in lecture (where both sides are updated at once). Illustrate the contents of the array as it is broken down, and then merged into an ordered state.

Enter each subsequent state as a comma separated list (as shown by the initial state). Do not include any spaces or brackets in your answer. If you follow these directions exactly and are marked off by the auto-grader, reach out to the instructional staff.

```
1 (initial) : 2,13,16,3,7,23,12,25 (given as example)
2 (down)    : 2,13,16,3,7,23,12,25 (given as example; nothing changed!)
3 (down)    :
4 (mid)     :
5 (up)      :
6 (up)      :
7 (up)      :
```

Answer

```
3 (down)    : 2,13,16,3,7,23,12,25
4 (mid)     : 2,13,16,3,7,23,12,25
5 (up)      : 2,13,3,16,7,23,12,25
6 (up)      : 2,3,13,16,7,12,23,25
7 (up)      : 2,3,7,12,13,16,23,25
```

Question 4 — 0.5 pts

What is the Tilde approximation order of the following code fragment? Assume that you are measuring the number of assignments to a[], and that n represents the number of indices between lo and hi, inclusive.

```
public static void merge(Comparable[] a, Comparable[] aux, int lo, int mid, int hi) {
    int i = lo, j = mid+1;
    for (int k = lo; k <= hi; k++)
        aux[k] = a[k];
    for (int k = lo; k <= hi; k++) {
        if      (i > mid)              a[k] = aux[j++];
        else if (j > hi)               a[k] = aux[i++];
        else if (less(aux[j], aux[i])) a[k] = aux[j++];
        else                           a[k] = aux[i++];
    }
}
```

1- $\sim n^2$
2- $\sim n$
3- $\sim (1/2)n$
4- $\sim (1/2)$
5- Does not exist or cannot be determined with information given.

Answer: 2

Question 5 **0.5 pts**

If you need to sort a large dataset on a system with limited memory, would it be a good idea to use merge sort? Explain.

1- Yes - merge sort has a cool name, so it's guaranteed to run fast.
2- No - merge sort requires a linear number of recursive calls to be made.
3- Yes - merge sort has proven optimal performance.
4- No - merge sort requires an auxiliary array to do the merging step.

Answer

4

Question 6 **0.5 pts**

When we talked about insertion sort, we found that it requires only n comparisons and `0` exchanges when the input is sorted. Does this violate the lower bound proof?

1- Yes - this means that some inputs will become unsorted.
2- No - the lower bound proof only applies to merge sort or other merging sorting algorithms.
3- Yes - no sorting algorithm can ever do better than $nlogn$ comparisons.
4- No - a sorted input is a special case, while the lower bound proof applies to all inputs.

Answer

4

Module 7: Cairn

Question 1 — 1.5 pts

Consider the following array: `8,9,17,4,3,20,25,5` Show a trace of execution for top-down mergesort using the method shown in lecture (where both sides are updated at once). Illustrate the contents of the array as it is broken down, and then merged into an ordered state.

Enter each subsequent state as a comma separated list (as shown by the initial state). Do not include any spaces or brackets in your answer. If you follow these directions exactly and are marked off by the auto-grader, reach out to the instructional staff.

```
1 (initial) : 8,9,17,4,3,20,25,5 (given as example)
2 (down)    : 8,9,17,4,3,20,25,5 (given as example; nothing changed!)
3 (down)    :
4 (mid)     :
5 (up)      :
6 (up)      :
7 (up)      :
```

Answer

```
3 (down)    : 8,9,17,4,3,20,25,5
4 (mid)     : 8,9,17,4,3,20,25,5
5 (up)      : 8,9,4,17,3,20,5,25
6 (up)      : 4,8,9,17,3,5,20,25
7 (up)      : 3,4,5,8,9,17,20,25
```

Question 2 — 0.5 pts

How (in general) are priority queues related to other sorting algorithms?

Group of answer choices

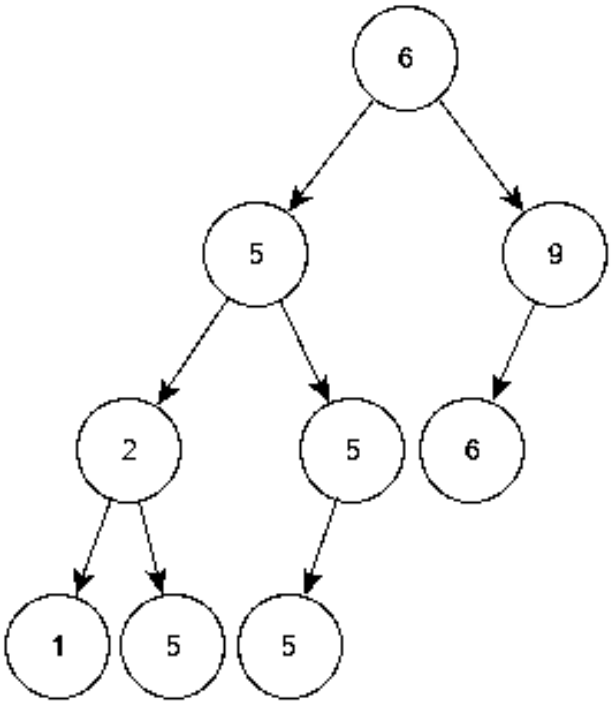
1- Both priority queues and the other four sorting algorithms must obey the lower bound proof.
2- They both involve comparing elements, and PQs may be used to create a straightforward sorting algorithm.
3- Priority queues are implementations of the same ADT that the sorting algorithms use.
4- Priority queues are more efficient implementation of insertion sort.

Answer

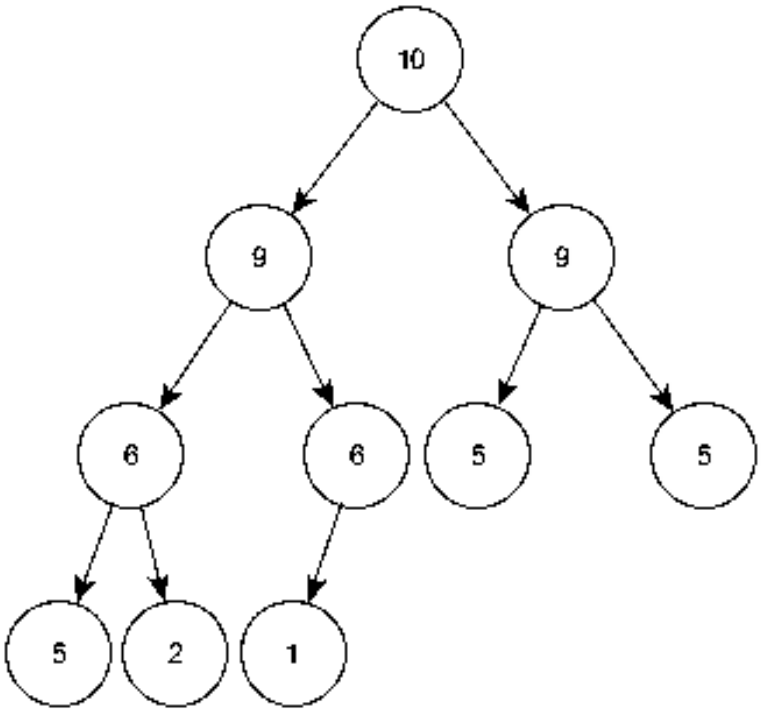
They both involve comparing elements, and PQs may be used to create a straightforward sorting algorithm.

Question 3 **1.5 pts**

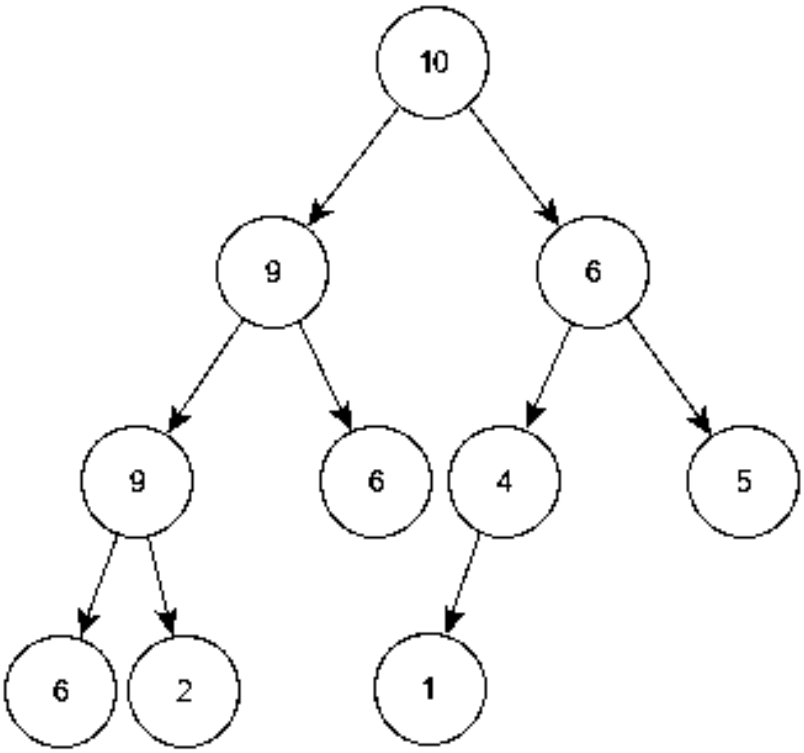
Consider the following values: 5, 9, 1, 5, 6, 2, 5, 6, 9, 10. Select a valid binary heap for this data.



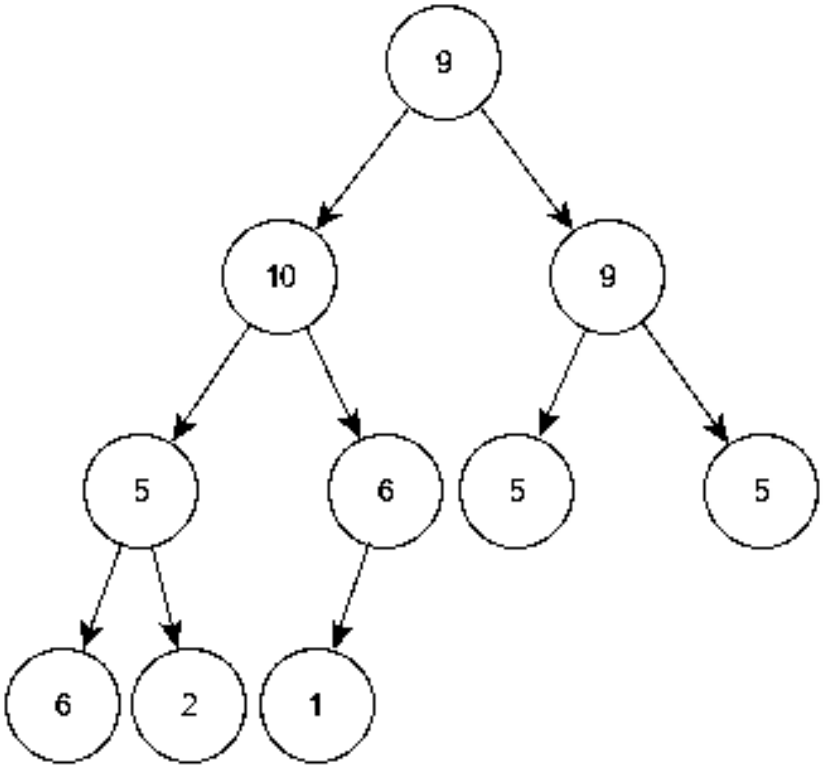
1-



2-



3-



4-

Answer: 2

Question 4 — 1 pts

Is your answer to the previous question unique? Explain.

Group of answer choices

1- No - the nodes can also be arranged to fit the BST ordering rule.
2- Yes - these nodes can only be used to draw a specific tree.
3- No - the same nodes can be used to draw multiple valid heaps.
4- Yes - the previous question had only one answer.

Answer

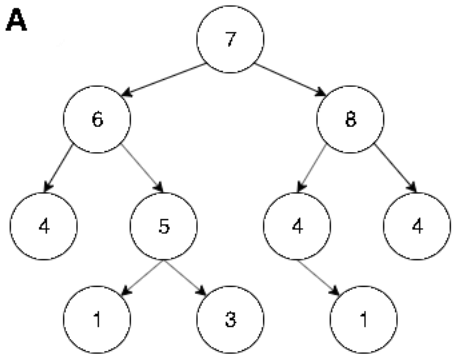
No - the same nodes can be used to draw multiple valid heaps.

Question 5 — 1.5 pts

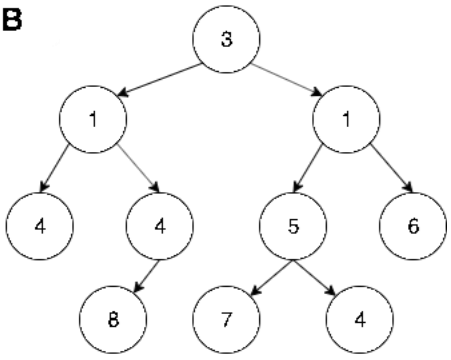
Consider the following priority queue array: `[0, 8, 6, 7, 4, 4, 4, 5, 1, 3, 1]`. Which of the diagrams below accurately represents it?

Remember: The first element of the array is never used.

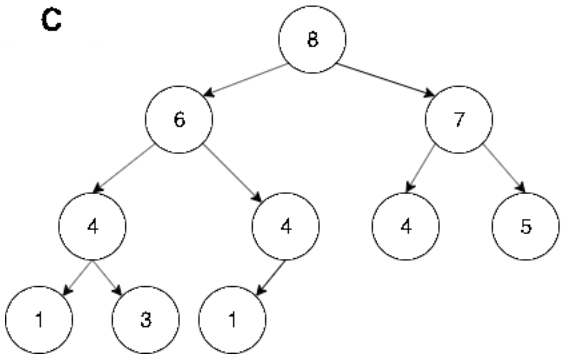
A



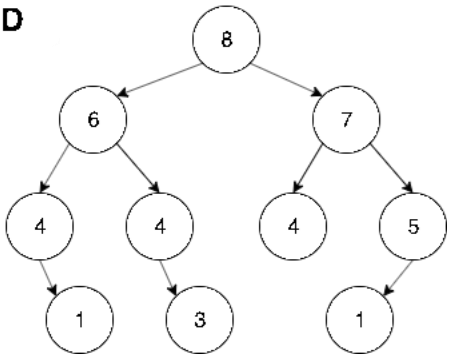
B



C



D

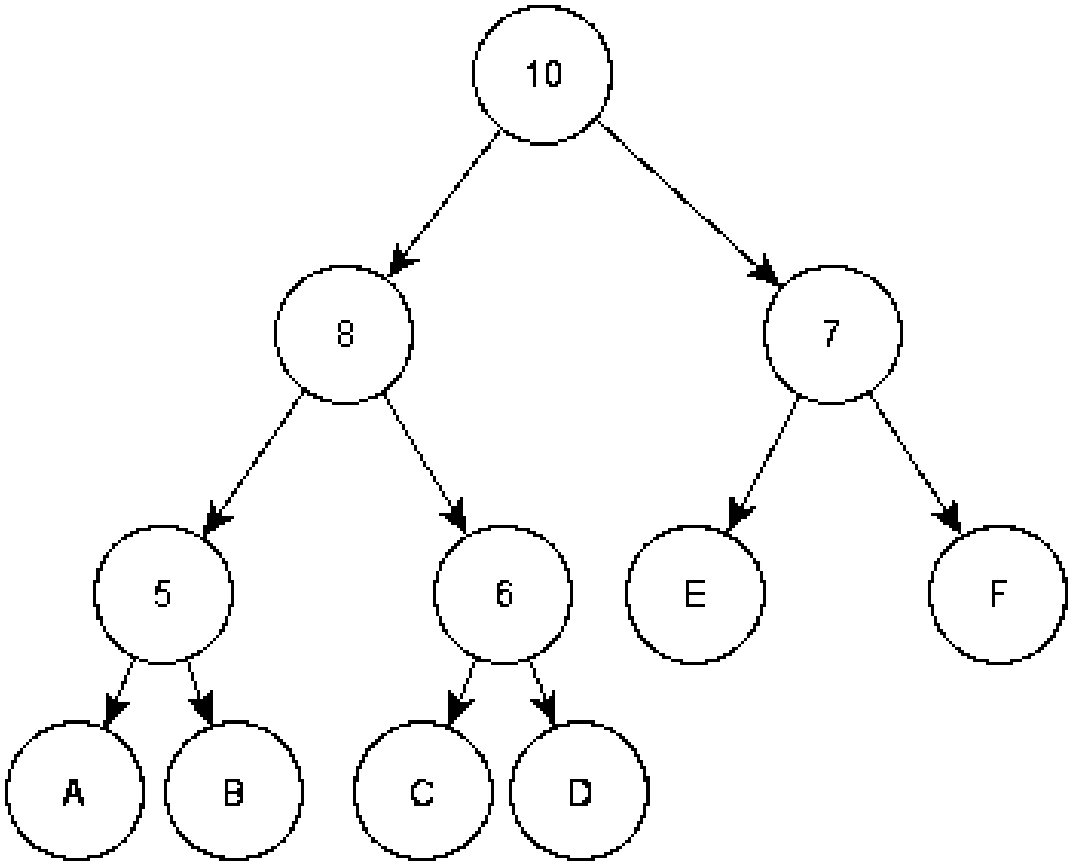


1- A
2- C
3- D
4- B

Answer: C

Question 6 **0.5 pts**

Suppose that you are inserting a node with value 4 into the max PQ show below. When it is initially added, which position (see lettered nodes) does it have in the heap/tree?



1- A
2- C
3- F
4- E
5- B
6- D

Answer

6

Question 7 **0.5 pts**

What is the Tilde approximation order of the following code fragment? Assume that you are measuring the number of comparisons (*less*) and that n represents the number of nodes in the heap.

```
private void sink(int k) {
    while (2*k <= N) {
        int j = 2*k;
        if (j < N && less(j, j+1)) j++;
        if (!less(k, j)) break;
        exch(k, j);
        k = j;
    }
}
```

1- Does not exist, or cannot be determined with information given.
2- $\sim(logn)^2$
3- $\sim(1/2)logn$
4- $\sim(1/2)n$
5- $\sim logn$

Answer

$\sim logn$

Module 9: Cairn

Question 1 **1 pts**

For a Proof of Termination of your own implementation of the BST delete() algorithm, you would need to: (select all that apply)

1- Show the algorithm terminates.
2- Show the algorithm is faster or as fast as another delete algorithm.
3- Show the algorithm touches each node at most once.
4- Show if a key/value pair exists, the algorithm will find it.

Answer: 1,2

Hint: *Module 8 Proof of Termination, Efficiency, Correctness Slides*.

Question 2 **1 pts**

If you are given a set of nodes (key/value pairs) to create a BST, could you create a BST such that it meets both the BST and max heap structural rules? Why or why not? Assume each node is unique (i.e., there are no duplicate keys).

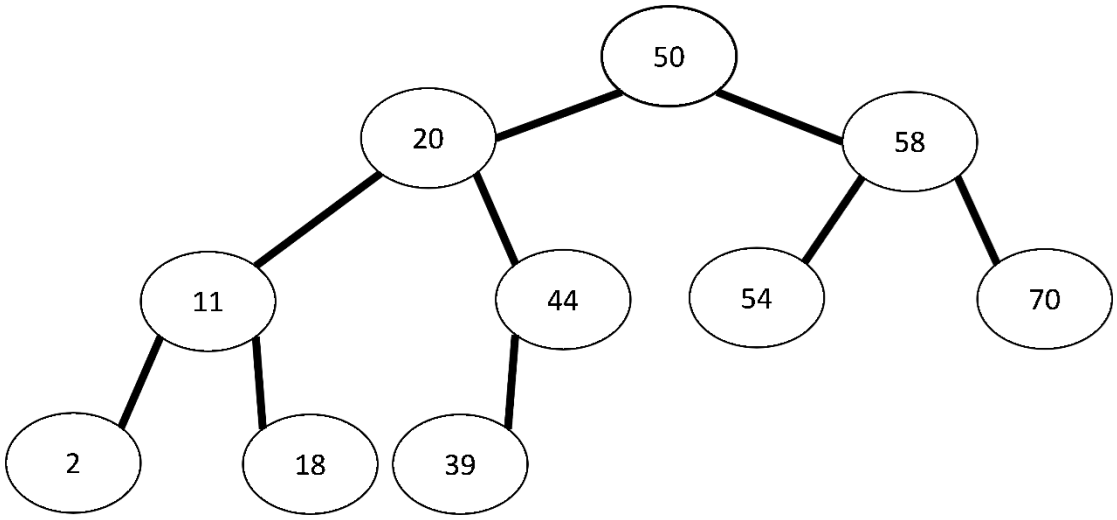
1- No - a max heap can look like a BST and max heap at the same time when the nodes are in a specific layout, but a BST can never be a BST and max heap structure at the same time.
2- No – a max heap can never be a BST and a max heap at the same time, and a BST can never be a BST and max heap at the same time.
3- Yes – a (small) tree can meet both BST and max heap structural rules at the same time when the nodes are in a specific layout.
4- Yes – a BST is always both a BST and max heap at the same time.

Answer: 3

Hint: *See lecture, starting at slide 12 for more information about BSTs and max heaps*.

Question 3 **1 pts**

Fill in the following traversals of the BST shown below:



Answers should be in order the nodes are visited and separated by a comma (and no spaces), e.g. "1,2,3" (no quotes in your answer). If you follow these directions exactly and are marked off by the auto-grader on the second submission, reach out to the instructional staff.

Inorder:

Postorder:

Preorder:

Answer

Inorder: 2,11,18,20,39,44,50,54,58,70

Postorder: 2,18,11,39,44,20,54,70,58,50

Preorder: 50,2,11,18,20,39,44,54,58,70

Hint: *postorder hint at end of M9 traversal video. For help with in-order traversal, see the keys() method (lectures starting at slide 34).*

Question 4 **1 pts**

Trace the given code and fill in the table for the **ordered** symbol table produced:

```
SymbolTable<String, Integer> ST = new SymbolTable<>();
ST.put( key: "B",  val: 22);
ST.put( key: "G",  val: 12);
ST.deleteMin();
ST.put( key: "C",  val: 35);
ST.put( key: "B",  val: 12);
ST.put( key: "A",  val: 50);
ST.put(ST.max(),  val: 20);
ST.put( key: "D",  val: 3);
ST.put( key: "E",  val: 84);
ST.deleteMax();
int currSize = ST.size();
ST.put( key: "F",  val: 12);
ST.put(ST.min(), ST.size());
ST.put( key: "B",  val: 20);
ST.delete(ST.floor( key: "Z"));
ST.put( key: "G", currSize);
```

7 key/value pairs should be listed in the table - if the key/value pair was deleted in the given code, leave the key in the table and enter the value as "-" (no spaces). The first pair is shown as an example.

Key	**Value**
A	6

Answer

Key	**Value**
A	6
B	20
C	35
D	3
E	84
F	-
G	5

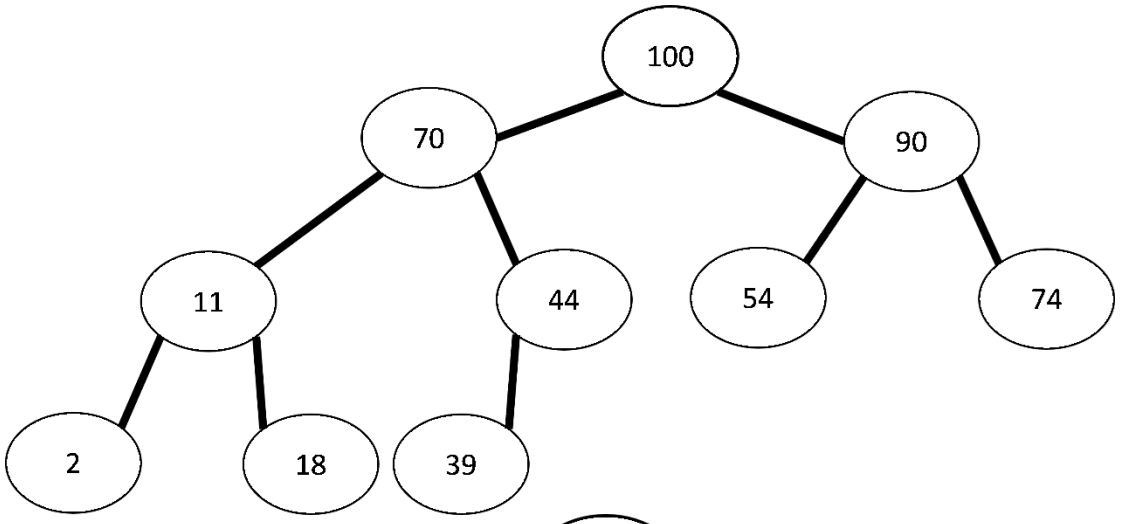
Hint: *Try to follow the code one line at a time and fill in the table as you go.*
See lectures starting at slide 4 for Symbol Table information and usage.

Question 5 **1 pts**

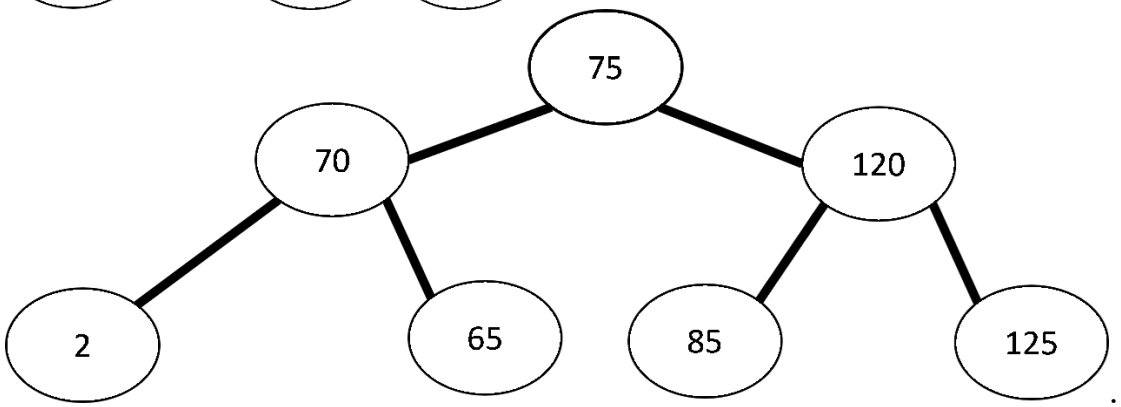
From the following trees, select the balanced BSTs:

(A BST is balanced if the height of its left and right sub-trees are different by at most one, recursively applied.)

1-

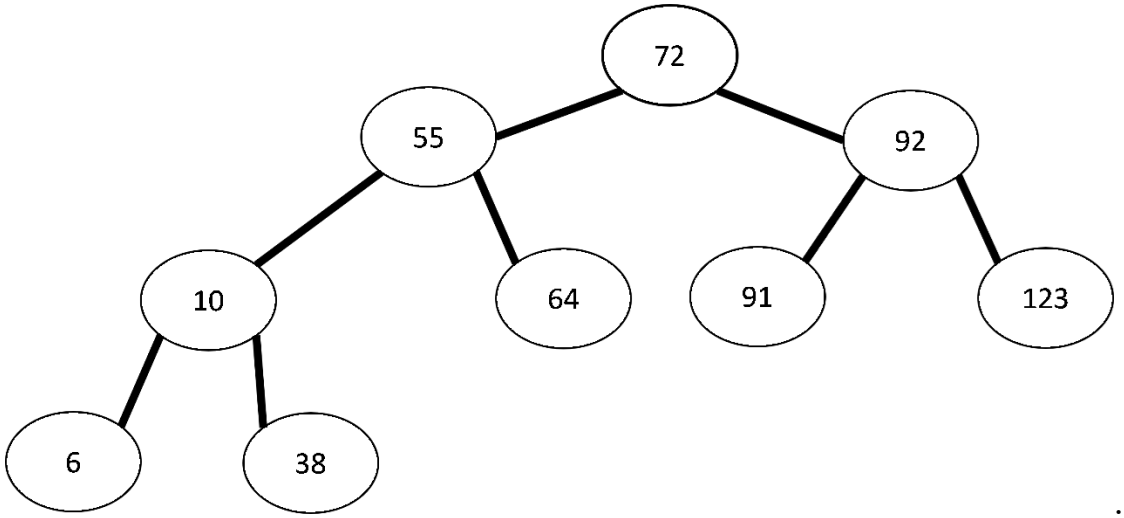


2-



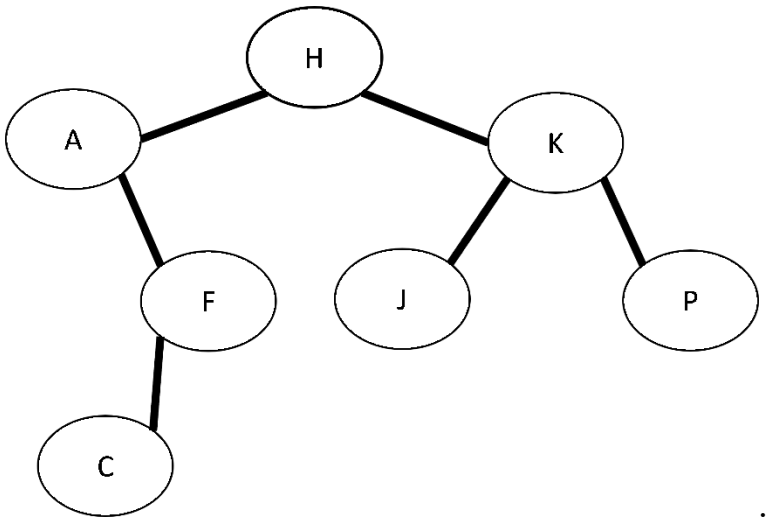
.

3-

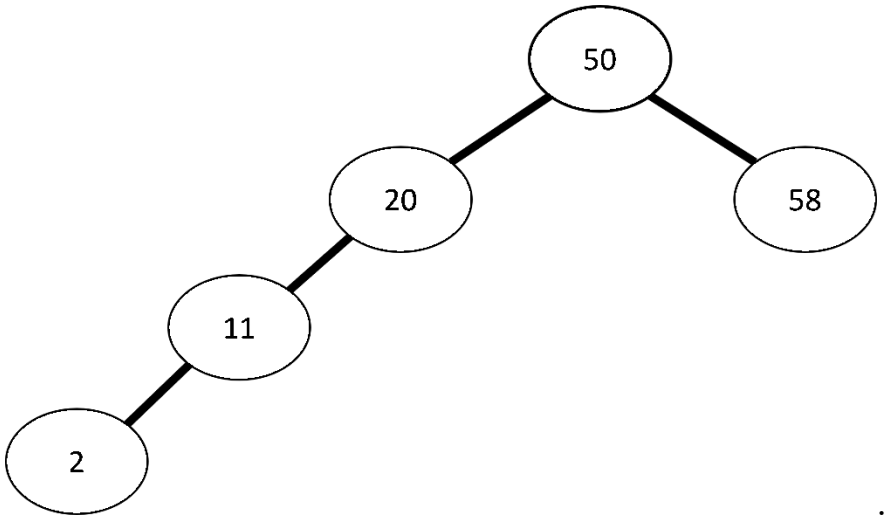


.

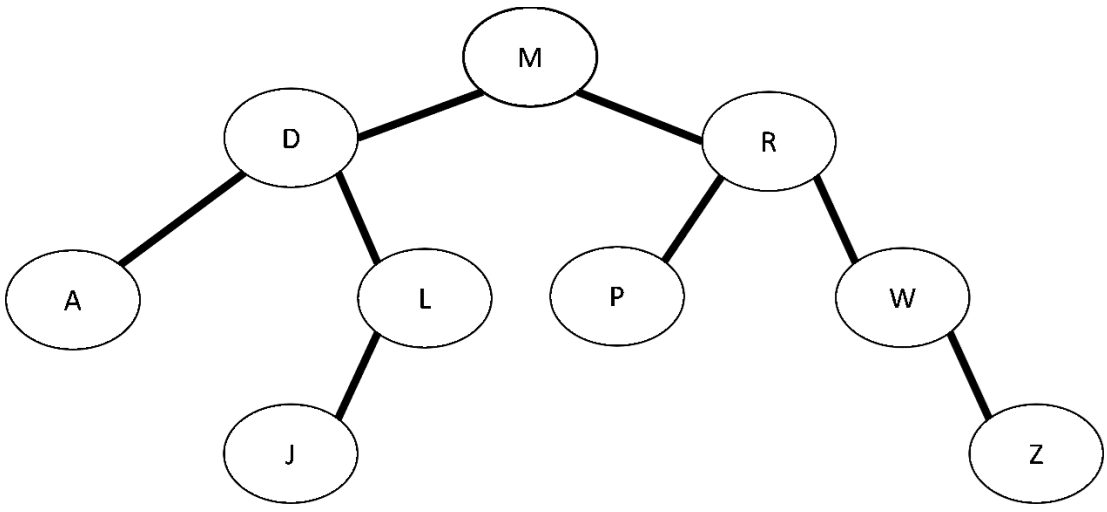
4-



5-



6-

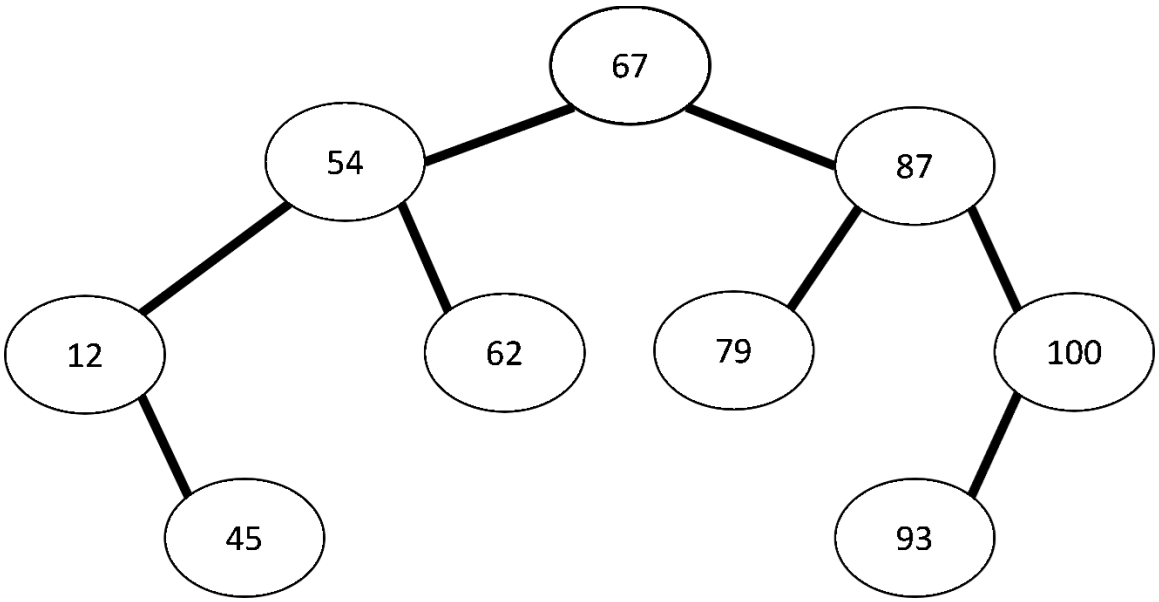


Answer: 3,6

Hint: *Look carefully at every node in each tree!*
See lecture, starting at slide 12, for information on BST structure.

Question 6 **1 pts**

Using the BST shown below, match the given code to an output: (each code block has a unique output)



Output 1:
```
6
158
67
```

Output 2:
```
6
87
false
```

Output 3:
```
16
null
33
```

Output 4:
```
101
30
true
```

1-
```
BST.deleteMax();
BST.put( key: 87,  val: 98);
BST.put( key: BST.get(87) + 2,  val: 101);
BST.put(BST.get(BST.max()),  val: 30);
System.out.println(BST.max());
System.out.println(BST.get(BST.max()));
System.out.println(BST.contains(100));
```

Output: [Select]

2-

```
BST.put( key: 13,  val: 200);
int currMin = BST.min();
BST.put( key: 87,  val: 25);
BST.put(BST.floor( key: 50),  val: 23);
BST.deleteMin();
BST.put( key: BST.max() - BST.min(),  val: 16);
System.out.println(BST.get(87));
System.out.println(BST.get(12));
System.out.println(BST.floor( key: 50) - currMin);
```

Output: [Select]

3-

```
BST.put( key: BST.size() * 5,  val: 6);
BST.delete(BST.floor( key: BST.size() * 2));
BST.delete(BST.ceiling(BST.max()));
BST.put( key: 112,  val: 40);
BST.delete(BST.floor( key: BST.max() - BST.get(45)));
System.out.println(BST.get(45));
System.out.println(BST.floor( key: BST.max() - BST.get(45)));
System.out.println(BST.contains(12));
```

Output: [Select]

4-

```
int counter = 0;
for(Integer key : BST.keys( lo: 48,  hi: 80)) {
    BST.put(key,  val: key * 2);
    BST.deleteMin();
    counter++;
}
BST.put(counter, BST.min());
System.out.println(BST.size());
System.out.println(BST.get(BST.floor( key: 80)));
System.out.println(BST.get(counter));
```

Output: [Select]

Answer:

Output: 4
Output: 3
Output: 2
Output: 1

Hint: *Draw the original tree and trace each code block while updating the tree.*
See lecture, starting at slide 20, for more information on the BST methods.

Question 7 **1 pts**

Which of the following series of inserts on a BST would result in the tree being searchable in $O(n)$ time?

1-
```
BST.put( key: 5,   val: 100);
BST.put( key: 15,  val: 4);
BST.put( key: 18,  val: 15);
BST.put( key: 25,  val: 25);
BST.put( key: 40,  val: 25);
BST.put( key: 42,  val: 55);
BST.put( key: 55,  val: 6);
```

2-
```
BST.put( key: 40,  val: 25);
BST.put( key: 5,   val: 100);
BST.put( key: 55,  val: 6);
BST.put( key: 15,  val: 4);
BST.put( key: 42,  val: 55);
BST.put( key: 18,  val: 15);
BST.put( key: 25,  val: 25);
```

3-
```
BST.put( key: 25,  val: 25);
BST.put( key: 42,  val: 55);
BST.put( key: 55,  val: 6);
BST.put( key: 15,  val: 4);
BST.put( key: 18,  val: 15);
BST.put( key: 40,  val: 25);
BST.put( key: 5,   val: 100);
```

4-
```
BST.put( key: 18,  val: 15);
BST.put( key: 55,  val: 6);
BST.put( key: 5,   val: 100);
BST.put( key: 15,  val: 4);
BST.put( key: 40,  val: 25);
BST.put( key: 42,  val: 55);
BST.put( key: 25,  val: 25);
```

Answer: 1

Hint: *Draw the tree that results from each series of inserts.*
See lecture, staring at slide 26, for more information about BST structure and its impact on searching performance.

Module 10: Cairn

Question 1

What is the primary purpose of a hash function in a hash table?
(Concept of a hash function)
a. To sort the elements in ascending order
b. To generate a unique identifier for each key
c. To map keys to indices in a fixed-size table
d. To manage collisions between keys

Answer: c. To map keys to indices in a fixed-size table
Explanation:
A hash function is designed to take an input (a key) and return an output (a hash code). This hash code is then mapped to an index in the hash table, allowing for quick storage and retrieval of values. It doesn't sort elements or generate unique identifiers.

Question 2

What does the "M" value represent in a hash table?
(Concept of the M value)
a. The number of keys in the hash table
b. The maximum size of the hash table
c. The hash code of the keys
d. The number of collisions in the hash table

Answer: b. The maximum size of the hash table
Explanation:
The "M" value refers to the capacity of the hash table, meaning the total number of slots available for storing keys. It's crucial in determining how keys are distributed and how collisions are managed.

Question 3

Which of the following is a key difference between separate chaining and linear probing in hash tables?
(Difference between separate chaining and linear probing)
a. Separate chaining uses linked lists, while linear probing resolves collisions within the same array.
b. Linear probing requires more memory than separate chaining.
c. Separate chaining stores keys in a continuous block of memory.
d. Linear probing supports duplicate keys, while separate chaining does not.

Answer: a. Separate chaining uses linked lists, while linear probing resolves collisions within the same array.

Explanation:
In separate chaining, each index in the hash table points to a linked list (or chain) of keys that hash to the same index. Linear probing, on the other hand, resolves collisions by finding the next available slot within the same array through sequential searching.

Question 4

Consider a separate chaining hash table of size 5. Keys 10, 20, 30, and 40 are added. What will the hash table look like if the hash function is key % 5?
(Contents of a separate chaining hash table after elements are added)
a. [[10], [20], [30], [40], []]
b. [[10, 20, 30, 40], [], [], [], []]
c. [[], [], [], [], [10, 20, 30, 40]]
d. [[10], [20], [], [], [30, 40]]

Answer: a. [[10], [20], [30], [40], []]
Explanation:
The hash function key % 5 maps each key to an index in the hash table.

- 10 % 5 = 0 → Goes to index 0
- 20 % 5 = 0 → Goes to index 0
- 30 % 5 = 0 → Goes to index 0
- 40 % 5 = 0 → Goes to index 0
  As a result, all elements chain at index 0.

Question 5

Consider a linear probing hash table of size 7. Keys 10, 20, and 17 are added. The hash function is key % 7. What will the hash table look like?
(Contents of a linear probing hash table after elements are added)

a. [10, 20, 17, null, null, null, null]
b. [null, null, null, null, null, null, null]
c. [10, null, null, 17, 20, null, null]
d. [10, null, 17, 20, null, null, null]

Answer: d. [10, null, 17, 20, null, null, null]

Explanation:
The hash function key % 7 determines the index for each key:

- Key 10: 10 % 7 = 3 → Place 10 at index 3.
- Key 20: 20 % 7 = 6 → Place 20 at index 6.

- Key 17: 17 % 7 = 3 → Collision occurs at index 3. Linear probing resolves the collision by finding the next available slot. Index 4 is empty, so 17 is placed there.

The final hash table will be:
[null, null, null, 10, 17, null, 20].

Question 6

Why is the "load factor" an important concept in hash tables?
a. It determines the maximum number of keys allowed in the table.
b. It measures the density of occupied slots in the hash table.
c. It controls the size of the hash function.
d. It avoids collisions during insertion.

Answer: b. It measures the density of occupied slots in the hash table.

Explanation:
The load factor is the ratio of the number of elements in the hash table to its total size (capacity). It helps determine when the table needs to resize (rehashing). A higher load factor increases the likelihood of collisions, while a lower load factor wastes memory.

Question 7

Which situation best describes when separate chaining is preferred over linear probing?
a. When memory is limited, and the table cannot resize.
b. When the table is nearly full, and collisions are frequent.
c. When keys have uniformly distributed hash codes.
d. When the hash table uses open addressing.

Answer: b. When the table is nearly full, and collisions are frequent.

Explanation:
Separate chaining handles collisions by creating linked lists for each index. This approach works well even when the table is almost full. Linear probing, in contrast, performs poorly under such conditions because it has to search sequentially for free slots, leading to clustering issues.

Quiz Before Midterm

Question 1 **0.5 pts**

In the context of object-oriented programming, what does 'state' refer to?

1- The class from which the object is instantiated.
2- The methods an object can execute.
3- The attributes or data held by an object.
4- The memory address of the object

Answer: 3

Question 2 **0.5 pts**

What is the key characteristic of an Abstract Data Type (ADT)?

1- It relies on the Java API for implementation.
2- It is always mutable.
3- It exposes its internal representation.
4- It is defined purely by its operations.

Answer: 4

Question 3 **0.5 pts**

Which method is NOT part of the basic stack API as discussed in the document?

1- `pop()`
2- `isEmpty()`
3- `push()`
4- `enqueue()`

Answer: 4

Question 4 **0.5 pts**

In a linked list implementation of a stack, what does the 'top' variable represent?

1- The last element added to the stack.
2- The first element added to the stack.
3- The total number of elements in the stack.
4- The maximum capacity of the stack.

Answer: 1

Question 5 **0.5 pts**

How can you make a stack implementation in Java more generic?

1- By using wildcard imports.

2- By hardcoding the data type.
3- By overloading the stack methods.
4- By defining the stack class with a generic type parameter.

Answer: 4

Question 6 **0.5 pts**

Which of the following is a potential drawback of using an array-based stack?

1- It does not support LIFO operations.
2- It may need to resize, leading to performance overhead.
3- It cannot store duplicate elements.
4- It requires manual memory management.

Answer: 2

Question 7 **0.5 pts**

What is the purpose of implementing the `Iterable` interface in a stack?

1- To support iteration over stack elements.
2- To allow elements to be accessed randomly.
3- To enable sorting of stack elements.
4- To provide direct access to the last element added.

Answer: 1

Question 8 **0.5 pts**

Why might you want to use a linked list instead of an array to implement a stack?

1- Linked lists automatically sort elements.
2- Linked lists can dynamically adjust size without resizing.
3- Linked lists allow for faster random access.
4- Linked lists use less memory than arrays.

Answer: 2

Question 9 **0.5 pts**

Which of the following represents a correct Big-Oh notation characterization?

1- $f(n) = O(n)$ for $f(n) = 2n + 3$
2- $f(n) = O(1)$ for $f(n) = n^2 + 1$
3- $f(n) = O(n^2)$ for $f(n) = n + 2$
4- $f(n) = O(n^3)$ for $f(n) = 5$

Answer: 1

Question 10 **0.5 pts**

Which notation is used to indicate a function that is both upper and lower bounded by the same function?

1- Theta (θ)
2- Big-Oh (O)
3- Tilde (∼)
4- Omega (Ω)

Answer: 1

Quiz Midterm

Question 1

1- In a stack, if a user tries to remove an element from an empty stack it is called... Answer: a

a. Underflow. b. Empty collection. c. Overflow. d. Garbage collection.

2- Pushing an element into stack already having five elements and stack size of 5, then stack becomes... Answer: a

a. Overflow. b. Crash. c. Underflow. d. User flow.

3- A linear collection of data elements where the linear node is given by means of pointer is called? Answer: b

a. Node list. b. Linked list. c. Primitive list. d. Unordered list.

4- In a generic stack implementation, what does the term "generic" mean? Answer: c

a. The stack can only store integers. b. The stack can only store strings. c. The stack can store elements of any data type. d. The stack can store elements of a specific data type chosen at runtime.

5- Linked list is considered as an example of a type of memory allocation... Answer: a

a. Dynamic. b. Static. c. Compile. d. Heap.

6- In the context of supporting iteration on a stack, what does the term "iterator" refer to? Answer: c

a. An algorithm for sorting elements. b. A method to remove elements from the stack. c. An object used to traverse the elements of the stack. d. A data structure to store elements temporarily.

7- If the input to selection sort is `A = [7, 23, 25, 13, 2, 12, 3, 16, 43]` then after two swaps `A =...` Answer: b

a. `[2, 13, 25, 3, 7, 12, 16, 43]` b. `[2, 3, 25, 13, 7, 12, 23, 16, 43]` c. `[2, 23, 25, 13, 7, 12, 16, 43]` d. `[7, 23, 25, 13, 2, 12, 3, 16, 43]`

8- Which of the following best describes the time complexity of the selection sort algorithm for sorting an array of size n? Answer: c

a. $O(n)$ b. $O(nlogn)$ c. $O(n^2)$ d. $O(logn)$

9- If the given array is already sorted in ascending order, how many swaps will the selection sort algorithm perform? Answer: c

a. 0 b. 1 c. $n-1$ d. n

10- The number of comparisons in the selection sort algorithm is... Answer: c

a. $O(n)$ b. $O(logn)$ c. $O(n^2)$ d. $O(nlogn)$

11- What is the worst-case time complexity of the insertion sort algorithm? Answer: c

a. $O(n)$ b. $O(nlogn)$ c. $O(n^2)$ d. $O(1)$

12- In insertion sort, the sorted subarray... Answer: a

a. Starts with the smallest element. b. Starts with the largest element. c. Starts with the median element. d. Starts with a single element.

13- In the insertion sort algorithm, how many comparisons are made to sort an already sorted array of size n? Answer: a

a. $n-1$ b. n c. $n/2$ d. $(n^2-n)/2$

14- Shell sort is an extension of which sorting algorithm? Answer: b

a. Merge sort b. Insertion sort c. Quick sort d. Selection sort

15- Which of the following functions grows the fastest as n increases to infinity? Answer: d

a. n^2 b. 2^n c. $log\ n$ d. $n!$

16- If an algorithm has a time complexity of $O(n^2)$, what does this imply? Answer: b

a. The algorithm always takes exactly n^2 operations to complete. b. The algorithm takes at most n^2 operations to complete. c. The algorithm takes at least n^2 operations to complete. d. The algorithm takes exactly n^2 operations to complete.

Question 2

Consider the following array:
`[7, 23, 25, 13, 2, 12, 3]`
Show a trace of execution for insertion sort.

The trace should include the initial state of the array, followed by the array's state after each pass is made.

Answer:

```
initial: [7, 23, 25, 13, 2, 12, 3]
i  =  1: [7, 23, 25, 13, 2, 12, 3]  // 0
i  =  2: [7, 23, 25, 13, 2, 12, 3]  // 0
i  =  3: [7, 13, 23, 25, 2, 12, 3]  // 2
i  =  4: [2, 7, 13, 23, 25, 12, 3]  // 4
i  =  5: [2, 7, 12, 13, 23, 25, 3]  // 3
i  =  6: [2, 3, 7, 12, 13, 23, 25]  // 5
```

total swaps: 14

Question 3

Consider the following array:
`[7, 23, 25, 13, 2, 12, 3]`
Show a trace of execution for selection sort.

The trace should include the initial state of the array, followed by the array's state after each pass is made.

Answer:

```
initial: [7, 23, 25, 13, 2, 12, 3]
i  =  0: [2, 23, 25, 13, 7, 12, 3]
i  =  1: [2, 3, 25, 13, 7, 12, 23]
i  =  2: [2, 3, 7, 13, 25, 12, 23]
i  =  3: [2, 3, 7, 12, 25, 13, 23]
i  =  4: [2, 3, 7, 12, 13, 25, 23]
i  =  5: [2, 3, 7, 12, 13, 23, 25]
i  =  6: [2, 3, 7, 12, 13, 23, 25]
```