

CSCI 2110
Data Structures and Algorithms
MIDTERM EXAM

TOPICS

Module 1: Key Concepts in Object Oriented Programming

- Traditional vs. Object-oriented programming
- Advantages of object-oriented programming
- Encapsulation – defining objects in Java class files
- this parameter and toString method
- Method overloading
- Garbage collection in Java
- Static methods and Static variables
- Inheritance
- Abstract classes and interfaces
- Polymorphism in Java
- Object class
- Generics

} → more focus

Module 2: Algorithm Time Complexity

- What is algorithm complexity?
- How is running time of an algorithm measured?
- How is it expressed as a function of the input size? - Examples
- Big O notation
- Deriving Big O given a function - Examples
- Practical examples of algorithms with various Big Os.
- Estimation Problems with Complexity
- Order Arithmetic: How to look at a piece of code and derive its Big O complexity
- Worst case, Best case and Average case complexity

Module 3: Unordered Lists

- Data Structures: The Big Picture
- **Unordered Lists**
- Definition and examples
- Implementation choices
- Generic Node Class
- Generic Linked List Class: Linked List methods and examples
- Linked List problems

CSCI 2110
Data Structures and Algorithms
PRACTICE QUESTION BANK FOR THE MIDTERM

Note 1: This is meant to be a question bank covering the types of questions you will get on the midterm. The actual number of questions that will be designed to fit midterm exam time.

Note 2: The question bank contains representative samples of different topics. Please be sure to study all the topics for the midterm.

Multiple Choice Set No. 1 (Choose the most appropriate answer in each of the following questions).

1. In a java class file, get methods are also known as:
 - a. accessor methods
 - b. constructors
 - c. void methods
 - d. mutator methods
2. If a class is named Student, what name can you use for a constructor for this class?
 - a. Student
 - b. Student.java
 - c. void Student
 - d. any name can be used since the constructor can be overloaded
3. When defining a constructor, what do you specify for the type of value returned?
 - a. Primitive data type such as int
 - b. Class name such as Student
 - c. void
 - d. None – a constructor does not have an explicit return type
4. This is automatically provided for a class if you do not write one yourself
 - a. default accessor method
 - b. default mutator method
 - c. default constructor
 - d. default instance variable
6. What is the signature of the method whose header is given below?
`public Rectangle modify(Rectangle r1, Point p1, int x)`
 - a. `modify(r1, p1, x)`
 - b. `Rectangle modify(r1, p1, x)`
 - c. `modify(Rectangle, Point, int)`
 - d. `Rectangle modify(Rectangle, Point, int)`
7. A non-static method
 - a. can change static variables in a class
 - b. can be called without object instantiation
 - c. has to be called from inside the class
 - d. can be called by static methods

8. Consider the following class declaration

```
public class MyClass{  
    private static int val;  
    private int num1;  
    private double num2;  
    //rest of the code omitted  
}
```

Another class MyDemo has a main method which instantiates two objects of type MyClass. Which of the following statements is correct?

- a. Each object gets a separate copy of val, num1 and num2.
- b. Each object gets a separate copy of val, but they both share one copy of num1 and num2.
- c. Each object gets a separate copy of num1 and num2, but they both share one copy of val.
- d. The above declaration has a syntax error.

For questions 9, 10 and 11, use the code below:

Consider a class to represent a Pokemon card. It has partial code given below:

//This class represents a Pokemon card. The card has a name (String) and hp (an int that represents //healthpoints). There is also a static variable price that represents the price of the Pokemon card.

```
public class Pokemon{  
    private String name;  
    private int hp;  
    private static double price;  
    //rest of the code missing  
}
```

9. Suppose you wanted to write a method in the Pokemon class that would allow another class to access the hp of this Pokemon. What would the header of such a method look like?

- a. public static int getHP()
- b. public int getHP()
- c. public static getHP(int hp)
- d. public int getHP(int hp)

10. Suppose you wanted to write a method in the Pokemon class that compares the hp of "this" Pokemon with the hp of another Pokemon and returns true if the hp of "this" Pokemon is greater. What would the header for such a method look like?

- a. public boolean compareHP(this.hp)
- b. public void compareHP(other.getHP())
- c. public void compareHP(Pokemon other)
- d. public boolean compareHP(Pokemon other)

11. Suppose you wanted to write a static method in the Pokemon class to set the price to a given value. What would the header for such a class look like?

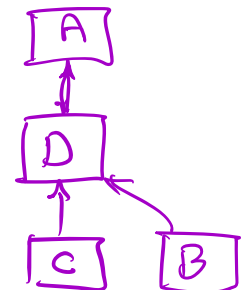
- a. public static double setPrice(static double p)
- b. public static void setPrice()
- c. public static double setPrice(double p)
- d. public static void setPrice(double p)

12. Consider the following group of class declarations (complete code not given):

```
public class C extends D {}  
public class B extends D {}  
public class D extends A {}
```

Which of the following statements is correct?

- a. D is the superclass of A, and B and C are sub-classes of D
- b. A is the subclass of B and C, and D is the superclass of B and C
- c. A is the superclass of D, and B and C are subclasses of D
- d. A is the subclass of D, and B and C are superclasses of D



13. Consider the following class declarations. If a client program has two lines:

```
GradStudent s1 = new GradStudent();  
System.out.println(s1.getInfo());
```

What will be the output?

```
public class Student {  
    public String getFood() {  
        return "Pizza";  
    }  
    public String getInfo() {  
        return this.getFood();  
    }  
}  
  
public class GradStudent extends Student {  
    public String getFood() {  
        return "Taco";  
    }  
}
```

Method overriding

- a. Taco
- b. Pizza
- c. The code won't compile since getInfo is not in GradStudent class
- d. The code won't compile since s1 is not a Student object

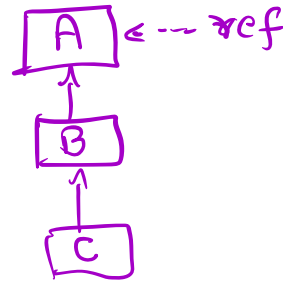
14. If ClassB extends ClassA, and ClassC extends ClassB, and the following declaration has been made:

ClassA ref;

Which of the following are valid?

- I. ref = new ClassA(); ✓
- II. ref = new ClassB(); ✓
- III. ref = new ClassC(); ✓

- a. I only
- b. I and II
- c. I, II and III
- d. None of the above.



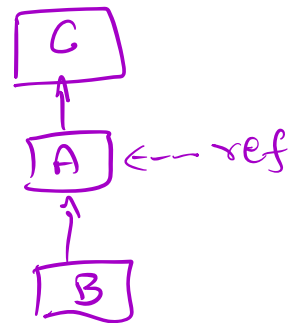
15. If ClassB extends ClassA, and ClassC is a superclass of ClassA, and the following declaration has been made:

ClassA ref;

Which of the following are valid?

- I. ref = new ClassA(); ✓
- II. ref = new ClassB(); ✓
- III. ref = new ClassC(); ✓

- a. I only
- b. I and II
- c. I, II and III
- d. None of the above.



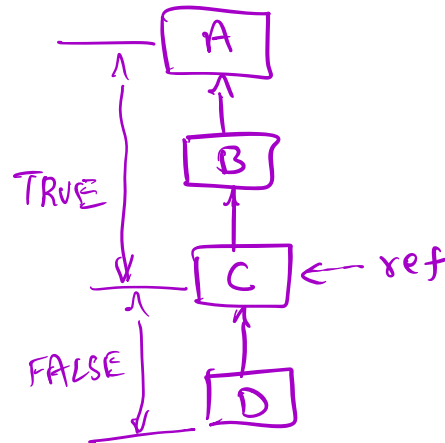
16. ClassB extends ClassA, and ClassC extends ClassB, and ClassD extends ClassC. The following is a part of the code in a program:

```
ClassB ref;  
ref = new ClassC();
```

Which of the following statements will return TRUE?

- I. System.out.println(ref instanceof ClassA);
- II. System.out.println(ref instanceof ClassB);
- III. System.out.println(ref instanceof ClassC);
- IV. System.out.println(ref instanceof ClassD);

- a. I only
- b. I and II
- c. I, II and III
- d. I, II, III and IV



17. What is the Big O complexity of the run time function $25n^4 + 45n + 256$?

- a. $O(n^4)$
- b. $O(n^5)$
- c. $O(n)$
- d. $O(256)$

18. What is the Big O complexity of the run time function $n^2 + 3000n + 500n^2\log n + 1000$?

- a. $O(n^2)$
- b. $O(n^2\log n)$
- c. $O(3000n)$
- d. $O(n^4\log n)$

19. What is the Big O complexity of the run time function $(3\log n + 5)(n^3 + 2)$?

- a. $O(n^2\log n)$
- b. $O(n^3\log n)$
- c. $O(n^3)$
- d. $O(3n\log n)$

$$= 3n^3\log n + 5n^3 + 6\log n + 10$$

20. What is the Big O complexity of the run time function $(n^3 + 2n^2 + 3)/n^2$?

- a. $O(n)$
- b. $O(n^2)$
- c. $O(n^3)$
- d. $O(1/n)$

$$\frac{n^3 + 2n^2 + 3}{n^2} = n + 2 + \frac{3}{n^2}$$

21. What is the Big O complexity of the run time function $(1+2+3+\dots+n)(1+2+3+\dots+n)$?

(Note: Sum of series $1+2+\dots+n = n(n+1)/2$)

- a. $O(n^4)$
- b. $O(n^3)$
- c. $O(n^2)$
- d. $O(n)$

$$\begin{aligned} & \frac{n(n+1)}{2} * \frac{n(n+1)}{2} \\ &= \frac{n^2(n+1)^2}{4} = \frac{n^2(n^2+2n+1)}{4} \\ &= \frac{n^4}{4} + \frac{2n^3}{4} + \frac{n^2}{4} \end{aligned}$$

$$\Rightarrow \log n^3 = 3 \log n$$

22. What is the Big O complexity of the run time function $\log n^3 + n \log n^4 + n \log n^2$?

- a. $O(n \log n)$
- b. $O(n^2 \log n)$
- c. $O(n^3 \log n)$
- d. $O(n^4 \log n)$

$$= 3 \log n + 4n \log n + 2n \log n$$

$$= 3 \log n + 6n \log n$$

23. What is the Big O complexity of the run time function $\sqrt{n} \sqrt{n} \log n^n$?

- a. $O(n \log n)$
- b. $O(n^2 \log n)$
- c. $O(n^3 \log n)$
- d. $O(n^n)$

$$= \sqrt{n} \sqrt{n} \log n^n = n \log n^n = n * n \log n = n^2 \log n$$

24. What is the Big O complexity of an algorithm that finds the average of an array of n items?

- a. $O(n)$
- b. $O(n^2)$
- c. $O(1)$
- d. $O(\log n)$

25. Which of the following has the fastest run time?

- a. $O(n)$
- b. $O(1)$
- c. $O(1/n)$
- d. $O(\log_2 n)$

$$\frac{1}{n^2} < \frac{1}{n} < 1 < \log n < n$$

Multiple Choice Set No. 2 (Choose the most appropriate answer in each of the following questions).

1. An abstract data type refers to

- a. the abstract methods in a class file.
- b. the type of data stored in a data structure with implementation details.
- c. what the data structure contains and what operations can be done without implementation details.
- d. what the data structure contains and what operations can be done with implementation details.

2. An algorithm with complexity $O(n^2)$ takes 5 ms to process 50 data items. The estimated time that it would take to process 100 data items is

- a. 25 ms
- b. 10 ms
- c. 20 ms
- d. 2500 ms

$$50 \times 50 \rightarrow 5$$

$$100 \times 100 \rightarrow x?$$

$$x = \frac{5 \times 100 \times 100}{50 \times 50}$$

$$= 20$$

3. An algorithm with complexity $O(n^2)$ takes 2 ms to process 50 data items. The estimated number of data items that it can process in 8 ms is

- a. 250
- b. 200
- c. 500
- d. 100

$$2 \rightarrow 50 \times 50$$

$$8 \rightarrow x * x$$

$$x^2 = \frac{50 \times 50 \times 8^4}{2^4}$$

$$x = \sqrt{50 \times 50 \times 2 \times 2}$$

$$= 50 \times 2 = 100$$

VISUALIZE!

For questions (4-10), assume that the following linked list has been created using the generic Node class and the generic LinkedList class. front is the reference to the first node and null is the reference from the last node. The linked list contains String data "Java", "C", "C++", and "Python" as shown.

front → Java → C → C++ → Python → null



Study the following codes and select the most appropriate answer.

4. What does the following piece of code display?

```
Node<T> curr = front;
while (curr!=null){
    System.out.print(curr.getData() + "→");
    curr = curr.getNext();
}
```

- a. Java → C → C++ → Python → null
- b. front → Java → C → C++ → Python → null
- c. Java → C → C++ → Python →
- d. Java → C → C++ →
- e. Null

5. What does the following piece of code display?

```
Node<T> curr = front;
while (curr.getNext()!=null){
    System.out.print(curr.getData() + "→");
    curr = curr.getNext();
}
```

- a. Java → C → C++ → Python → null
- b. front → Java → C → C++ → Python → null
- c. Java → C → C++ → Python →
- d. Java → C → C++ →
- e. null

6. What does the following piece of code display?

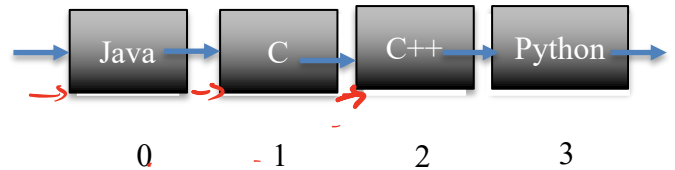
```
Node<T> curr = front;
System.out.println(curr.getNext().getNext().getData());
```

- a. Java
- b. C
- c. C++
- d. Python
- e. It will give a NullPointerException

7. What does the following piece of code display?

```
Node<T> curr = front;
for (int i = 0; i < 2; i++){
    curr = curr.getNext();
}
System.out.println(curr.getData());
```

- a. Java
- b. C
- c. C++
- d. Python
- e. It will give a NullPointerException



8. What does the following piece of code display?

```
Node<T> curr = front;
for (int i = 0; i <= 3; i++){
    curr = curr.getNext();
}
System.out.println(curr.getData());
```

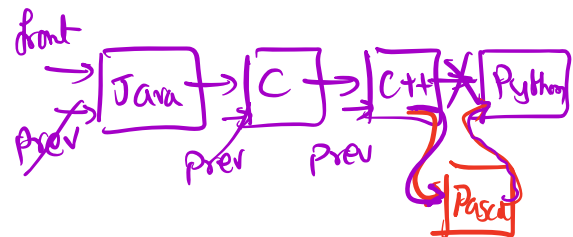
- a. Java
- b. C
- c. C++
- d. Python
- e. It will give a NullPointerException

9. Suppose you want to add a node with data "Pascal" after "C++". That is, the new linked list should be:

front → Java → C → C++ → Pascal → Python → **null**

Consider the following piece of code to accomplish the above task:

```
Node<T> prev = front;
prev = prev.getNext();
prev = prev.getNext();
//Missing line 1
//Missing line 2
```



The missing lines 1 and 2, respectively, are:

- a. `Node<T> newN = new Node<T> ("Pascal", prev.getNext());` //Missing line 1
`prev.setNext(newN);` //Missing line 2
- b. `prev.setNext(newN);` //Missing line 1
`Node<T> newN = new Node<T> ("Pascal", prev.getNext());` //Missing line 2
- c. `prev.getNext().setNext(newN);` //Missing line 1
`Node<T> newN = new Node<T> ("Pascal", prev.getNext().getNext());` //Missing line 2
- d. `Node<T> newN = new Node<T> ("Pascal", prev.getNext().getNext());` //Missing line 1
`prev.getNext().setNext(newN);` //Missing line 2
- e. None of the above

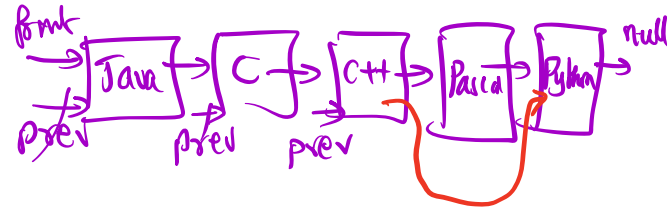
10. Now suppose that you have the following linked list:

front → Java → C → C++ → Pascal → Python → **null**

You want to delete the node with “Pascal”.

Consider the following piece of code to accomplish the above task:

```
Node<T> prev = front;
prev = prev.getNext();
prev = prev.getNext();
//Missing line
```



Which of the following is the correct code for the missing line?

- a. `prev.setNext (prev.getNext () .getNext ()) ;`
- b. `prev.setNext (prev.getNext ()) ;`
- c. `prev.setNext (prev.getNext () .getNext () .getNext ()) ;`
- d. None of the above

Question 2: Short answer questions

In your own words, answer the following questions, very briefly:

1. What does it mean for an algorithm to have a complexity of $O(1)$?

Constant time complexity – the run time doesn't increase with increase in the input size.

2. Which has larger time complexity: $O(1)$ or $O(1/n)$? Why?

$O(1)$ because with $O(1/n)$, the time complexity decreases as n increases.

3. What is the use of the instanceof operator in Java?

Helps keep track of what type of object is referred to by a variable. Useful in polymorphism.

4. What is an abstract class in Java? Give an example.

Class from which objects cannot be instantiated. Other subclasses (which are concrete) implement the methods in the abstract class and can instantiate objects.

Example: Car class → abstract; Audi class → concrete

5. Give an example of an algorithm that have each of the following complexities:

Big O Complexity	Algorithm
$O(n)$	Linear search of an array of n items
$O(n^2)$	Evaluation of a polynomial of degree n .
$O(n^3)$	Multiplication of two $n \times n$ matrices.
$O(\log_2 n)$	Binary search of a sorted array of n items.
$O(n \log_2 n)$	Merge Sort of an array of n items.

Question 3: Programming and Program Analysis Type Questions

1. Write a class called Point that has two attributes (xpos and ypos), a constructor that sets xpos and ypos, set methods for xpos and ypos, get methods for xpos and ypos, and a toString method that returns the values. The class must be written as a generic class, which means that it should work for any type of object, say Integer, or Double, or String. **Comments not required.**

```
public class Point<T>{
//continue

    private T xpos, ypos;
    public Point(T xpos, T ypos){
        this.xpos=xpos;
        this.ypos=ypos;
    }
    public void setX(T xpos){this.xpos=xpos;}
    public void setY(T ypos){this.ypos=ypos;}
    public T getX(){return xpos;}
    public T getY(){return ypos;}
    public String toString(){return "xpos: " + xpos + ",ypos: " + ypos;}
}
```

2. The following is a method to find the sum of an array of integers. Analyze the code line by line (for the line numbers given) and determine the total run time of the algorithm. Assume that the time for one basic operation is t. Express it in terms of n, where n is the array length.

```
        public static int findSum(int[] arr){
1.            int sum = 0;
2.            int index = 0;
3.            while (index<arr.length){
4.                sum = sum + arr[index];
5.                index++;
6.            }
            return sum;
        }
```

Answer:

Line no.	Time
1.	t
2.	t
3.	(n+1)t
4.	nt
5.	nt
6.	t

Total run time = $t + t + (n+1)t + nt + nt + t = 3nt + 4t$

3. Analyze **each of** the following **codes** line by line (**for the given line numbers**) and determine the total run time of the algorithm. Assume that the time for one basic operation is t . Express it in terms of n , where n is the array length.

```

    public static int myMethod(int[] arr){
1.      int max=0, min=0, sum=0;
2.      int index = arr.length-1;
3.      while (index!=0){
4.          if (arr[index] > max){
5.              max = arr[index];
6.          if (arr[index] < min)
7.              min=arr[index];
8.          sum = sum+arr[index];
9.          index--;
        }
10.     return sum;
    }

```

Answer:

Line no.	Time		
		5.	$(n-1)t \rightarrow$ worst case
		6.	$(n-1)t$
1.	$3t$	7.	$(n-1)t \rightarrow$ worst case
2.	t	8.	$(n-1)t$
3.	nt	9.	$(n-1)t$
4.	$(n-1)t$	10.	t

Total run time = $3t + t + nt + 6(n-1)t + t = 4t + nt + 6nt - 6t + t = 7nt - t$

```

    public static double myMethod(double[] arr){
1.      double sum=0.0;
2.      int index = arr.length-1;
3.      while (index>=0){
4.          if (arr[index]!=0)
5.              sum = sum+arr[index];
6.          index--;
        }
7.     return sum;
    }

```

Answer:

Line no.	Time
1.	t
2.	t
3.	$(n+1)t$
4.	nt
5.	$nt \leftarrow$ worst case
6.	t
7.	t

Total run time = $t + t + (n+1)t + nt + nt + t + t = 4nt + 4t$

Question 4: An algorithm takes 30 milliseconds to process 256 data items. Estimate how long it will take to process 1024 data items if the complexity of the algorithm is each of the following:

- a) $O(n)$
- b) $O(\sqrt{n})$
- c) $O(n \log_2 n)$

(Just write the expressions and put in the values. No need to calculate the final answers).

a)
$$\begin{array}{l} 256 \rightarrow 30 \\ 1024 \rightarrow x \end{array} \quad x = \frac{30 \times 1024}{256} = 120$$

b)
$$\begin{array}{l} \sqrt{256} \rightarrow 30 \\ \sqrt{1024} \rightarrow x \end{array} \quad x = \frac{30 \times \sqrt{1024}}{\sqrt{256}} = 60$$

c)
$$\begin{array}{l} 256 \log 256 \rightarrow 30 \\ 1024 \log 1024 \rightarrow x \end{array} \quad x = \frac{30 \times 1024 \log 1024}{256 \log 256} = 150$$

Question 5: Derive the Big O complexity of each of the following code segments, separately.
 What is the Big O complexity of all the code segments together (written one below the other)?

Code Segment 1:

```
for (int i = 1; i <= n; i++)
    sum++;
```

$O(n)$

Code Segment 2:

```
for (int i = 1; i <= n; i++)
    for (int j = 1; j <= n; j++)
        sum++;
```

$O(n^2)$

Code Segment 3:

```
if (x==10)
    for (int i = 1; i <= n; i++)
        sum++;
else{
    for(int i=1;i<=n;i++)
        for(int j=1; j<=n;j++)
            for(int k=1;k<=n;k++)
                sum++;
}
```

$\begin{matrix} 1 \\ \{ \\ n \end{matrix}$

$\begin{matrix} \\ \{ \\ n^3 \end{matrix}$

$1 + \text{MAX}(n, n^3)$
 $= 1 + n^3$
 $\rightarrow O(n^3)$

Code Segment 4:

```
for (int j = 1; j < n; j=2*j)
    sum++;
```

$O(\log_2 n)$

Code Segment 5:

```
for (int i = 1; i <= n; i++) {
    if (found==true)
        for (int j = 1; j <= n; j++)
            sum++;
    else
        for (int j = 1; j <= n; j++)
            for(int k=1; k<=n;k++)
                sum++;
}
```

$\begin{matrix} 1 \\ \left. \begin{matrix} \left. \begin{matrix} \\ \left. \begin{matrix} \\ n^2 \end{matrix} \right] n^2 \end{matrix} \right] n \end{matrix} \right\} n$

$n (1 + \text{MAX}(n, n^2))$
 $= n (1 + n^2)$
 $= n + n^3$
 $\rightarrow O(n^3)$

Code Segment 6:

```
for (int i=1; i<=n; i++)
    for (int j=1; j<=n; j = 2 * j)
        for (int k=1; k<=n; k = k * 2)
            count++;
```

$O(n (\log_2 n)^2)$

OVERALL = $O(n^3)$

Question 6:

Suppose the generic Node class has been developed as shown below.

```
public class Node<T>{
    private T data;
    private Node<T> next;
    public Node (T data, Node<T> next){
        this.data = data;
        this.next = next;
    }
    public T getData(){
        return data;
    }
    public Node<T> getNext(){
        return this.next;
    }
    public void setData(T data){
        this.data = data;
    }
    public void setNext(Node<T> next){
        this.next = next;
    }
}
```

The LinkedList<T> class has the following structure.

```
public class LinkedList<T>
{
    private Node<T> front;
    private int count;

    public LinkedList()
    {
        front = null;
        count=0;
    }
}
```

Add the following methods to the above LinkedList class:

```
//scan the list and display the items in the list
public void enumerate() {
```

```
    Node<T> curr = front;
    while (curr!=null){
        System.out.print(curr.getData() + "->");
        curr = curr.getNext();
    }
}
```

```
//scan the list and display the first, third, fifth, etc. items in the list. //For
example, if the list is
// front → Java → C → C++ → Pascal → Python → null
// it should display: Java C++ Python
```

```
public void displayOdd() {
    Node<T> curr = front;
    int i = 1;
    while (curr!=null) {
        if (i%2!=0)
            System.out.print(curr.getData() + " ");
        curr=curr.getNext();
        i++;
    }
}
```

```
//Add a given item after the first node. If the list is empty, just return.  
public void addAfterFront(T item){
```

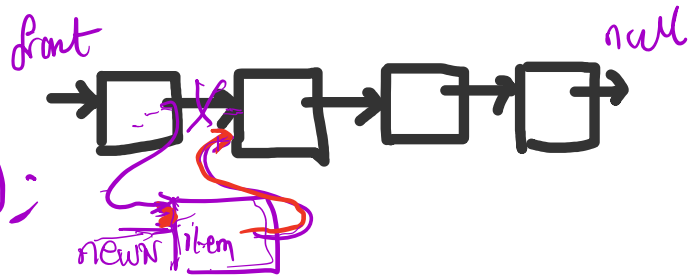
```
if (count == 0) return;
```

```
Node<T> newN = new Node<T>  
    ( item, front.getNext());
```

```
front.setNext(newN);
```

```
count++;
```

```
}
```



```
//Remove the second last item (last but one) in the list. If the list has only //zero  
nodes or only one node, just return.
```

```
public void removeSecondLast(){
```

```
if (count == 0 || count == 1) return;
```

```
Node<T> curr = front;
```

```
while (curr.getNext().getNext().getNext() != null){
```

```
    curr = curr.getNext();
```

```
    curr.setNext(curr.getNext().getNext());
```

```
    count--;
```

```
}
```

