INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

OBJECT ORIENTED PROGRAMMING WITH JAVA LABORATORY							
I Semester: AE / ME / CE / ECE / EEE / CSE / CSE (AI & ML) / CSE (DS) / CSE (CS) / IT							
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**	
		L	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
ACSD02	**Foundation**	0	1	2	2	40	60	100
Contact Classes: 15	**Tutorial Classes: NIL**	**Practical Classes: 30**				**Total Classes: 45**		
Prerequisite: There are no prerequisites to take this course.								

I. COURSE OVERVIEW:

This course provides a solid foundation in object-oriented programming concepts and hands-on experience in using them. It introduces the concepts of abstraction and reusable code design via the object-oriented paradigm. Through a series of examples and exercises students gain coding skills and develop an understanding of professional programming practices. Mastering Java facilitate the learning of other technologies.

II. COURSES OBJECTIVES:
The students will try to learn

   I.   The strong foundation with the Java Virtual Machine, its concepts and features.
   II. The systematic understanding of key aspects of the Java Class Library
   III. The usage of a modern IDE with an object oriented programming language to develop programs.

III. COURSE OUTCOMES:
At the end of the course students should be able to:

CO 1   Develop non-trivial programs in an modern programming language.

CO 2   Apply the principles of selection and iteration.

CO 3   Appreciate uses of modular programming concepts for handling complex problems.

CO 4   Recognize and apply principle features of object-oriented design such as abstraction and encapsulation.

CO 5   Design classes with a view of flexibility and reusability.

CO 6   Code, test and evaluate small use cases to conform to a specification.

EXERCISES FOR OBJECT ORIENTED PROGRAMMING WITH JAVA LABORATORY

Note: Students are encouraged to bring their own laptops for laboratory practice sessions.

1. Getting Started Exercises

1.1 HelloWorld

1. Install JDK on your machine.

2. Write a Hello-world program using JDK and a source-code editor, such as:

   o   For All Platforms: Sublime Text, Atom

   o   For Windows: TextPad, NotePad++

   o   For macOS: jEdit, gedit

   o   For Ubuntu: gedit

3. Do ALL the exercises.

1.2 Writing Good Programs

The only way to learn programming is program, program and program. Learning programming is like learning cycling, swimming or any other sports. You can't learn by watching or reading books. Start to program immediately. On the other hands, to improve your programming, you need to read many books and study how the masters program.

It is easy to write programs that work. It is much harder to write programs that not only work but also easy to maintain and understood by others – I call these *good programs*. In the real world, writing program is not meaningful. You have to write good programs, so that others can understand and maintain your programs.

Pay particular attention to:

1. Coding Style:

   o   Read "Java Code Convention"
       (@ https://www.oracle.com/technetwork/java/codeconventions-150003.pdf or google "Java Code Convention").

   o   Follow the *Java Naming Conventions* for variables, methods, and classes STRICTLY. Use *CamelCase* for names. Variable and method names begin with lowercase, while class names begin with uppercase. Use nouns for variables (e.g., `radius`) and class names (e.g., `Circle`). Use verbs for methods (e.g., `getArea()`, `isEmpty()`).

   o   **Use Meaningful Names**: Do not use names like a, b, c, d, x, x1, x2, and x1688 - they are meaningless. Avoid single-alphabet names like i, j, k. They are easy to type, but usually meaningless. Use single-alphabet names only when their meaning is clear, e.g., x, y, z for co-ordinates and i for array index. Use meaningful names like `row` and `col` (instead of x and y, i and j, x1 and x2), `numStudents` (not n), `maxGrade`, `size` (not n), and `upperbound` (not n again). Differentiate between singular and plural nouns (e.g., use `books` for an array of books, and book for each item).

2. Program Documentation: Comment! Comment! and more Comment to explain your code to other people and to yourself three days later.

1.3 CheckPassFail (if-else)

Write a program called **CheckPassFail** which prints "PASS" if the int variable "mark" is more than or equal to 50; or prints "FAIL" otherwise. The program shall always print "DONE" before exiting.

Hints

Use >= for *greater than or equal to* comparison.

```
/* Trying if-else statement.
 */
public class CheckPassFail {  // Save as "CheckPassFail.java"
   public static void main(String[] args) {  // Program entry point
      int mark = 49;   // Set the value of "mark" here!
      System.out.println("The mark is " + mark);

      // if-else statement
      if ( ...... ) {
         System.out.println( ...... );
      } else {
         System.out.println( ...... );
      }
      System.out.println( ...... );
   }
}
```

Try

mark = 0, 49, 50, 51, 100 and verify your results.

Take note of the source-code **indentation**!!! Whenever you open a block with '{', indent all the statements inside the block by 3 (or 4 spaces). When the block ends, un-indent the closing '}' to align with the opening statement.

1.4 CheckOddEven (if-else)

Write a program called **CheckOddEven** which prints "Odd Number" if the int variable "number" is odd, or "Even Number" otherwise. The program shall always print "bye!" before exiting.

Hints

n is an even number if (*n* % 2) is 0; otherwise, it is an odd number. Use == for comparison, e.g., (n % 2) == 0.

```
/**
 * Trying if-else statement and modulus (%) operator.
 */
public class CheckOddEven {   // Save as "CheckOddEven.java"
   public static void main(String[] args) {  // Program entry point
      int number = 49;        // Set the value of "number" here!
      System.out.println("The number is " + number);
      if ( ...... ) {
```

```
         System.out.println( ...... );    // even number
      } else {
         System.out.println( ...... );    // odd number
      }
      System.out.println( ...... );
   }
}
```

Try

number = 0, 1, 88, 99, -1, -2 and verify your results.

Again, take note of the source-code indentation! Make it a good habit to ident your code properly, for ease of reading your program.

1.5 *PrintNumberInWord (nested-if, switch-case)*

Write a program called **PrintNumberInWord** which prints "ONE", "TWO",... , "NINE", "OTHER" if the int variable "number" is 1, 2,... , 9, or other, respectively. Use (a) a "nested-if" statement; (b) a "switch-case-default" statement.

Hints

```
/**
 * Trying nested-if and switch-case statements.
 */
public class PrintNumberInWord {   // Save as "PrintNumberInWord.java"
   public static void main(String[] args) {
      int number = 5;  // Set the value of "number" here!

      // Using nested-if
      if (number == 1) {    // Use == for comparison
         System.out.println( ...... );
      } else if ( ...... ) {
         ......
      } else if ( ...... ) {
         ......
      ......
      ......
      } else {
         ......
      }

      // Using switch-case-default
      switch(number) {
         case 1:
            System.out.println( ...... ); break;   // Don't forget the "break"
after each case!
         case 2:
            System.out.println( ...... ); break;
         ......
         ......
         default: System.out.println( ...... );
      }
   }
}
```

Try

`number = 0`, 1, 2, 3, …, 9, 10 and verify your results.

1.6 PrintDayInWord (nested-if, switch-case)

Write a program called **PrintDayInWord** which prints "Sunday", "Monday", … "Saturday" if the `int` variable "dayNumber" is 0, 1, …, 6, respectively. Otherwise, it shall print "Not a valid day". Use (a) a "`nested-if`" statement; (b) a "`switch-case-default`" statement.

Try

`dayNumber = 0`, 1, 2, 3, 4, 5, 6, 7 and verify your results.

2. Exercises on Number Systems (for Science/Engineering Students)

To be proficient in programming, you need to be able to operate on these number systems:

1. Decimal (used by human beings for input and output)
2. Binary (used by computer for storage and processing)
3. Hexadecimal (shorthand or compact form for binary)

2.1   Exercises (Number Systems Conversion)

1. Convert the following *decimal* numbers into *binary* and *hexadecimal* numbers:
   a. 108
   b. 4848
   c. 9000

   Convert the following binary numbers into hexadecimal and decimal numbers:

   a. 10000000
   b. 101010101010
   c. 1000011000

   Convert the following hexadecimal numbers into binary and decimal numbers:

   a. 1234
   b. 80F
   c. ABCDE

   Convert the following decimal numbers into binary equivalent:

   a. 123.456D
   b. 19.25D

2.2 Exercise (Integer Representation)

1. What are the ranges of 8-bit, 16-bit, 32-bit and 64-bit integer, in "unsigned" and "signed" representation?
2. Give the value of 88, 0, 1, 127, and 255 in 8-bit unsigned representation.
3. Give the value of +88, -88 , -1, 0, +1, -128, and +127 in 8-bit 2's complement signed representation.
4. Give the value of +88, -88 , -1, 0, +1, -127, and +127 in 8-bit sign-magnitude representation.
5. Give the value of +88, -88 , -1, 0, +1, -127 and +127 in 8-bit 1's complement representation.

2.3 Exercises (Floating-point Numbers)

1. Compute the largest and smallest positive numbers that can be represented in the 32-bit normalized form.
2. Compute the largest and smallest negative numbers can be represented in the 32-bit normalized form.
3. Repeat (1) for the 32-bit denormalized form.
4. Repeat (2) for the 32-bit denormalized form.

Hints:

1. Largest positive number: S=0, E=1111 1110 (254), F=111 1111 1111 1111 1111 1111. Smallest positive number: S=0, E=0000 00001 (1), F=000 0000 0000 0000 0000 0000.
2. Same as above, but S=1.
3. Largest positive number: S=0, E=0, F=111 1111 1111 1111 1111 1111. Smallest positive number: S=0, E=0, F=000 0000 0000 0000 0000 0001.
4. Same as above, but S=1.

2.4 Exercises (Data Representation)

For the following 16-bit codes:

```
0000 0000 0010 1010;
1000 0000 0010 1010;
```

Give their values, if they are representing:

1. a 16-bit unsigned integer;
2. a 16-bit signed integer;
3. two 8-bit unsigned integers;
4. two 8-bit signed integers;
5. a 16-bit Unicode characters;
6. two 8-bit ISO-8859-1 characters.

3. Exercises on Decision and Loop

3.1 SumAverageRunningInt (Decision & Loop)

Write a program called **SumAverageRunningInt** to produce the sum of 1, 2, 3, ..., to 100. Store 1 and 100 in variables lowerbound and upperbound, so that we can change their values easily. Also compute and display the average.

The output shall look like:

```
The sum of 1 to 100 is 5050
The average is 50.5
```

Hints

```
/**
 * Compute the sum and average of running integers from a lowerbound to an
upperbound using loop.
 */
```

```
public class SumAverageRunningInt {    // Save as "SumAverageRunningInt.java"
   public static void main (String[] args) {
      // Define variables
      int sum = 0;           // The accumulated sum, init to 0
      double average;        // average in double
      final int LOWERBOUND = 1;
      final int UPPERBOUND = 100;

      // Use a for-loop to sum from lowerbound to upperbound
      for (int number = LOWERBOUND; number <= UPPERBOUND; ++number) {
            // The loop index variable number = 1, 2, 3, ..., 99, 100
         sum += number;      // same as "sum = sum + number"
      }
      // Compute average in double. Beware that int / int produces int!
      ......
      // Print sum and average
      ......
   }
}
```

Try

1. Modify the program to use a "while-do" loop instead of "for" loop.

```
int sum = 0;

      int number = LOWERBOUND;          // declare and init loop index variable
      while (number <= UPPERBOUND) {   // test
         sum += number;
         ++number;                      // update
      }
```

2. Modify the program using do-while loop

```
int sum = 0;

      int number = LOWERBOUND;              // declare and init loop index variable
      do {
         sum += number;
         ++number;                          // update
      } while (number <= UPPERBOUND);   // test
```

3. What is the difference between "for" and "while-do" loops? What is the difference between "while-do" and "do-while" loops?
4. Modify the program to sum from 111 to 8899, and compute the average. Introduce an int variable called count to count the numbers in the specified range (to be used in computing the average).
5. Modify the program to find the "sum of the squares" of all the numbers from 1 to 100, i.e. 1*1 + 2*2 + 3*3 + ... + 100*100.
6. Modify the program to produce two sums: sum of odd numbers and sum of even numbers from 1 to 100. Also computer their absolute difference.

3.2 Product1ToN (or Factorial) (Decision & Loop)

Write a program called Product1ToN to compute the product of integers from 1 to 10 (i.e.,

1×2×3×…×10), as an int. Take note that It is the same as factorial of N.

Hints

Declare an int variable called `product`, initialize to 1, to accumulate the product.

```
// Define variables
int product = 1;      // The accumulated product, init to 1
final int LOWERBOUND = 1;
final int UPPERBOUND = 10;
```

Try

1. Compute the product from 1 to 11, 1 to 12, 1 to 13 and 1 to 14. Write down the product obtained and decide if the results are correct.

   HINTS: Factorial of 13 (=6227020800) is outside the range of int [-2147483648, 2147483647]. Take note that computer programs may not produce the correct result even though the code seems correct!

2. Repeat the above, but use long to store the product. Compare the products obtained with int for N=13 and N=14.

   HINTS: With long, you can store factorial of up to 20.

3.3 HarmonicSum (Decision & Loop)

Write a program called **HarmonicSum** to compute the sum of a harmonic series, as shown below, where *n*=50000. The program shall compute the sum from *left-to-right* as well as from the *right-to-left*. Are the two sums the same? Obtain the absolute difference between these two sums and explain the difference. Which sum is more accurate?

$$Harmonic(n) = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n}$$

Hints

```
/**
 * Compute the sum of harmonics series from left-to-right and right-to-left.
 */
public class HarmonicSum {    // Save as "HarmonicSum.java"
   public static void main (String[] args) {
      // Define variables
      final int MAX_DENOMINATOR = 50000;  // Use a more meaningful name instead of
n
      double sumL2R = 0.0;         // Sum from left-to-right
      double sumR2L = 0.0;         // Sum from right-to-left
      double absDiff;              // Absolute difference between the two sums

      // for-loop for summing from left-to-right
      for (int denominator = 1; denominator <= MAX_DENOMINATOR; ++denominator) {
         // denominator = 1, 2, 3, 4, 5, ..., MAX_DENOMINATOR
         ......
         // Beware that int/int gives int, e.g., 1/2 gives 0.
      }
      System.out.println("The sum from left-to-right is: " + sumL2R);

      // for-loop for summing from right-to-left
      ......
```

```
        // Find the absolute difference and display
        if (sumL2R > sumR2L) ......
        else ......
    }
}
```

3.4 ComputePI (Decision & Loop)

Write a program called **ComputePI** to compute the value of π, using the following series expansion. Use the maximum denominator (MAX_DENOMINATOR) as the terminating condition. Try MAX_DENOMINATOR of 1000, 10000, 100000, 1000000 and compare the PI obtained. Is this series suitable for computing PI? Why?

$$\pi = 4 \times \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11} + \frac{1}{13} - \frac{1}{15} + \cdots \right)$$

Hints

Add to sum if the denominator % 4 is 1, and subtract from sum if it is 3.

```
        double sum = 0.0;
        int MAX_DENOMINATOR = 1000;    // Try 10000, 100000, 1000000
        for (int denominator = 1; denominator <= MAX_DENOMINATOR; denominator += 2)
{
            // denominator = 1, 3, 5, 7, ..., MAX_DENOMINATOR
        if (denominator % 4 == 1) {
            sum += ......;
        } else if (denominator % 4 == 3) {
            sum -= ......;
        } else {    // remainder of 0 or 2
            System.out.println("Impossible!!!");
        }
    }
    ......
```

Try

1. Instead of using maximum denominator as the terminating condition, rewrite your program to use the maximum number of terms (MAX_TERM) as the terminating condition.

```
int MAX_TERM = 10000;   // number of terms used in computation
        int sum = 0.0;
        for (int term = 1; term <= MAX_TERM; term++) {
                // term = 1, 2, 3, 4, ..., MAX_TERM
            if (term % 2 == 1) {   // odd term number: add
                sum += 1.0 / (term * 2 - 1);
            } else {                // even term number: subtract
                ......
            }
        }
```

2. JDK maintains the value of π in a built-in double constant called Math.PI (=3.141592653589793). Add a statement to compare the values obtained and the Math.PI, in percents of Math.PI, i.e., (piComputed / Math.PI) * 100.

3.5 CozaLozaWoza (Decision & Loop)

Write a program called **CozaLozaWoza** which prints the numbers 1 to 110, 11 numbers per line. The program shall print "Coza" in place of the numbers which are multiples of 3, "Loza" for multiples of 5, "Woza" for multiples of 7, "CozaLoza" for multiples of 3 and 5, and so on. The output shall look like:

```
1 2 Coza 4 Loza Coza Woza 8 Coza Loza 11
Coza 13 Woza CozaLoza 16 17 Coza 19 Loza CozaWoza 22
23 Coza Loza 26 Coza Woza 29 CozaLoza 31 32 Coza
......
```

Hints

```java
public class CozaLozaWoza {   // Save as "CozaLozaWoza.java"
   public static void main(String[] args) {
      final int LOWERBOUND = 1, UPPERBOUND = 110;
      for (int number = LOWERBOUND; number <= UPPERBOUND; ++number) {
            // number = LOWERBOUND+1, LOWERBOUND+2, ..., UPPERBOUND
         // Print "Coza" if number is divisible by 3
         if ( ...... ) {
            System.out.print("Coza");
         }
         // Print "Loza" if number is divisible by 5
         if ( ...... ) {
            System.out.print(.....);
         }
         // Print "Woza" if number is divisible by 7
         ......
         // Print the number if it is not divisible by 3, 5 and 7 (i.e., it has
not been processed above)
         if ( ...... ) {
            ......
         }
         // After processing the number, print a newline if number is divisible by
11;
         // else print a space
         if ( ...... ) {
            System.out.println();  // print newline
         } else {
            System.out.print( ...... );  // print a space
         }
      }
   }
}
```

Notes

1. You cannot use nested-if (if … else if … else if … else) for this problem. It is because the tests are not mutually exclusive. For example, 15 is divisible by both 3 and 5. Nested-if is only applicable if the tests are mutually exclusive.

2. The tests above look messy. A better solution is to use a `boolean` flag to keep track of whether the number has been processed, as follows:

```java
    final int LOWERBOUND = 1, UPPERBOUND = 110;

    boolean printed;
    for (int number = LOWERBOUND; number <= UPPERBOUND; ++number) {
        printed = false;  // init before processing each number
        // Print "Coza" if number is divisible by 3
        if ( ...... ) {
            System.out.print( ...... );
            printed = true;   // processed!
        }
        // Print "Loza" if number is divisible by 5
        if ( ...... ) {
            System.out.print( ..... );
            printed = true;   // processed!
        }
        // Print "Woza" if number is divisible by 7
        ......
        // Print the number if it has not been processed
        if (!printed) {
            ......
        }
        // After processing the number, print a newline if it is divisible by 11;
        // else, print a space
        ......
    }
```

3.6 *Fibonacci (Decision & Loop)*

Write a program called **Fibonacci** to print the first 20 Fibonacci numbers F(n), where F(n)=F(n−1)+F(n−2) and F(1)=F(2)=1. Also compute their average. The output shall look like:

```
The first 20 Fibonacci numbers are:
1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597 2584 4181 6765
The average is 885.5
```

Hints

```java
/**
 * Print first 20 Fibonacci numbers and their average
 */
public class Fibonacci {
    public static void main (String[] args) {
        int n = 3;                // The index n for F(n), starting from n=3, as n=1 and
n=2 are pre-defined
        int fn;                   // F(n) to be computed
        int fnMinus1 = 1;   // F(n-1), init to F(2)
        int fnMinus2 = 1;   // F(n-2), init to F(1)
        int nMax = 20;       // maximum n, inclusive
        int sum = fnMinus1 + fnMinus2;  // Need sum to compute average
        double average;

        System.out.println("The first " + nMax + " Fibonacci numbers are:");
        ......

        while (n <= nMax) {  // n starts from 3
            // n = 3, 4, 5, ..., nMax
```

```
        // Compute F(n), print it and add to sum
        ......
        // Increment the index n and shift the numbers for the next iteration
        ++n;
        fnMinus2 = fnMinus1;
        fnMinus1 = fn;
     }

     // Compute and display the average (=sum/nMax).
     // Beware that int/int gives int.
     ......
  }
}
```

Try

1. *Tribonacci numbers* are a sequence of numbers T(n) similar to *Fibonacci numbers*, except that a number is formed by adding the three previous numbers, i.e., T(n)=T(n-1)+T(n-2)+T(n-3), T(1) =T(2)=1, and T(3)=2. Write a program called **Tribonacci** to produce the first twenty Tribonacci numbers.

3.7 *ExtractDigits (Decision & Loop)*

Write a program called **ExtractDigits** to extract each digit from an int, in the reverse order. For example, if the int is 15423, the output shall be "3 2 4 5 1", with a space separating the digits.

Hints

The *coding pattern* for extracting individual digits from an integer *n* is:
   1. Use (n % 10) to extract the last (least-significant) digit.
   2. Use n = n / 10 to drop the last (least-significant) digit.
   3. Repeat if (n > 0), i.e., more digits to extract.

Take note that *n* is destroyed in the process. You may need to clone a copy.

```
  int n = ...;
    while (n > 0) {
       int digit = n % 10;  // Extract the least-significant digit
       // Print this digit
       ......
       n = n / 10;  // Drop the least-significant digit and repeat the loop
    }
```

4. Exercises on Input, Decision and Loop

4.1 *Add2Integer (Input)*

Write a program called Add2Integers that prompts user to enter two integers. The program shall read the two integers as int; compute their sum; and print the result. For example,

```
Enter first integer: 8
Enter second integer: 9
The sum is: 17
```

Hints

```java
import java.util.Scanner;   // For keyboard input
/**
 * 1. Prompt user for 2 integers
 * 2. Read inputs as "int"
 * 3. Compute their sum in "int"
 * 4. Print the result
 */
public class Add2Integers {  // Save as "Add2Integers.java"
   public static void main (String[] args) {
      // Declare variables
      int number1, number2, sum;

      // Put up prompting messages and read inputs as "int"
      Scanner in = new Scanner(System.in);  // Scan the keyboard for input
      System.out.print("Enter first integer: ");   // No  newline  for  prompting
message
      number1 = in.nextInt();                      // Read next input as "int"
      ......
      in.close();  // Close Scanner

      // Compute sum
      sum = ......

      // Display result
      System.out.println("The sum is: " + sum);    // Print with newline
   }
}
```

4.2 SumProductMinMax3 (Arithmetic & Min/Max)

Write a program called SumProductMinMax3 that prompts user for three integers. The program shall read the inputs as int; compute the sum, product, minimum and maximum of the three integers; and print the results. For example,

```
Enter 1st integer: 8
Enter 2nd integer: 2
Enter 3rd integer: 9
The sum is: 19
The product is: 144
The min is: 2
The max is: 9
```

Hints

```java
   // Declare variables
   int number1, number2, number3;  // The 3 input integers
   int sum, product, min, max;     // To compute these

   // Prompt and read inputs as "int"
   Scanner in = new Scanner(System.in);  // Scan the keyboard
   ......
   ......
   in.close();

   // Compute sum and product
```

```
        sum = ......
        product = ......

        // Compute min
        // The "coding pattern" for computing min is:
        // 1. Set min to the first item
        // 2. Compare current min with the second item and update min if second item
is smaller
        // 3. Repeat for the next item
        min = number1;          // Assume min is the 1st item
        if (number2 < min) {  // Check if the 2nd item is smaller than current min
           min = number2;       // Update min if so
        }
        if (number3 < min) {  // Continue for the next item
           min = number3;
        }

        // Compute max - similar to min
        ......

        // Print results
        ......
```

Try

1. Write a program called `SumProductMinMax5` that prompts user for five integers. The program shall read the inputs as `int`; compute the sum, product, minimum and maximum of the five integers; and print the results. Use five `int` variables: `number1`, `number2`, ..., `number5` to store the inputs.

4.3 CircleComputation (double & printf())

Write a program called **CircleComputation** that prompts user for the radius of a circle in floating point number. The program shall read the input as `double`; compute the diameter, circumference, and area of the circle in `double`; and print the values rounded to 2 decimal places. Use System-provided constant `Math.PI` for pi. The formulas are:

```
diameter = 2.0 * radius;

area = Math.PI * radius * radius;

circumference = 2.0 * Math.PI * radius;
```

Hints

```
    // Declare variables
       double radius, diameter, circumference, area;   // inputs and results - all
in double
       ......

       // Prompt and read inputs as "double"
       System.out.print("Enter the radius: ");
       radius = in.nextDouble();  // read input as double

       // Compute in "double"
       ......

       // Print results using printf() with the following format specifiers:
       //   %.2f for a double with 2 decimal digits
       //   %n for a newline
```

```
        System.out.printf("Diameter is: %.2f%n", diameter);
        ......
```

Try

1. Write a program called **SphereComputation** that prompts user for the radius of a sphere in floating point number. The program shall read the input as double; compute the volume and surface area of the sphere in double; and print the values rounded to 2 decimal places. The formulas are:

```
surfaceArea = 4 * Math.PI * radius * radius;

volume = 4 /3 * Math.PI * radius * radius * radius;    // But this does not work in
programming?! Why?
```

Take note that you cannot name the variable surface area with a space or surface-area with a dash. Java's naming convention is surfaceArea. Other languages recommend surface_area with an underscore.

2. Write a program called **CylinderComputation** that prompts user for the base radius and height of a cylinder in floating point number. The program shall read the inputs as double; compute the base area, surface area, and volume of the cylinder; and print the values rounded to 2 decimal places. The formulas are:

```
baseArea = Math.PI * radius * radius;

surfaceArea = 2.0 * Math.PI * radius + 2.0 * baseArea;

volume = baseArea * height;
```

4.4 Swap2Integers

Write a program called Swap2Integers that prompts user for two integers. The program shall read the inputs as int, save in two variables called number1 and number2; swap the contents of the two variables; and print the results. For examples,

```
Enter first integer: 9
Enter second integer: -9
After the swap, first integer is: -9, second integer is: 9
```

Hints

To swap the contents of two variables x and y, you need to introduce a temporary storage, say temp, and do: temp ⇐ x; x ⇐ y; y ⇐ temp.

4.5 IncomeTaxCalculator (Decision)

The progressive income tax rate is mandated as follows:

Taxable Income	Rate (%)
First $20,000	0
Next $20,000	10
Next $20,000	20
The remaining	30

For example, suppose that the taxable income is $85000, the income tax payable is $20000*0% + $20000*10% + $20000*20% + $25000*30%.

Write a program called **IncomeTaxCalculator** that reads the taxable income (in int). The program shall calculate the income tax payable (in double); and print the result rounded to 2 decimal places. For examples,

```
Enter the taxable income: $41234
The income tax payable is: $2246.80

Enter the taxable income: $67891
The income tax payable is: $8367.30

Enter the taxable income: $85432
The income tax payable is: $13629.60

Enter the taxable income: $12345
The income tax payable is: $0.00
```

Hints

```java
// Declare constants first (variables may use these constants)
// The keyword "final" marked these as constant (i.e., cannot be changed).
// Use uppercase words joined with underscore to name constants
final double TAX_RATE_ABOVE_20K = 0.1;
final double TAX_RATE_ABOVE_40K = 0.2;
final double TAX_RATE_ABOVE_60K = 0.3;

// Declare variables
int taxableIncome;
double taxPayable;
......

// Compute tax payable in "double" using a nested-if to handle 4 cases
if (taxableIncome <= 20000) {          // [0, 20000]
   taxPayable = ......;
} else if (taxableIncome <= 40000) {  // [20001, 40000]
   taxPayable = ......;
} else if (taxableIncome <= 60000) {  // [40001, 60000]
   taxPayable = ......;
} else {                              // [60001, ]
   taxPayable = ......;
}
// Alternatively, you could use the following nested-if conditions
// but the above follows the table data
//if (taxableIncome > 60000) {         // [60001, ]
//   ......
//} else if (taxableIncome > 40000) {  // [40001, 60000]
//   ......
//} else if (taxableIncome > 20000) {  // [20001, 40000]
//   ......
//} else {                             // [0, 20000]
//   ......
//}

// Print results rounded to 2 decimal places
System.out.printf("The income tax payable is: $%.2f%n", ...);
```

Try

Suppose that a 10% tax rebate is announced for the income tax payable, capped at $1,000, modify your program to handle the tax rebate. For example, suppose that the tax payable is $12,000, the rebate is $1,000, as 10% of $12,000 exceed the cap.

4.6 *IncomeTaxCalculatorWithSentinel (Decision & Loop)*

Based on the previous exercise, write a program called IncomeTaxCalculatorWithSentinel which shall repeat the calculation until user enter -1. For example,

```
Enter the taxable income (or -1 to end): $41000
The income tax payable is: $2200.00

Enter the taxable income (or -1 to end): $62000
The income tax payable is: $6600.00

Enter the taxable income (or -1 to end): $73123
The income tax payable is: $9936.90

Enter the taxable income (or -1 to end): $84328
The income tax payable is: $13298.40

Enter the taxable income: $-1
bye!
```

The -1 is known as the *sentinel value*. (Wiki: In programming, a *sentinel value*, also referred to as a flag value, trip value, rogue value, signal value, or dummy data, is a special value which uses its presence as a condition of termination.)

Hints

The *coding pattern* for handling input with sentinel value is as follows:

```
// Declare constants first
final int SENTINEL = -1;    // Terminating value for input
......
// Declare variables
int taxableIncome;
double taxPayable;
......

// Read the first input to "seed" the while loop
System.out.print("Enter the taxable income (or -1 to end): $");
taxableIncome = in.nextInt();

while (taxableIncome != SENTINEL) {
   // Compute tax payable
   ......
   // Print result
   ......

   // Read the next input
   System.out.print("Enter the taxable income (or -1 to end): $");
   taxableIncome = in.nextInt();
      // Repeat the loop body, only if the input is not the SENTINEL value.
```

```
        // Take note that you need to repeat these two statements
inside/outside the loop!
    }
    System.out.println("bye!");
```

Take note that we repeat the input statements inside and outside the loop. Repeating statements is NOT a good programming practice. This is because it is easy to repeat (Cntl-C/Cntl-V), but hard to maintain and synchronize the repeated statements. In this case, we have no better choices!

4.7 *PensionContributionCalculatorWithSentinel (Decision & Loop)*

Based on the previous PensionContributionCalculator,
write a program called **PensionContributionCalculatorWithSentinel** which shall repeat the calculations until user enter -1 for the salary. For examples,

```
Enter the monthly salary (or -1 to end): $5123
Enter the age: 21
The employee's contribution is: $1024.60
The employer's contribution is: $870.91
The total contribution is: $1895.51

Enter the monthly salary (or -1 to end): $5123
Enter the age: 64
The employee's contribution is: $384.22
The employer's contribution is: $461.07
The total contribution is: $845.30

Enter the monthly salary (or -1 to end): $-1
bye!
```

Hints

```
    // Read the first input to "seed" the while loop
    System.out.print("Enter the monthly salary (or -1 to end): $");
    salary = in.nextInt();

    while (salary != SENTINEL) {
       // Read the remaining
       System.out.print("Enter the age: ");
       age = in.nextInt();

       ......
       ......

       // Read the next input and repeat
       System.out.print("Enter the monthly salary (or -1 to end): $");
       salary = in.nextInt();
    }
```

4.8 *SalesTaxCalculator (Decision & Loop)*

A sales tax of 7% is levied on all goods and services consumed. It is also mandatory that all the price tags should include the sales tax. For example, if an item has a price tag of $107, the actual price is $100 and $7 goes to the sales tax.

Write a program using a loop to continuously input the tax-inclusive price (in double); compute the actual price and the sales tax (in double); and print the results rounded to 2 decimal places. The program shall terminate in response to input of -1; and print the total price, total actual price, and total sales tax. For examples,

```
Enter the tax-inclusive price in dollars (or -1 to end): 107
Actual Price is: $100.00, Sales Tax is: $7.00

Enter the tax-inclusive price in dollars (or -1 to end): 214
Actual Price is: $200.00, Sales Tax is: $14.00

Enter the tax-inclusive price in dollars (or -1 to end): 321
Actual Price is: $300.00, Sales Tax is: $21.00

Enter the tax-inclusive price in dollars (or -1 to end): -1
Total Price is: $642.00
Total Actual Price is: $600.00
Total Sales Tax is: $42.00
```

Hints

```java
      // Declare constants
      final double SALES_TAX_RATE = 0.07;
      final int SENTINEL = -1;          // Terminating value for input

      // Declare variables
      double price, actualPrice, salesTax;  // inputs and results
      double totalPrice = 0.0, totalActualPrice = 0.0, totalSalesTax = 0.0;  // to
accumulate
      ......

      // Read the first input to "seed" the while loop
      System.out.print("Enter the tax-inclusive price in dollars (or -1 to end):
");
      price =  in.nextDouble();

      while (price != SENTINEL) {
         // Compute the tax
         ......
         // Accumulate into the totals
         ......
         // Print results
         ......

         // Read the next input and repeat
         System.out.print("Enter  the  tax-inclusive  price  in  dollars  (or  -1  to
end): ");
         price =  in.nextDouble();
      }
      // print totals
      ......
```

4.9 *ReverseInt (Loop with Modulus/Divide)*

Write a program that prompts user for a positive integer. The program shall read the input as int; and print the "reverse" of the input integer. For examples,

```
Enter a positive integer: 12345
The reverse is: 54321
```

Hints

Use the following *coding pattern* which uses a while-loop with repeated modulus/divide operations to extract and drop the last digit of a positive integer.

```
    // Declare variables
    int inNumber;   // to be input
    int inDigit;    // each digit
    ......

    // Extract and drop the "last" digit repeatably using a while-loop with
modulus/divide operations
    while (inNumber > 0) {
       inDigit = inNumber % 10; // extract the "last" digit
       // Print this digit (which is extracted in reverse order)
       ......
       inNumber /= 10;          // drop "last" digit and repeat
    }
    ......
```

4.10 *SumOfDigitsInt (Loop with Modulus/Divide)*

Write a program that prompts user for a positive integer. The program shall read the input as `int`; compute and print the sum of all its digits. For examples,

```
Enter a positive integer: 12345
The sum of all digits is: 15
```

Hints

See "ReverseInt".

4.11 *InputValidation (Loop with boolean flag)*

Your program often needs to validate the user's inputs, e.g., marks shall be between 0 and 100.

Write a program that prompts user for an integer between `0-10` or `90-100`. The program shall read the input as `int`; and repeat until the user enters a valid input. For examples,

```
Enter a number between 0-10 or 90-100: -1
Invalid input, try again...
Enter a number between 0-10 or 90-100: 50
Invalid input, try again...
Enter a number between 0-10 or 90-100: 101
Invalid input, try again...
Enter a number between 0-10 or 90-100: 95
You have entered: 95
```

Hints

Use the following *coding pattern* which uses a do-while loop controlled by a `boolean` flag to do input validation. We use a do-while instead of while-do loop as we need to execute the body to prompt and process the input at least once.

```
    // Declare variables
    int numberIn;       // to be input
    boolean isValid;    // boolean flag to control the loop
    ......

    // Use a do-while loop controlled by a boolean flag
    // to repeatably read the input until a valid input is entered
    isValid = false;    // default assuming input is not valid
    do {
       // Prompt and read input
       ......

       // Validate input by setting the boolean flag accordingly
       if (numberIn ......) {
          isValid = true;    // exit the loop
       } else {
          System.out.println(......);   // Print error message and repeat
       }
    } while (!isValid);
    ......
```

4.12 AverageWithInputValidation (Loop with boolean flag)

Write a program that prompts user for the mark (between 0-100 in int) of 3 students; computes the average (in double); and prints the result rounded to 2 decimal places. Your program needs to perform input validation. For examples,

```
Enter the mark (0-100) for student 1: 56
Enter the mark (0-100) for student 2: 101
Invalid input, try again...
Enter the mark (0-100) for student 2: -1
Invalid input, try again...
Enter the mark (0-100) for student 2: 99
Enter the mark (0-100) for student 3: 45
The average is: 66.67
```

Hints

```
    // Declare constant
    final int NUM_STUDENTS = 3;

    // Declare variables
    int numberIn;
    boolean isValid;    // boolean flag to control the input validation loop
    int sum = 0;
    double average;
    ......

    for (int studentNo = 1; studentNo <= NUM_STUDENTS; ++studentNo) {
        // Prompt user for mark with input validation
        ......
        isValid = false;    // reset assuming input is not valid
        do {
            ......
        } while (!isValid);

        sum += ......;
```

```
    }
    ......
```

5. Exercises on Nested-Loops

5.1 *SquarePattern (nested-loop)*

Write a program called **SquarePattern** that prompts user for the size (a non-negative integer in int); and prints the following square pattern using two nested for-loops.

```
Enter the size: 5
# # # # #
# # # # #
# # # # #
# # # # #
# # # # #
```

Hints

The *code pattern* for printing 2D patterns using nested loops is:

```
    // Outer loop to print each of the rows
    for (int row = 1; row <= size; row++) {  // row = 1, 2, 3, ..., size
        // Inner loop to print each of the columns of a particular row
        for (int col = 1; col <= size; col++) {  // col = 1, 2, 3, ..., size
            System.out.print( ...... );    // Use print() without newline inside
the inner loop
            ......
        }
        // Print a newline after printing all the columns
        System.out.println();
    }
```

Notes

1. You should name the loop indexes row and col, NOT i and j, or x and y, or a and b, which are meaningless.
2. The row and col could start at 1 (and upto size), or start at 0 (and upto size-1). As computer counts from 0, it is probably more efficient to start from 0. However, since humans counts from 1, it is easier to read if you start from 1.

Try

Rewrite the above program using nested while-do loops.

5.2 *CheckerPattern (nested-loop)*

Write a program called **CheckerPattern** that prompts user for the size (a non-negative integer in int); and prints the following checkerboard pattern.

```
Enter the size: 7
# # # # # # #
 # # # # # # #
# # # # # # #
 # # # # # # #
```

```
# # # # # # #
 # # # # # # #
# # # # # # #
```

Hints

```java
 // Outer loop to print each of the rows
      for (int row = 1; row <= size; row++) {   // row = 1, 2, 3, ..., size
         // Inner loop to print each of the columns of a particular row
         for (int col = 1; col <= size; col++) {   // col = 1, 2, 3, ..., size
            if ((row % 2) == 0) {    // row 2, 4, 6, ...
               ......
            }
            System.out.print( ...... );    // Use print() without newline inside
the inner loop
            ......
         }
         // Print a newline after printing all the columns
         System.out.println();
      }
```

5.3 *TimeTable (nested-loop)*

Write a program called **TimeTable** that prompts user for the size (a positive integer in int); and prints the multiplication table as shown:

```
Enter the size: 10
 * |   1   2   3   4   5   6   7   8   9  10
-----------------------------------------------
 1 |   1   2   3   4   5   6   7   8   9  10
 2 |   2   4   6   8  10  12  14  16  18  20
 3 |   3   6   9  12  15  18  21  24  27  30
 4 |   4   8  12  16  20  24  28  32  36  40
 5 |   5  10  15  20  25  30  35  40  45  50
 6 |   6  12  18  24  30  36  42  48  54  60
 7 |   7  14  21  28  35  42  49  56  63  70
 8 |   8  16  24  32  40  48  56  64  72  80
 9 |   9  18  27  36  45  54  63  72  81  90
10 |  10  20  30  40  50  60  70  80  90 100
```

Hints

1. Use printf() to format the output, e.g., each cell is %4d.

2. See "Java Basics" article.

5.4 *TriangularPattern (nested-loop)*

Write 4 programs called **TriangularPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in int); and prints each of the patterns as shown:

```
Enter the size: 8

#                      # # # # # # # #     # # # # # # # #                      #
# #                    # # # # # # #         # # # # # # #                    # #
```

```
# # #                  # # # # # #               # # # # # #                        # # #
# # # #                # # # # # #                 # # # # #                       # # # #
# # # # #              # # # #                       # # # #                       # # # # #
# # # # # #            # # #                          # # #                       # # # # # #
# # # # # # #          # #                             # #                       # # # # # # #
# # # # # # # #        #                                #                        # # # # # # #
     (a)                    (b)                      (c)                              (d)
```

Hints

1. On the main diagonal, row = col. On the opposite diagonal, row + col = size + 1, where row and col begin from 1.
2. You need to print the *leading* blanks, in order to push the # to the right. The *trailing* blanks are optional, which does not affect the pattern.
3. For pattern (a), if (row >= col) print #. Trailing blanks are optional.
4. For pattern (b), if (row + col <= size + 1) print #. Trailing blanks are optional.
5. For pattern (c), if (row >= col) print #; else print blank. Need to print the *leading* blanks.
6. For pattern (d), if (row + col >= size + 1) print #; else print blank. Need to print the *leading* blanks.
7. The *coding pattern* is:

```
// Outer loop to print each of the rows
    for (int row = 1; row <= size; row++) {  // row = 1, 2, 3, ..., size
        // Inner loop to print each of the columns of a particular row
        for (int col = 1; col <= size; col++) {  // col = 1, 2, 3, ..., size
            if (......) {
                System.out.print("# ");
            } else {
                System.out.print("  ");  // Need to print the "leading" blanks
            }
        }
        // Print a newline after printing all the columns
        System.out.println();
    }
```

5.5 *BoxPattern (nested-loop)*

Write 4 programs called **BoxPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in int); and prints the pattern as shown:

```
Enter the size: 8

# # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #
#           #     #                             #     #           #     # #         # #
#           #       #                         #         #       #       #   #     #   #
#           #         #                     #             #   #         #     # #     #
#           #           #                 #               #   #         #     # #     #
#           #             #             #               #       #       #   #     #   #
#           #               #         #               #           #     # #         # #
# # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #     # # # # # # #
     (a)                (b)                (c)                (d)                (e)
```

Hints

1. On the main diagonal, row = col. On the opposite diagonal, row + col = size + 1, where row and col begin from 1.

2. For pattern (a), `if (row == 1 || row == size || col == 1 || col == size)` print #; else print blank. Need to print the intermediate blanks.
3. For pattern (b), `if (row == 1 || row == size || row == col)` print #; else print blank.

5.6 *HillPattern (nested-loop)*

Write 3 programs called **HillPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in `int`); and prints the pattern as shown:

```
Enter the rows: 6

      #              # # # # # # # # # #              #            # # # # # # # # # #
     # # #           # # # # # # # # #              # # #          # # # # #   # # # # #
    # # # # #        # # # # # # #                 # # # # #       # # # #       # # # #
   # # # # # # #     # # # # #                    # # # # # # #    # # #           # # #
  # # # # # # # # #    # # #                     # # # # # # # # # # # #             # #
 # # # # # # # # # # #   #                      # # # # # # # # # # #   #               #
      (a)               (b)                     # # # # # # # # #       # #           # #
                                                 # # # # # # #          # # #       # # #
                                                  # # # # #             # # # #   # # # #
                                                   # # #                # # # # # # # # #
                                                    #                   # # # # # # # # #
                                                   (c)                      (d)
```

Hints

For pattern (a):

```
for (int row = 1; ......) {
        // numCol = 2*numRows - 1
        for (int col = 1; ......) {
           if ((row + col >= numRows + 1) && (row >= col - numRows + 1)) {
              ......;
           } else {
              ......;
           }
        }
        ......;
     }
```

or, use 2 sequential inner loops to print the columns:

```
    for (int row = 1; row <= rows; row++) {
       for (int col = 1; col <= rows; col++) {
          if ((row + col >= rows + 1)) {
             ......
          } else {
             ......
          }
       }
       for (int col = 2; col <= rows; col++) {   // skip col = 1
          if (row >= col) {
             ......
          } else {
             ......
```

```
        }
      }
    ......
  }
```

5.7 *NumberPattern (nested-loop)*

Write 4 programs called **NumberPatternX** (X = A, B, C, D) that prompts user for the size (a non-negative integer in `int`); and prints the pattern as shown:

```
Enter the size: 8

1                 1 2 3 4 5 6 7 8                1    8 7 6 5 4 3 2 1
1 2               1 2 3 4 5 6 7                2 1    7 6 5 4 3 2 1
1 2 3             1 2 3 4 5 6               3 2 1    6 5 4 3 2 1
1 2 3 4           1 2 3 4 5             4 3 2 1    5 4 3 2 1
1 2 3 4 5         1 2 3 4            5 4 3 2 1    4 3 2 1
1 2 3 4 5 6       1 2 3          6 5 4 3 2 1    3 2 1
1 2 3 4 5 6 7     1 2        7 6 5 4 3 2 1    2 1
1 2 3 4 5 6 7 8   1      8 7 6 5 4 3 2 1    1
     (a)              (b)              (c)              (d)
```

6. Magic(Special) Numbers

6.1. Amicable umbers

Two different numbers are said to be so Amicable numbers if each sum of divisors is equal to the other number. Amicalble Numbers are: (220, 284), (1184, 1210), (2620, 2924), (5020, 5564), (6232, 6368). For example,

```
Enter 1st number: 228
Enter 2nd number: 220
The numbers are Amicable Numbers.
```

Hints

```
220 and 284 are Amicable Numbers.

Divisors of 220 = 1, 2, 4, 5, 10, 11, 20, 22, 44, 55, 110

1+2+4+5+10+11+20+22+44+55+110 = 284

Divisors of 284 = 1, 2, 4, 71, 142

1+2+4+71+142 = 220
```

6.2. Armstrong Number

Armstrong number is a positive number if it is equal to the sum of cubes of its digits is called Armstrong number and if its sum is not equal to the number then it's not a Armstrong number. For example,

Hints

Examples: 153 is Armstrong

(1*1*1)+(5*5*5)+(3*3*3) = 153

6.3. Capricorn Number

A number is called Capricorn or Kaprekar number whose square is divided into two parts in any conditions and parts are added, the additions of parts is equal to the number, is called Capricorn or Kaprekar number. For example,

```
Enter a number : 45
45 is a Capricorn/Kaprekar number
Enter a number : 297
297 is a Capricorn/Kaprekar number
Enter a number : 44
44 is not a Capricorn/Kaprekar number
```

Hints

```
Number = 45
(45)2  = 2025

All parts for 2025:
202   + 5   =    207 (not 45)
20    + 25  =    45
2+  025   =    27 (not 45)
```

From the above we can see one combination is equal to number so that 45 is Capricorn or Kaprekar number.

Try

Write a Java program to generate and show all Kaprekar numbers less than 1000.

6.4. Circular Prime

A circular prime is a prime number with the property that the number generated at each intermediate step when cyclically permuting its digits will be prime. For example, 1193 is a circular prime, since 1931, 9311 and 3119 all are also prime. For example,

```
Enter a number : 137
137 is a Circular Prime
```

```
Enter a number : 44
44 is not a Circular Prime
```

6.5. Happy Number

A happy number is a natural number in a given number base that eventually reaches 1 when iterated over the perfect digital invariant function for. Those numbers that do not end in 1 are -unhappy numbers. For example,

```
Enter a number : 31
31 is a Happy number

Enter a number : 32
32 is not a Happy number
```

6.6. Automorphic Number

An Automorphic number is a number whose square "ends" in the same digits as the number itself. For example,

```
Enter a number : 5
5 is a Automorphic Number

Enter a number : 25
25 is a Automorphic Number

Enter a number : 2
2 is not a Automorphic Number
```

Hints

```
5*5 = 25, 6*6 = 36, 25*25 = 625

5,6,25 are automorphic numbers
```

6.7. Disarium Number

A number is called Disarium number if the sum of its power of the positions from left to right is equal to the number. For example,

```
Enter a number : 135
135 is a Disarium Number

Enter a number : 32
32 is not a Disarium Number
```

Hints

$$1^1 + 3^2 + 5^3 = 1 + 9 + 125 = 135$$

6.8. Magic Number

Magic number is the if the sum of its digits recursively are calculated till a single digit If the single digit

is 1 then the number is a magic number. Magic number is very similar with Happy Number. For example,

```
Enter a number : 226
226 is a Magic Number

Enter a number : 32
32 is not a Magic Number
Enter number = 541
153 is a Magic Number
```

Hints

```
226 is said to be a magic number

2+2+6=10 sum of digits is 10 then again 1+0=1 now we get a single digit number is 1.if we single
digit number will now 1 them it would not a magic number.
```

6.9. Neon Number

A neon number is a number where the sum of digits of square of the number is equal to the number. For example if the input number is 9, its square is 9*9 = 81 and sum of the digits is 9. i.e. 9 is a neon number. For example,

```
Enter a number: 9
9 is a Neon Number

Enter a number: 8
8 is not a Neon Number
```

6.10. Palindromic Number

A palindromic number is a number that remains the same when its digits are reversed. For example,

```
Enter a number : 16461
16461 is a Palendromic Number

Enter a number : 1234
1234 is not a Plaindromic Number
```

6.11. Perfect Number

A perfect number is a positive integer that is equal to the sum of its positive divisors, excluding the number itself. For instance, 6 has divisors 1, 2 and 3, and 1 + 2 + 3 = 6, so 6 is a perfect number. For example,

```
Enter a number : 6
6 is a Perfect Number

Enter a number : 3
3 is not a Perfect Number
```

6.12. Special Number

A number is said to be special number when the sum of factorial of its digits is equal to the number itself. Example- 145 is a Special Number as 1!+4!+5!=145. For example,

```
Enter a number : 145
145 is a Special Number


Enter a number : 23
23 is not a Special Number
```

6.13. Spy Number

A spy number is a number where the sum of its digits equals the product of its digits. For example, 1124 is a spy number, the sum of its digits is 1+1+2+4=8 and the product of its digits is 1*1*2*4=8. For example,

```
Enter a number : 1124
1124 is a Spy Number


Enter a number : 12
12 is not a Spy Number
```

6.14. Ugly Number

A number is said to be an Ugly number if positive numbers whose prime factors only include 2, 3, 5. For example, 6(2×3), 8(2x2x2), 15(3×5) are ugly numbers while 14(2×7) is not ugly since it includes another prime factor 7. Note that 1 is typically treated as an ugly number. For example,

```
Enter a number : 6
6 is an Ugly Number


Enter a number : 14
14 is not an Ugly Number
```

7. Exercises on `String` and `char` Operations

7.1 ReverseString (String & char)

Write a program called **ReverseString**, which prompts user for a `String`, and prints the *reverse* of the `String` by extracting and processing each character. The output shall look like:

```
Enter a String: abcdef
The reverse of the String "abcdef" is "fedcba".
```

Hints

For a `String` called `inStr`, you can use `inStr.length()` to get the *length* of the `String`; and `inStr.charAt(idx)` to retrieve the `char` at the `idx` position, where `idx` begins at 0, up to `instr.length() - 1`.

```
    // Define variables
    String inStr;          // input String
    int inStrLen;          // length of the input String
```

```
        ......

        // Prompt and read input as "String"
        System.out.print("Enter a String: ");
        inStr = in.next();    // use next() to read a String
        inStrLen = inStr.length();

        // Use inStr.charAt(index) in a loop to extract each character
        // The String's index begins at 0 from the left.
        // Process the String from the right
        for (int charIdx = inStrLen - 1; charIdx >= 0; --charIdx) {
            // charIdx = inStrLen-1, inStrLen-2, ... ,0
            ......
        }
```

7.2 CountVowelsDigits (String & char)

Write a program called **CountVowelsDigits**, which prompts the user for a String, counts the number of vowels (a, e, i, o, u, A, E, I, O, U) and digits (0-9) contained in the string, and prints the counts and the percentages (rounded to 2 decimal places). For example,

```
Enter a String: testing12345
Number of vowels: 2 (16.67%)
Number of digits: 5 (41.67%)
```

Hints

1. To check if a char c is a digit, you can use boolean expression (c >= '0' && c <= '9'); or use built-in boolean function Character.isDigit(c).
2. You could use in.next().toLowerCase() to convert the input String to lowercase to reduce the number of cases.
3. To print a % using printf(), you need to use %%. This is because % is a prefix for format specifier in printf(), e.g., %d and %f.

7.3 PhoneKeyPad (String & char)

On you phone keypad, the alphabets are mapped to digits as follows:

ABC(2), DEF(3), GHI(4), JKL(5), MNO(6), PQRS(7), TUV(8), WXYZ(9).

Write a program called **PhoneKeyPad**, which prompts user for a String (case insensitive), and converts to a sequence of keypad digits. Use (a) a nested-if, (b) a switch-case-default.

Hints

1. You can use in.next().toLowerCase() to read a String and convert it to lowercase to reduce your cases.
2. In switch-case, you can handle multiple cases by omitting the break statement, e.g.,

```
switch (inChar) {
   case 'a': case 'b': case 'c':  // No break for 'a' and 'b', fall thru 'c'
      System.out.print(2); break;
   case 'd': case 'e': case 'f':
      ......
```

```
    default:
        ......
}
```

7.4 Caesar's Code (String & char)

Caesar's Code is one of the simplest encryption techniques. Each letter in the plaintext is replaced by a letter some fixed number of position (n) down the alphabet cyclically. In this exercise, we shall pick n=3. That is, `'A'` is replaced by `'D'`, `'B'` by `'E'`, `'C'` by `'F'`, ..., `'X'` by `'A'`, ..., `'Z'` by `'C'`.

Write a program called **CaesarCode** to cipher the Caesar's code. The program shall prompt user for a plaintext string consisting of mix-case letters only; compute the ciphertext; and print the ciphertext in uppercase. For example,

```
Enter a plaintext string: Testing
The ciphertext string is: WHVWLQJ
```

Hints

1. Use `in.next().toUpperCase()` to read an input string and convert it into uppercase to reduce the number of cases.
2. You can use a big nested-if with 26 cases (`'A'`-`'Z'`). But it is much better to consider `'A'` to `'W'` as one case; `'X'`, `'Y'` and `'Z'` as 3 separate cases.
3. Take note that char `'A'` is represented as Unicode number 65 and char `'D'` as 68. However, `'A'` + 3 gives 68. This is because char + int is implicitly casted to int + int which returns an int value. To obtain a char value, you need to perform explicit type casting using `(char)('A' + 3)`. Try printing (`'A'` + 3) with and without type casting.

7.5 Decipher Caesar's Code (String & char)

Write a program called **DecipherCaesarCode** to decipher the Caesar's code described in the previous exercise. The program shall prompts user for a ciphertext string consisting of mix-case letters only; compute the plaintext; and print the plaintext in uppercase. For example,

```
Enter a ciphertext string: wHVwLQJ
The plaintext string is: TESTING
```

7.6 Exchange Cipher (String & char)

This simple cipher exchanges `'A'` and `'Z'`, `'B'` and `'Y'`, `'C'` and `'X'`, and so on.
Write a program called **ExchangeCipher** that prompts user for a plaintext string consisting of mix-case letters only. You program shall compute the ciphertext; and print the ciphertext in uppercase. For examples,

```
Enter a plaintext string: abcXYZ
The ciphertext string is: ZYXCBA
```

Hints

1. Use `in.next().toUpperCase()` to read an input string and convert it into uppercase to reduce the number of cases.
2. You can use a big nested-if with 26 cases (`'A'`-`'Z'`), or use the following relationship:

```
'A' + 'Z' == 'B' + 'Y' == 'C' + 'X' == ... == plainTextChar + cipherTextChar
Hence, cipherTextChar = 'A' + 'Z' - plainTextChar
```

7.7 *TestPalindromicWord* and *TestPalindromicPhrase* (String & char)

A word that reads the same backward as forward is called a *palindrome*, e.g., "mom", "dad", "racecar", "madam", and "Radar" (case-insensitive).

Write a program called **TestPalindromicWord**, that prompts user for a word and prints ""xxx" is|is not a palindrome".

A phrase that reads the same backward as forward is also called a palindrome, e.g., "Madam, I'm Adam", "A man, a plan, a canal - Panama!" (ignoring punctuation and capitalization).

Modify your program (called **TestPalindromicPhrase**) to check for palindromic phrase. Use in.nextLine() to read a line of input.

Hints

1. Maintain two indexes, forwardIndex (fIdx) and backwardIndex (bIdx), to scan the phrase forward and backward.

```
        int fIdx = 0, bIdx = strLen - 1;
        while (fIdx < bIdx) {
           ......
           ++fIdx;
           --bIdx;
        }
        // or
        for (int fIdx = 0, bIdx = strLen - 1; fIdx < bIdx; ++fIdx, --bIdx) {
           ......
        }
```

2. You can check if a char c is a letter either using built-in boolean function Character.isLetter(c); or boolean expression (c >= 'a' && c <= 'z'). Skip the index if it does not contain a letter.

7.8 *CheckBinStr* (String & char)

The binary number system uses 2 symbols, 0 and 1. Write a program called **CheckBinStr** to verify a binary string. The program shall prompt user for a binary string; and decide if the input string is a valid binary string. For example,

```
Enter a binary string: 10101100
"10101100" is a binary string

Enter a binary string: 10120000
"10120000" is NOT a binary string
```

Hints

Use the following coding pattern which involves a boolean flag to check the input string.

```
// Declare variables
     String inStr;      // The input string
     int inStrLen;      // The length of the input string
     char inChar;       // Each char of the input string
```

```
        boolean isValid;  // "is" or "is not" a valid binary string?
        ......

        isValid = true;  // Assume that the input is valid, unless our check fails
        for (......) {
            inChar = ......;
            if (!(inChar == '0' || inChar == '1')) {
                isValid = false;
                break;  // break the loop upon first error, no need to continue for
more errors
                     // If this is not encountered, isValid remains true after the
loop.
            }
        }
        if (isValid) {
            System.out.println(......);
        } else {
            System.out.println(......);
        }
        // or using one liner
        //System.out.println(isValid ? ... : ...);
```

7.9 CheckHexStr (String & char)

The hexadecimal (hex) number system uses 16 symbols, 0-9 and A-F (or a-f). Write a program to verify a hex string. The program shall prompt user for a hex string; and decide if the input string is a valid hex string. For examples,

```
Enter a hex string: 123aBc
"123aBc" is a hex string

Enter a hex string: 123aBcx
"123aBcx" is NOT a hex string
```

Hints

```
if (!((inChar >= '0' && inChar <= '9')
      || (inChar >= 'A' && inChar <= 'F')
      || (inChar >= 'a' && inChar <= 'f'))) {   // Use positive logic and then
reverse
    ......
}
```

7.10 Bin2Dec (String & char)

Write a program called **Bin2Dec** to convert an input binary string into its equivalent decimal number. Your output shall look like:

```
Enter a Binary string: 1011
The equivalent decimal number for binary "1011" is: 11

Enter a Binary string: 1234
error: invalid binary string "1234"
```

Hints

See "Code Example".

7.11 *Hex2Dec (String & char)*

Write a program called **Hex2Dec** to convert an input hexadecimal string into its equivalent decimal number. Your output shall look like:

```
Enter a Hexadecimal string: 1a
The equivalent decimal number for hexadecimal "1a" is: 26

Enter a Hexadecimal string: 1y3
error: invalid hexadecimal string "1y3"
```

Hints

See "Code Example".

7.12 *Oct2Dec (String & char)*

Write a program called **Oct2Dec** to convert an input Octal string into its equivalent decimal number. For example,

```
Enter an Octal string: 147
The equivalent decimal number "147" is: 103
```

8. Exercises on Arrays

8.1 *PrintArray (Array)*

Write a program called `PrintArray` which prompts user for the number of items in an array (a non-negative integer), and saves it in an `int` variable called NUM_ITEMS. It then prompts user for the values of all the items and saves them in an `int` array called `items`. The program shall then print the contents of the array in the form of [x1, x2, ..., xn]. For example,

```
Enter the number of items: 5
Enter the value of all items (separated by space): 3 2 5 6 9
The values are: [3, 2, 5, 6, 9]
```

Hints

```
      // Declare variables
      tinal int NUM_ITEMS;
      int[] items;   // Declare array name, to be allocated after NUM_ITEMS is
known
      ......

      // Prompt for for the number of items and read the input as "int"
      ......
      NUM_ITEMS = ......

      // Allocate the array
      items = new int[NUM_ITEMS];
```

```java
    // Prompt and read the items into the "int" array, if array length > 0
    if (items.length > 0) {
        ......
        for (int i = 0; i < items.length; ++i) {   // Read all items
            ......
        }
    }

    // Print array contents, need to handle first item and subsequent items
differently
    ......
    for (int i = 0; i < items.length; ++i) {
        if (i == 0) {
            // Print the first item without a leading commas
            ......
        } else {
            // Print the subsequent items with a leading commas
            ......
        }
        // or, using a one liner
        //System.out.print((i == 0) ? ...... : ......);
    }
```

8.2 *PrintArrayInStars (Array)*

Write a program called **printArrayInStars** which prompts user for the number of items in an array (a non-negative integer), and saves it in an int variable called NUM_ITEMS. It then prompts user for the values of all the items (non-negative integers) and saves them in an int array called items. The program shall then print the contents of the array in a graphical form, with the array index and values represented by number of stars. For examples,

```
Enter the number of items: 5
Enter the value of all items (separated by space): 7 4 3 0 7
0: *******(7)
1: ****(4)
2: ***(3)
3: (0)
4: *******(7)
```

Hints

```java
    // Declare variables
    final int NUM_ITEMS;
    int[] items;   // Declare array name, to be allocated after NUM_ITEMS is
known
    ......
    ......
    // Print array in "index: number of stars" using a nested-loop
    // Take note that rows are the array indexes and columns are the value in
that index
    for (int idx = 0; idx < items.length; ++idx) {   // row
        System.out.print(idx + ": ");
        // Print value as the number of stars
        for (int starNo = 1; starNo <= items[idx]; ++starNo) {   // column
            System.out.print("*");
        }
        ......
```

```
        }
    ......
```

8.3 *GradesStatistics (Array)*

Write a program which prompts user for the number of students in a class (a non-negative integer), and saves it in an `int` variable called numStudents. It then prompts user for the grade of each of the students (integer between 0 to 100) and saves them in an `int` array called grades. The program shall then compute and print the average (in `double` rounded to 2 decimal places) and minimum/maximum (in `int`).

```
Enter the number of students: 5
Enter the grade for student 1: 98
Enter the grade for student 2: 78
Enter the grade for student 3: 78
Enter the grade for student 4: 87
Enter the grade for student 5: 76
The average is: 83.40
The minimum is: 76
The maximum is: 98
```

8.4 *Hex2Bin (Array for Table Lookup)*

Write a program called **Hex2Bin** that prompts user for a hexadecimal string and print its equivalent binary string. The output shall look like:

```
Enter a Hexadecimal string: 1abc
The equivalent binary for hexadecimal "1abc" is: 0001 1010 1011 1100
```

Hints

1. Use an array of 16 `Strings` containing binary strings corresponding to hexadecimal number 0-9A-F (or a-f), as follows

```
final String[] HEX_BITS = {"0000", "0001", "0010", "0011",
                           "0100", "0101", "0110", "0111",
                           "1000", "1001", "1010", "1011",
                           "1100", "1101", "1110", "1111"};
```

8.5 *Dec2Hex (Array for Table Lookup)*

Write a program called **Dec2Hex** that prompts user for a positive decimal number, read as `int`, and print its equivalent hexadecimal string. The output shall look like:

```
Enter a decimal number: 1234
The equivalent hexadecimal number is 4D2
```

9. Exercises on Methods

9.1 *exponent() (method)*

Write a method called exponent(int base, int exp) that returns an `int` value of base raises to the power of exp. The signature of the method is:

```
   public static int exponent(int base, int exp);
```

Assume that exp is a non-negative integer and base is an integer. Do not use any Math library functions.

Also write the main() method that prompts user for the base and exp; and prints the result. For example,

```
Enter the base: 3
Enter the exponent: 4
3 raises to the power of 4 is: 81
```

Hints

```
......
public class Exponent {
   public static void main(String[] args) {
      // Declare variables
      int exp;    // exponent (non-negative integer)
      int base;   // base (integer)
      ......
      // Prompt and read exponent and base
      ......
      // Print result
      System.out.println(base + " raises to the power of " + exp + " is: "
+ exponent(base, exp));
   }

   // Returns "base" raised to the power "exp"
   public static int exponent(int base, int exp) {
      int product = 1;   // resulting product

      // Multiply product and base for exp number of times
      for (......) {
         product *= base;
      }

      return product;
   }
}
```

9.2 *isOdd() (method)*

Write a boolean method called isOdd() in a class called **OddEvenTest**, which takes an int as input and returns true if the it is odd. The signature of the method is as follows:

```
public static boolean isOdd(int number);
```

Also write the main() method that prompts user for a number, and prints "ODD" or "EVEN". You should test for negative input. For examples,

```
Enter a number: 9
9 is an odd number

Enter a number: 8
```

```
8 is an even number

Enter a number: -5
-5 is an odd number
```
Hints

See Notes.

9.3 `hasEight()` (method)

Write a boolean method called hasEight(), which takes an int as input and returns true if the number contains the digit 8 (e.g., 18, 168, 1288). The signature of the method is as follows:

```
public static boolean hasEight(int number);
```

Write a program called **MagicSum**, which prompts user for integers (or -1 to end), and produce the sum of numbers containing the digit 8. Your program should use the above methods. A sample output of the program is as follows:

```
Enter a positive integer (or -1 to end): 1

Enter a positive integer (or -1 to end): 2

Enter a positive integer (or -1 to end): 3

Enter a positive integer (or -1 to end): 8

Enter a positive integer (or -1 to end): 88

Enter a positive integer (or -1 to end): -1

The magic sum is: 96
```

Hints

The *coding pattern* to repeat until input is -1 (called *sentinel* value) is:

```
final int SENTINEL = -1;   // Terminating input
int number;

// Read first input to "seed" the while loop
System.out.print("Enter a positive integer (or -1 to end): ");
number = in.nextInt();

while (number != SENTINEL) {   // Repeat until input is -1
   ......
   ......

   // Read next input. Repeat if the input is not the SENTINEL
   // Take note that you need to repeat these codes!
   System.out.print("Enter a positive integer (or -1 to end): ");
   number = in.nextInt();
}
```

You can either repeatably use modulus/divide (n%10 and n=n/10) to extract and drop each digit in int; or convert the int to String and use the String's charAt() to inspect each char.

9.4 `print()` (Array & Method)

Write a method called **print()**, which takes an int array and print its contents in the form of [a1, a2, ..., an]. Take note that there is no comma after the last element. The method's signature is as follows:

```
public static void print(int[] array);
```

Also write a test driver to test this method (you should test on empty array, one-element array, and n-element array).

How to handle double[] or float[]? You need to write a overloaded version for double[] and a overloaded version for float[], with the following signatures:

```
public static void print(double[] array)
public static void print(float[] array)
```

The above is known as *method overloading*, where the same method name can have many versions, differentiated by its parameter list.

Hints

For the first element, print its value; for subsequent elements, print commas followed by the value.

9.5 arrayToString() (Array & Method)

Write a method called **arrayToString()**, which takes an int array and return a String in the form of [a1, a2, ..., an]. Take note that this method returns a String, the previous exercise returns void but prints the output. The method's signature is as follows:

```
public static String arrayToString(int[] array);
```

Also write a test driver to test this method (you should test on empty array, one-element array, and n-element array).

Notes: This is similar to the built-in function Arrays.toString(). You could study its source code.

9.6 contains() (Array & Method)

Write a boolean method called **contains()**, which takes an array of int and an int; and returns true if the array contains the given int. The method's signature is as follows:

```
public static boolean contains(int[] array, int key);
```

Also write a test driver to test this method.

9.7 search() (Array & Method)

Write a method called **search()**, which takes an array of int and an int; and returns the array *index* if the array contains the given int; or -1 otherwise. The method's signature is as follows:

```
public static int search(int[] array, int key);
```

Also write a test driver to test this method.

9.8 equals() (Array & Method)

Write a boolean method called **equals()**, which takes two arrays of int and returns true if the two arrays are exactly the same (i.e., same length and same contents). The method's signature is as follows:

```
public static boolean equals(int[] array1, int[] array2)
```

Also write a test driver to test this method.

9.9 copyOf() (Array & Method)

Write a boolean method called **copyOf()**, which takes an int Array and returns a copy of the given array. The method's signature is as follows:

```
public static int[] copyOf(int[] array)
```

Also write a test driver to test this method.

Write another version for **copyOf()** which takes a second parameter to specify the length of the new array. You should truncate or pad with zero so that the new array has the required length.

```
public static int[] copyOf(int[] array, int newLength)
```

NOTES: This is similar to the built-in function `Arrays.copyOf()`.

9.10 swap() (Array & Method)

Write a method called **swap()**, which takes two arrays of int and swap their contents if they have the same length. It shall return true if the contents are successfully swapped. The method's signature is as follows:

```
public static boolean swap(int[] array1, int[] array2)
```

Also write a test driver to test this method.

Hints

You need to use a temporary location to swap two storage locations.

```
// Swap item1 and item2
int item1, item2, temp;
temp = item1;
item1 = item2;
item2 = item1;
// You CANNOT simply do: item1 = item2; item2 = item2;
```

9.11 reverse() (Array & Method)

Write a method called **reverse()**, which takes an array of int and reverse its contents. For example, the reverse of [1,2,3,4] is [4,3,2,1]. The method's signature is as follows:

```
public static void reverse(int[] array)
```

Take note that the array passed into the method can be modified by the method (this is called "*pass by reference*"). On the other hand, primitives passed into a method cannot be modified. This is because a clone is created and passed into the method instead of the original copy (this is called "*pass by value*").

Also write a test driver to test this method.

Hints

You might use two indexes in the loop, one moving forward and one moving backward to point to the two elements to be swapped.

```
for (int fIdx = 0, bIdx = array.length - 1; fIdx < bIdx; ++fIdx, --bIdx) {

   // Swap array[fIdx] and array[bIdx]
   // Only need to transverse half of the array elements
}
```

You need to use a temporary location to swap two storage locations.

```
// Swap item1 and item2
int item1, item2, temp;
temp = item1;
item1 = item2;
item2 = item1;
// You CANNOT simply do: item1 = item2; item2 = item2;
```

9.12 GradesStatistics (Array & Method)

Write a program called **GradesStatistics**, which reads in *n* grades (of int between 0 and 100, inclusive) and displays the *average*, *minimum*, *maximum*, *median* and *standard deviation*. Display the floating-point values upto 2 decimal places. Your output shall look like:

```
Enter the number of students: 4
Enter the grade for student 1: 50
Enter the grade for student 2: 51
Enter the grade for student 3: 56
Enter the grade for student 4: 53
The grades are: [50, 51, 56, 53]
The average is: 52.50
The median is: 52.00
The minimum is: 50
The maximum is: 56
The standard deviation is: 2.29
```

The formula for calculating standard deviation is:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=0}^{n-1} x_i^2 - \mu^2}, \text{ where } \mu \text{ is the mean}$$

Hints:

```
public class GradesStatistics {
   public static int[] grades;   // Declare an int[], to be allocated later.
                                 // This array is accessible by all the methods.

   public static void main(String[] args) {
      readGrades();  // Read and save the inputs in global int[] grades
      System.out.println("The grades are: ");
      print(grades);
      System.out.println("The average is " + average(grades));
      System.out.println("The median is " + median(grades));
      System.out.println("The minimum is " + min(grades));
      System.out.println("The maximum is " + max(grades));
      System.out.println("The standard deviation is " + stdDev(grades));
   }

   // Prompt user for the number of students and allocate the global "grades"
array.
   // Then, prompt user for grade, check for valid grade, and store in "grades".
```

```
    public static void readGrades() { ....... }

    // Print the given int array in the form of [x1, x2, x3,..., xn].
    public static void print(int[] array) { ....... }

    // Return the average value of the given int[]
    public static double average(int[] array) { ...... }

    // Return the median value of the given int[]
    // Median is the center element for odd-number array,
    // or average of the two center elements for even-number array.
    // Use Arrays.sort(anArray) to sort anArray in place.
    public static double median(int[] array) { ...... }

    // Return the maximum value of the given int[]
    public static int max(int[] array) {
        int max = array[0];    // Assume that max is the first element
        // From second element, if the element is more than max, set the max to this
element.
        ......
    }

    // Return the minimum value of the given int[]
    public static int min(int[] array) { ....... }

    // Return the standard deviation of the given int[]
    public static double stdDev(int[] array) { ....... }
}
```

Take note that besides readGrade() that relies on global variable grades, all the methods are *self-contained general utilities* that operate on any given array.

9.13 *GradesHistogram (Array & Method)*

Write a program called **GradesHistogram**, which reads in *n* grades (as in the previous exercise), and displays the horizontal and vertical histograms. For example:

```
 0 -  9: ***
10 - 19: ***
20 - 29:
30 - 39:
40 - 49: *
50 - 59: *****
60 - 69:
70 - 79:
80 - 89: *
90 -100: **


                          *

                          *

    *       *             *

    *       *             *                      *
```

```
  *    *           *    *                *    *
 0-9  10-19 20-29 30-39 40-49 50-59 60-69 70-79 80-89 90-100
```

10. Exercises on Command-line Arguments, Recursion

10.1 *Arithmetic (Command-Line Arguments)*

Write a program called **Arithmetic** that takes three command-line arguments: two integers followed by an arithmetic operator (+, -, * or /). The program shall perform the corresponding operation on the two integers and print the result. For example:

```
java Arithmetic 3 2 +
3+2=5

java Arithmetic 3 2 -
3-2=1

java Arithmetic 3 2 /
3/2=1
```

Hints

The method main(String[] args) takes an argument: "an array of String", which is often (but not necessary) named args. This parameter captures the command-line arguments supplied by the user when the program is invoked. For example, if a user invokes:

```
java Arithmetic 12345 4567 +
```

The three command-line arguments "12345", "4567" and "+" will be captured in a String array {"12345",   "4567",   "+"} and passed into the main() method as the argument args. That is,

```
args is: {"12345", "4567", "+"}  // args is a String array
args.length is: 3                // length of the array
args[0] is: "12345"              // 1st element of the String array
args[1] is: "4567"               // 2nd element of the String array
args[2] is: "+"                  // 3rd element of the String array
args[0].length() is: 5           // length of 1st String element
args[1].length() is: 4           // length of the 2nd String element
args[2].length() is: 1           // length of the 3rd String element
```
```java
public class Arithmetic {
  public static void main (String[] args) {
    int operand1, operand2;
    char theOperator;

    // Check if there are 3 command-line arguments in the
    //  String[] args by using length variable of array.
    if (args.length != 3) {
      System.err.println("Usage: java Arithmetic int1 int2 op");
      return;
    }

    // Convert the 3 Strings args[0], args[1], args[2] to int and char.
    // Use the Integer.parseInt(aStr) to convert a String to an int.
    operand1 = Integer.parseInt(args[0]);
    operand2 = ......
```

```
    // Get the operator, assumed to be the first character of
    //  the 3rd string. Use method charAt() of String.
    theOperator = args[2].charAt(0);
    System.out.print(args[0] + args[2] + args[1] + "=");

    switch(theOperator) {
      case ('-'): System.out.println(operand1 - operand2); break;
      case ('+'): ......
      case ('*'): ......
      case ('/'): ......
      default:
        System.err.println("Error: invalid operator!");
    }
  }
}
```

Notes:

- To provide command-line arguments, use the "cmd" or "terminal" to run your program in the form "java *ClassName arg1 arg2 ....*".

- To provide command-line arguments in Eclipse, right click the source code ⇒ "Run As" ⇒ "Run Configurations..." ⇒ Select "Main" and choose the proper main class ⇒ Select "Arguments" ⇒ Enter the command-line arguments, e.g., "3 2 +" in "Program Arguments".

- To provide command-line arguments in NetBeans, right click the "Project" name ⇒ "Set Configuration" ⇒ "Customize..." ⇒ Select categories "Run" ⇒ Enter the command-line arguments, e.g., "3 2 +" in the "Arguments" box (but make sure you select the proper Main class).

Question: Try "java Arithmetic 2 4 *" (in CMD shell and Eclipse/NetBeans) and explain the result obtained. How to resolve this problem?

In Windows' CMD shell, * is known as a wildcard character, that expands to give the list of file in the directory (called Shell Expansion). For example, "dir *.java" lists all the file with extension of ".java". You could double-quote the * to prevent shell expansion. Eclipse has a bug in handling this, even * is double-quoted. NetBeans??

SumDigits (Command-line Arguments)

Write a program called **SumDigits** to sum up the individual digits of a positive integer, given in the command line. The output shall look like:

```
java SumDigits 12345
The sum of digits = 1 + 2 + 3 + 4 + 5 = 15
```

Exercises on Recursion

In programming, a recursive function (or method) calls itself. The classical example is factorial(n), which can be defined recursively as f(n)=n*f(n-1). Nonetheless, it is important to take note that a recursive function should have a terminating condition (or base case), in the case of factorial, f(0)=1. Hence, the full definition is:

```
factorial(n) = 1, for n = 0
factorial(n) = n * factorial(n-1), for all n > 1
```

For example, suppose n = 5:

```
// Recursive call
factorial(5) = 5 * factorial(4)
factorial(4) = 4 * factorial(3)
factorial(3) = 3 * factorial(2)
factorial(2) = 2 * factorial(1)
factorial(1) = 1 * factorial(0)
factorial(0) = 1   // Base case
// Unwinding
factorial(1) = 1 * 1 = 1
factorial(2) = 2 * 1 = 2
factorial(3) = 3 * 2 = 6
factorial(4) = 4 * 6 = 24
factorial(5) = 5 * 24 = 120 (DONE)
```

10.2 Factorial Recursive

Write a *recursive* method called `factorial()` to compute the factorial of the given integer.

```
public static int factorial(int n)
```

The recursive algorithm is:

```
factorial(n) = 1, if n = 0

factorial(n) = n * factorial(n-1), if n > 0
```

Compare your code with the *iterative* version of the `factorial()`:

```
factorial(n) = 1*2*3*...*n
```

Hints

Writing recursive function is straight forward. You simply translate the recursive definition into code with `return`.

```
// Return the factorial of the given integer, recursively
public static int factorial(int n) {
   if (n == 0) {
      return 1;    // base case
   } else {
      return n * factorial(n-1);   // call itself
   }
   // or one liner
   // return (n == 0) ? 1 : n*factorial(n-1);
}
```

Notes

1. Recursive version is often much shorter.

2. The recursive version uses much more computational and storage resources, and it need to save its current states before each successive recursive call, so as to unwind later.

10.3 Fibonacci (Recursive)

Write a *recursive* method to compute the Fibonacci number of n, defined as follows:

```
F(0) = 0

F(1) = 1

F(n) = F(n-1) + F(n-2)   for n >= 2
```

Compare the recursive version with the *iterative* version written earlier.

```
// Translate the recursive definition into code with return statements
public static int fibonacci(int n) {
    if (n == 0) {
        return 0;
    } else if (n == 1) {
        return 1;
    } else {
        return fibonacci(n-1) + fibonacci(n-2);
    }
}
```

10.4 Length of a Running Number Sequence (Recursive)

A special number sequence is defined as follows:

```
S(1) = 1
S(2) = 12
S(3) = 123
S(4) = 1234

......
S(9) = 123456789          // length is 9
S(10) = 12345678910       // length is 11
S(11) = 1234567891011     // length is 13
S(12) = 123456789101112   // length is 15
......
```

Write a *recursive* method to compute the length of S(n), defined as follows:

```
len(1) = 1
len(n) = len(n-1) + numOfDigits(n)
```

Also write an *iterative* version.

10.5 GCD (Recursive)

Write a recursive method called gcd() to compute the greatest common divisor of two given integers.

```
public static void int gcd(int a, int b)


gcd(a,b) = a, if b = 0
gcd(a,b) = gcd(b, remainder(a,b)), if b > 0
```

11. More (Difficult) Exercises

11.1 JDK Source Code

Extract the source code of the class Math from the JDK source code (JDK Installed Directory ⇒ "lib" ⇒ "src.zip" ⇒ "java.base" ⇒ "java" ⇒ "lang" ⇒ "Math.java"). Study how constants such as E and PI are defined. Also study how methods such as abs(), max(), min(), toDegree(), etc, are written.

Also study the "Integer.java", "String.java".

11.2 Matrices (2D Arrays)

Similar to Math class, write a Matrix library that supports matrix operations (such as addition, subtraction, multiplication) via 2D arrays. The operations shall support both double and int. Also write a test class to exercise all the operations programmed.

Hints

```java
public class Matrix {
   // Method signatures
   public static void print(int[][] m);
   public static void print(double[][] m);
   public static boolean haveSameDimension(int[][] m1, int[][] m2);   // Used in add(), subtract()
   public static boolean haveSameDimension(double[][] m1, double[][] m2);
   public static int[][] add(int[][] m1, int[][] m2);
   public static double[][] add(double[][] m1, double[][] m2);
   public static int[][] subtract(int[][] m1, int[][] m2);
   public static double[][] subtract(double[][] m1, double[][] m2);
   public static int[][] multiply(int[][] m1, int[][] m2);
   public static double[][] multiply(double[][] m1, double[][] m2);
   ......
}
```

11.3 *PrintAnimalPattern (Special Characters and Escape Sequences)*

Write a program called **PrintAnimalPattern**, which uses println() to produce this pattern:

```
        '__'
        (@@)
  /========\/
 / || %% ||
*  ||----||
   ¥¥     ¥¥
   ""     ""
```

Hints

Use escape sequence \uhhhh where hhhh are four hex digits to display Unicode characters such as ¥ and ©. ¥ is 165 (00A5H) and © is 169 (00A9H) in both ISO-8859-1 (Latin-1) and Unicode character sets.

Double-quote (") and black-slash (\) require escape sequence inside a String. Single quote (') does not require escape sign.

Try

Print the same pattern using printf(). (Hints: Need to use %% to print a % in printf() because % is the suffix for format specifier.)

11.4 Print Patterns (nested-loop)

Write a method to print each of the followings patterns using nested loops in a class called **PrintPatterns**. The program shall prompt user for the sizde of the pattern. The signatures of the methods are:

```
public static void printPatternX(int size);   // X: A, B, C,...; size is a positive
integer.
```

(a)
```
# # # # # # # # # # #
  # # # # # # # # #
    # # # # # # #
      # # # # #
        # # #
          #
```

(b)
```
          #
        # # #
      # # # # #
    # # # # # # #
  # # # # # # # # #
# # # # # # # # # # #
```

(c)
```
          #
        # # #
      # # # # #
    # # # # # # #
  # # # # # # # # #
# # # # # # # # # # #
  # # # # # # # # #
    # # # # # # #
      # # # # #
        # # #
          #
```

(d)
```
1
1 2
1 2 3
1 2 3 4
1 2 3 4 5
1 2 3 4 5 6
1 2 3 4 5 6 7
1 2 3 4 5 6 7 8
```

(e)
```
1 2 3 4 5 6 7 8
1 2 3 4 5 6 7
1 2 3 4 5 6
1 2 3 4 5
1 2 3 4
1 2 3
1 2
1
```

(f)
```
              1
            2 1
          3 2 1
        4 3 2 1
      5 4 3 2 1
    6 5 4 3 2 1
  7 6 5 4 3 2 1
8 7 6 5 4 3 2 1
```

(g)
```
8 7 6 5 4 3 2 1
7 6 5 4 3 2 1
6 5 4 3 2 1
5 4 3 2 1
4 3 2 1
3 2 1
2 1
1
```

(h)
```
              1
            1 2 1
          1 2 3 2 1
        1 2 3 4 3 2 1
      1 2 3 4 5 4 3 2 1
    1 2 3 4 5 6 5 4 3 2 1
  1 2 3 4 5 6 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
```

(i)
```
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
  1 2 3 4 5 6 7 6 5 4 3 2 1
    1 2 3 4 5 6 5 4 3 2 1
      1 2 3 4 5 4 3 2 1
        1 2 3 4 3 2 1
          1 2 3 2 1
            1 2 1
              1
```

```
1                         1
1 2                     2 1
1 2 3                 3 2 1
1 2 3 4             4 3 2 1
1 2 3 4 5         5 4 3 2 1
1 2 3 4 5 6     6 5 4 3 2 1
1 2 3 4 5 6 7 7 6 5 4 3 2 1
```

```
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7   7 6 5 4 3 2 1
1 2 3 4 5 6       6 5 4 3 2 1
1 2 3 4 5           5 4 3 2 1
1 2 3 4               4 3 2 1
1 2 3                   3 2 1
1 2                       2 1
```

```
1 2 3 4 5 6 7 8 7 6 5 4 3 2 1        1                              1
              (j)                                  (k)


              1
            2 3 2
          3 4 5 4 3
        4 5 6 7 6 5 4
      5 6 7 8 9 8 7 6 5
    6 7 8 9 0 1 0 9 8 7 6
  7 8 9 0 1 2 3 2 1 0 9 8 7
8 9 0 1 2 3 4 5 4 3 2 1 0 9 8
              (l)
```

11.5 Print Triangles (nested-loop)

Write a method to print each of the following patterns using nested-loops in a class called **PrintTriangles**. The program shall prompt user for the number of rows. The signatures of the methods are:

```
public static void printXxx(int numRows);   // Xxx is the pattern's name
```

```
                              1
                          1   2   1
                      1   2   4   2   1
                  1   2   4   8   4   2   1
              1   2   4   8  16   8   4   2   1
          1   2   4   8  16  32  16   8   4   2   1
      1   2   4   8  16  32  64  32  16   8   4   2   1
  1   2   4   8  16  32  64 128  64  32  16   8   4   2   1
                  (a) PowerOf2Triangle


1                                              1
1  1                                        1     1
1  2  1                                   1    2    1
1  3  3  1                              1    3    3    1
1  4  6  4  1                         1    4    6    4    1
1  5 10 10  5  1                    1    5   10   10    5    1
1  6 15 20 15  6  1               1    6   15   20   15    6    1
(b) PascalTriangle1                 (c) PascalTriangle2
```

11.6 Trigonometric Series

Write a method to compute sin(x) and cos(x) using the following series expansion, in a class called **TrigonometricSeries**. The signatures of the methods are:

```
public static double sin(double x, int numTerms);   // x in radians, NOT degrees
public static double cos(double x, int numTerms);
```

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \frac{x^9}{9!} - \cdots$$

$$\cos(x) = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \frac{x^8}{8!} - \cdots$$

Compare the values computed using the series with the JDK methods `Math.sin()`, `Math.cos()` at x=0, π/6, π/4, π/3, π/2 using various numbers of terms.

Hints

Do not use `int` to compute the factorial; as factorial of 13 is outside the `int` range. Avoid generating large numerator and denominator. Use `double` to compute the terms as:

$$\frac{x^n}{n!} = \left(\frac{x}{n}\right)\left(\frac{x}{n-1}\right)\cdots\left(\frac{x}{1}\right)$$

11.7 Exponential Series

Write a method to compute e and `exp(x)` using the following series expansion, in a class called **ExponentialSeries**. The signatures of the methods are:

```
public static double exp(int numTerms);    // x in radians
public static double exp(double x, int numTerms);
```

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \cdots$$

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \cdots$$

11.8 Special Series

Write a method to compute the sum of the series in a class called `SpecialSeries`. The signature of the method is:

```
public static double specialSeries(double x, int numTerms);
```

$$x + \frac{1}{2} \times \frac{x^3}{3} + \frac{1 \times 3}{2 \times 4} \times \frac{x^5}{5} + \frac{1 \times 3 \times 5}{2 \times 4 \times 6} \times \frac{x^7}{7} + \frac{1 \times 3 \times 5 \times 7}{2 \times 4 \times 6 \times 8} \times \frac{x^9}{9} + \cdots; \quad -1 \le x \le 1$$

11.9 `FactorialInt` (Handling Overflow)

Write a program called **FactorialInt** to list all the factorials that can be expressed as an `int` (i.e., 32-bit signed integer in the range of [-2147483648, 2147483647]). Your output shall look like:

```
The factorial of 1 is 1
The factorial of 2 is 2
...
The factorial of 12 is 479001600
The factorial of 13 is out of range
```

Hints

The maximum and minimum values of a 32-bit `int` are kept in constants `Integer.MAX_VALUE` and `Integer.MIN_VALUE`, respectively. Try these statements:

```
System.out.println(Integer.MAX_VALUE);
System.out.println(Integer.MIN_VALUE);
```

```
System.out.println(Integer.MAX_VALUE + 1);
```

Take note that in the third statement, Java Runtime does not flag out an overflow error, but silently wraps the number around. Hence, you cannot use F(n) * (n+1) > Integer.MAX_VALUE to check for overflow. Instead, overflow occurs for F(n+1) if (Integer.MAX_VALUE / Factorial(n)) < (n+1), i.e., no more room for the next number.

Try

Modify your program called **FactorialLong** to list all the factorial that can be expressed as a long (64-bit signed integer). The maximum value for long is kept in a constant called Long.MAX_VALUE.

11.10 *FibonacciInt (Handling Overflow)*

Write a program called **FibonacciInt** to list all the Fibonacci numbers, which can be expressed as an int (i.e., 32-bit signed integer in the range of [-2147483648, 2147483647]). The output shall look like:

```
F(0) = 1
F(1) = 1
F(2) = 2
...
F(45) = 1836311903
F(46) is out of the range of int
```

Hints

The maximum and minimum values of a 32-bit int are kept in constants Integer.MAX_VALUE and Integer.MIN_VALUE, respectively. Try these statements:

```
System.out.println(Integer.MAX_VALUE);
System.out.println(Integer.MIN_VALUE);
System.out.println(Integer.MAX_VALUE + 1);
```

Take note that in the third statement, Java Runtime does not flag out an overflow error, but silently wraps the number around. Hence, you cannot use F(n) = F(n-1) + F(n-2) > Integer.MAX_VALUE to check for overflow. Instead, overflow occurs for F(n) if Integer.MAX_VALUE – F(n-1) < F(n-2) (i.e., no more room for the next Fibonacci number).

Try

Write a similar program called **TribonacciInt** for Tribonacci numbers.

11.11 Number System Conversion

Write a method call **toRadix()** which converts a positive integer from one radix into another. The method has the following header:

```
public static String toRadix(String in, int inRadix, int outRadix)  // The input
and output are treated as String.
```

Write a program called **NumberConversion**, which prompts the user for an input string, an input radix, and an output radix, and display the converted number. The output shall look like:

```
Enter a number and radix: A1B2
Enter the input radix: 16
Enter the output radix: 2
"A1B2" in radix 16 is "1010000110110010" in radix 2.
```

11.12 *NumberGuess*

Write a program called **NumberGuess** to play the number guessing game. The program shall generate a random number between 0 and 99. The player inputs his/her guess, and the program shall response with "Try higher", "Try lower" or "You got it in n trials" accordingly. For example:

```
java NumberGuess
Key in your guess:
50
Try higher
70
Try lower
65
Try lower
61
You got it in 4 trials!
```

Hints

Use `Math.random()` to produce a random number in `double` between `0.0` (inclusive) and `1.0` (exclusive). To produce an int between 0 and 99, use:

```
final int SECRET_NUMBER = (int)(Math.random()*100);  // truncate to int
```

11.13 *WordGuess*

Write a program called **WordGuess** to guess a word by trying to guess the individual characters. The word to be guessed shall be provided using the command-line argument. Your program shall look like:

```
java WordGuess testing
Key in one character or your guess word: t
Trial 1: t__t___
Key in one character or your guess word: g
Trial 2: t__t__g
Key in one character or your guess word: e
Trial 3: te_t__g
Key in one character or your guess word: testing
Congratulation!
You got in 4 trials
```

Hints

Set up a `boolean` array (of the length of the word to be guessed) to indicate the positions of the word that have been guessed correctly.

Check the length of the input `String` to determine whether the player enters a single character or a guessed word. If the player enters a single character, check it against the word to be guessed, and update the `boolean` array that keeping the result so far.

Try

Try retrieving the word to be guessed from a text file (or a dictionary) randomly.

11.14 `DateUtil`

Complete the following methods in a class called **DateUtil**:

- `boolean isLeapYear(int year)`: returns `true` if the given `year` is a leap year. A year is a leap year if it is divisible by 4 but not by 100, or it is divisible by 400.
- `boolean isValidDate(int year, int month, int day)`: returns `true` if the given `year`, `month` and `day` constitute a given date. Assume that year is between 1 and 9999, month is between 1 (Jan) to 12 (Dec) and day shall be between 1 and 28|29|30|31 depending on the month and whether it is a leap year.
- `int getDayOfWeek(int year, int month, int day)`: returns the day of the week, where 0 for SUN, 1 for MON, ..., 6 for SAT, for the given date. Assume that the date is valid.
- `String toString(int year, int month, int day)`: prints the given date in the format "xxxday d mmm yyyy", e.g., "Tuesday 14 Feb 2012". Assume that the given date is valid.

Hints

To find the day of the week (Reference: Wiki "Determination of the day of the week"):

1700-	1800-	1900-	2000-	2100-	2200-	2300-	2400-
4	2	0	6	4	2	0	6

1. Based on the first two digit of the year, get the number from the following "century" table.
2. Take note that the entries 4, 2, 0, 6 repeat.
3. Add to the last two digit of the year.
4. Add to "the last two digit of the year divide by 4, truncate the fractional part".
5. Add to the number obtained from the following month table:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Non-Leap Year	0	3	3	6	1	4	6	2	5	0	3	5
Leap Year	6	2					same as above					

6. Add to the day.
7. The sum modulus 7 gives the day of the week, where 0 for SUN, 1 for MON, ..., 6 for SAT.

For example: 2012, Feb, 17

```
(6 + 12 + 12/4 + 2 + 17) % 7 = 5 (Fri)
```

The skeleton of the program is as follows:

```java
/* Utilities for Date Manipulation */
public class DateUtil {

   // Month's name - for printing
   public static String[] strMonths
       = {"Jan", "Feb", "Mar", "Apr", "May", "Jun",
          "Jul", "Aug", "Sep", "Oct", "Nov", "Dec"};

   // Number of days in each month (for non-leap years)
   public static int[] daysInMonths
       = {31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};

   // Returns true if the given year is a leap year
   public static boolean isLeapYear(int year) { ...... }

   // Return true if the given year, month, day is a valid date
   // year: 1-9999
   // month: 1(Jan)-12(Dec)
   // day: 1-28|29|30|31. The last day depends on year and month
   public static boolean isValidDate(int year, int month, int day) { ...... }

   // Return the day of the week, 0:Sun, 1:Mon, ..., 6:Sat
   public static int getDayOfWeek(int year, int month, int day) { ...... }

   // Return String "xxxday d mmm yyyy" (e.g., Wednesday 29 Feb 2012)
   public static String printDate(int year, int month, int day) { ...... }

   // Test Driver
   public static void main(String[] args) {
      System.out.println(isLeapYear(1900));  // false
      System.out.println(isLeapYear(2000));  // true
      System.out.println(isLeapYear(2011));  // false
      System.out.println(isLeapYear(2012));  // true

      System.out.println(isValidDate(2012, 2, 29));  // true
      System.out.println(isValidDate(2011, 2, 29));  // false
      System.out.println(isValidDate(2099, 12, 31)); // true
      System.out.println(isValidDate(2099, 12, 32)); // false

      System.out.println(getDayOfWeek(1982, 4, 24));  // 6:Sat
      System.out.println(getDayOfWeek(2000, 1, 1));    // 6:Sat
      System.out.println(getDayOfWeek(2054, 6, 19));   // 5:Fri
      System.out.println(getDayOfWeek(2012, 2, 17));   // 5:Fri

      System.out.println(toString(2012, 2, 14)); // Tuesday 14 Feb 2012
   }
}
```

Notes

You can compare the day obtained with the Java's Calendar class as follows:

```java
// Construct a Calendar instance with the given year, month and day
Calendar cal = new GregorianCalendar(year, month - 1, day);  // month is 0-based
// Get the day of the week number: 1 (Sunday) to 7 (Saturday)
int dayNumber = cal.get(Calendar.DAY_OF_WEEK);
String[] calendarDays = { "Sunday", "Monday", "Tuesday", "Wednesday",
                          "Thursday", "Friday", "Saturday" };

// Print result
System.out.println("It is " + calendarDays[dayNumber - 1]);
```

The calendar we used today is known as *Gregorian calendar*, which came into effect in October 15, 1582 in some countries and later in other countries. It replaces the *Julian calendar*. 10 days were removed from the calendar, i.e., October 4, 1582 (Julian) was followed by October 15, 1582 (Gregorian). The only difference between the Gregorian and the Julian calendar is the "leap-year rule". In Julian calendar, every four years is a leap year. In Gregorian calendar, a leap year is a year that is divisible by 4 but not divisible by 100, or it is divisible by 400, i.e., the Gregorian calendar omits century years which are not divisible by 400. Furthermore, Julian calendar considers the first day of the year as march 25th, instead of January 1st.

This above algorithm work for Gregorian dates only. It is difficult to modify the above algorithm to handle pre-Gregorian dates. A better algorithm is to find the number of days from a known date.

12. Exercises on Classes and Objects

12.1 The *Rectangle* Class

A class called `Rectangle`, which models a rectangle with a length and a width (in `float`), is designed as shown in the following class diagram. Write the `Rectangle` class.

Hints:
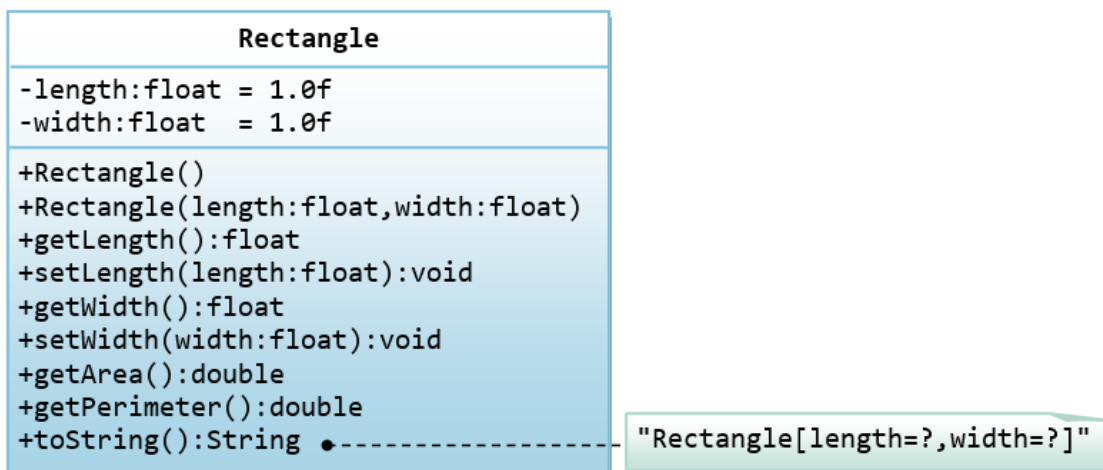
The expected output is:

```
Rectangle[length=1.2,width=3.4]
Rectangle[length=1.0,width=1.0]
Rectangle[length=5.6,width=7.8]
length is: 5.6
width is: 7.8
area is: 43.68
perimeter is: 26.80
```

12.2 The *Employee* Class

A class called `Employee`, which models an employee with an ID, name and salary, is designed as shown in the following class diagram. The method `raiseSalary(percent)` increases the salary by the given percentage. Write the `Employee` class.

Hints:
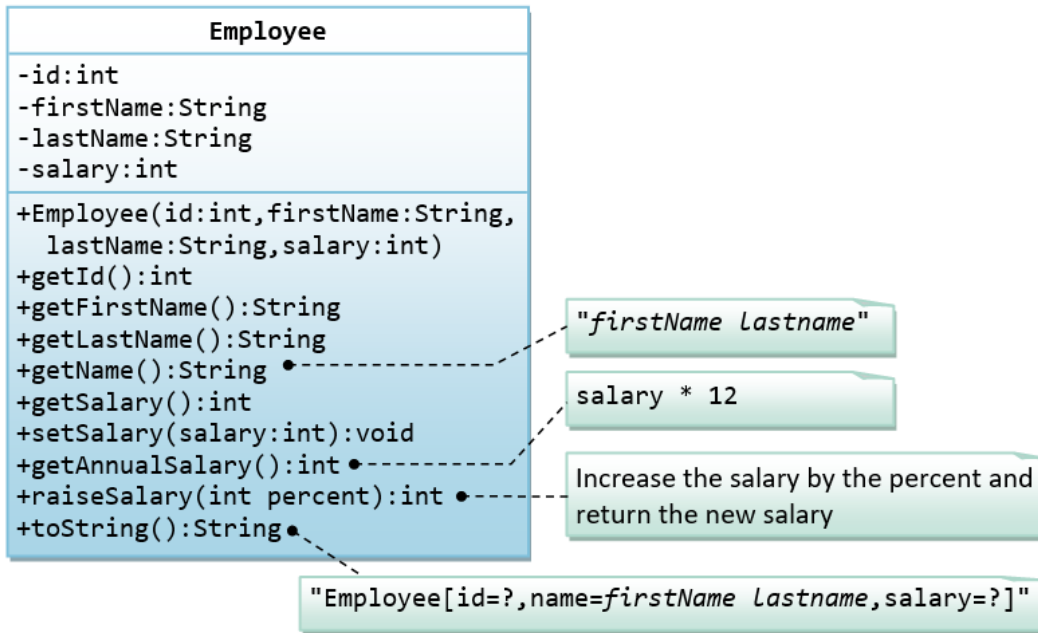
The expected out is:

```
Employee[id=8,name=Peter Tan,salary=2500]
Employee[id=8,name=Peter Tan,salary=999]
id is: 8
firstname is: Peter
lastname is: Tan
salary is: 999
name is: Peter Tan
annual salary is: 11988
1098
Employee[id=8,name=Peter Tan,salary=1098]
```

12.3 The InvoiceItem Class

A class called InvoiceItem, which models an item of an invoice, with ID, description, quantity and unit price, is designed as shown in the following class diagram. Write the InvoiceItem class.

Hints:

```
InvoiceItem
-id:String
-desc:String
-qty:int
-unitPrice:double

+InvoiceItem(id:String,desc:String,
    qty:int,unitPrice:double)
+getId():String
+getDesc():String
+getQty():int
+setQty(qty:int):void
+getUnitPrice():double
+setUnitPrice(unitPrice:double):void
+getTotal():double •----------------------- unitPrice*qty
+toString():String•

            "InvoiceItem[id=?,desc=?,qty=?,unitPrice=?]"
```
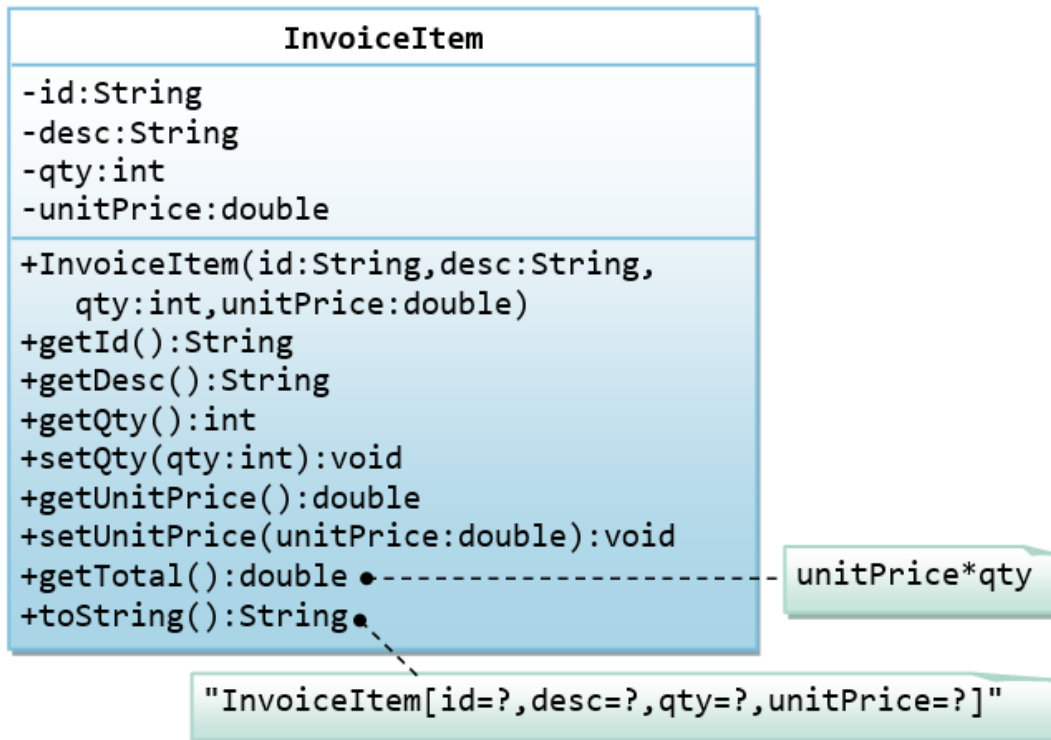
The expected output is:

```
InvoiceItem[id=A101,desc=Pen Red,qty=888,unitPrice=0.08]
InvoiceItem[id=A101,desc=Pen Red,qty=999,unitPrice=0.99]
id is: A101
desc is: Pen Red
qty is: 999
unitPrice is: 0.99
The total is: 989.01
```

12.4 The Account Class

A class called Account, which models a bank account of a customer, is designed as shown in the following class diagram. The methods credit(amount) and debit(amount) add or subtract the given amount to the balance. The method transferTo(anotherAccount, amount) transfers the given amount from this Account to the given anotherAccount. Write the Account class.

Hints:

Account

```
Account
```
-id:String
-name:String
-balance:int = 0

+Account(id:String,name:String)
+Account(id:String,name:String,
   balance:int)
+getId():String
+getName():String
+getBalance():int
+credit(amount:int):int
+debit(amount:int):int
+transferTo(another:Account,
   amount:int):int
+toString():String

Add amount to balance, return balance

If amount <= balance
   subtract amount from balance
else print "Amount exceeded balance"
return balance

If amount <= balance
   transfer amount to the given Account
else print "Amount exceeded balance"
return balance

"Account[id=?,name=?,balance=?]"

The expected output is:

```
Account[id=A101,name=Tan Ah Teck,balance=88]
Account[id=A102,name=Kumar,balance=0]
ID: A101
Name: Tan Ah Teck
Balance: 88
Account[id=A101,name=Tan Ah Teck,balance=188]
Account[id=A101,name=Tan Ah Teck,balance=138]
Amount exceeded balance
Account[id=A101,name=Tan Ah Teck,balance=138]
Account[id=A101,name=Tan Ah Teck,balance=38]
Account[id=A102,name=Kumar,balance=100]
```

12.5 The `Date` Class

A class called `Date`, which models a calendar date, is designed as shown in the following class diagram. Write the `Date` class.
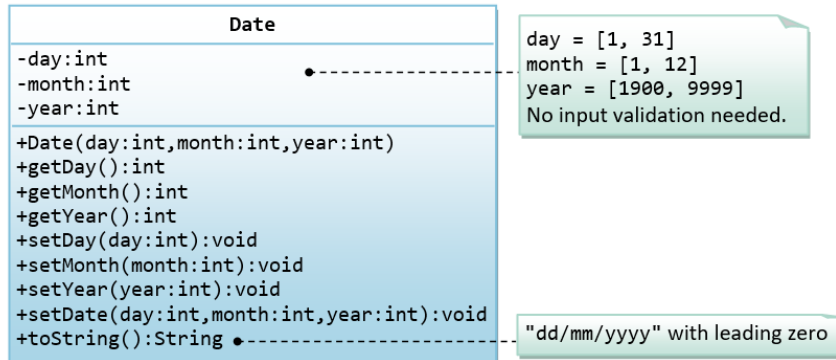
Hints:

Date
-day:int -month:int -year:int
+Date(day:int,month:int,year:int) +getDay():int +getMonth():int +getYear():int +setDay(day:int):void +setMonth(month:int):void +setYear(year:int):void +setDate(day:int,month:int,year:int):void +toString():String

```
day = [1, 31]
month = [1, 12]
year = [1900, 9999]
No input validation needed.
```

"dd/mm/yyyy" with leading zero

The expected output is:
```
01/02/2014
09/12/2099
Month: 12
Day: 9
Year: 2099
03/04/2016
```

13. Exercises on Inheritance

13.1 An Introduction to OOP Inheritance - The `Circle` and `Cylinder` Classes

This exercise shall guide you through the important concepts in inheritance.

Circle
-radius:double = 1.0 -color:String = "red"
+Circle() +Circle(radius:double) +Circle(radius:double,color:String) +getRadius():double +setRadius(radius:double):void +getColor():String +setColor(color:String):void +getArea():double +toString():String

"Circle[radius=r,color=c]"

extends — superclass / subclass

Cylinder
-height:double = 1.0
+Cylinder() +Cylinder(radius:double) +Cylinder(radius:double,height:double) +Cylinder(radius:double,height:double,   color:String) +getHeight():double +setHeight(height:double):void +getVolume():double

In this exercise, a subclass called `Cylinder` is derived from the superclass `Circle` as shown in the class diagram (where an an arrow pointing up from the subclass to its superclass). Study how the subclass `Cylinder` invokes the superclass' constructors (via `super()` and `super(radius)`) and inherits the variables and methods from the superclass `Circle`.

You can reuse the `Circle` class that you have created in the previous exercise. Make sure that you keep "`Circle.class`" in the same directory.

```java
public class Cylinder extends Circle {  // Save as "Cylinder.java"
   private double height;  // private variable

   // Constructor with default color, radius and height
   public Cylinder() {
      super();        // call superclass no-arg constructor Circle()
      height = 1.0;
   }
   // Constructor with default radius, color but given height
   public Cylinder(double height) {
      super();        // call superclass no-arg constructor Circle()
      this.height = height;
   }
   // Constructor with default color, but given radius, height
   public Cylinder(double radius, double height) {
      super(radius);  // call superclass constructor Circle(r)
      this.height = height;
   }

   // A public method for retrieving the height
   public double getHeight() {
      return height;
   }

   // A public method for computing the volume of cylinder
   //   use superclass method getArea() to get the base area
   public double getVolume() {
      return getArea()*height;
   }
}
```

Method Overriding and "Super": The subclass `Cylinder` inherits `getArea()` method from its superclass `Circle`. Try *overriding* the `getArea()` method in the subclass `Cylinder` to compute the surface area (=2π×radius×height + 2×base-area) of the cylinder instead of base area. That is, if `getArea()` is called by a `Circle` instance, it returns the area. If `getArea()` is called by a `Cylinder` instance, it returns the surface area of the cylinder.

If you override the `getArea()` in the subclass `Cylinder`, the `getVolume()` no longer works. This is because the `getVolume()` uses the *overridden* `getArea()` method found in the same class. (Java runtime will search the superclass only if it cannot locate the method in this class). Fix the `getVolume()`.

Hints: After overridding the `getArea()` in subclass `Cylinder`, you can choose to invoke the `getArea()` of the superclass `Circle` by calling `super.getArea()`.

Try:

Provide a `toString()` method to the `Cylinder` class, which overrides the `toString()` inherited from the superclass `Circle`, e.g.,

```
@Override
public String toString() {        // in Cylinder class
    return "Cylinder: subclass of " + super.toString()  // use Circle's toString()
            + " height=" + height;
}
```

Try out the `toString()` method in `TestCylinder`.

13.2 Superclass *Person* and its subclasses

Write the classes as shown in the following class diagram. Mark all the overridden methods with annotation `@Override`.
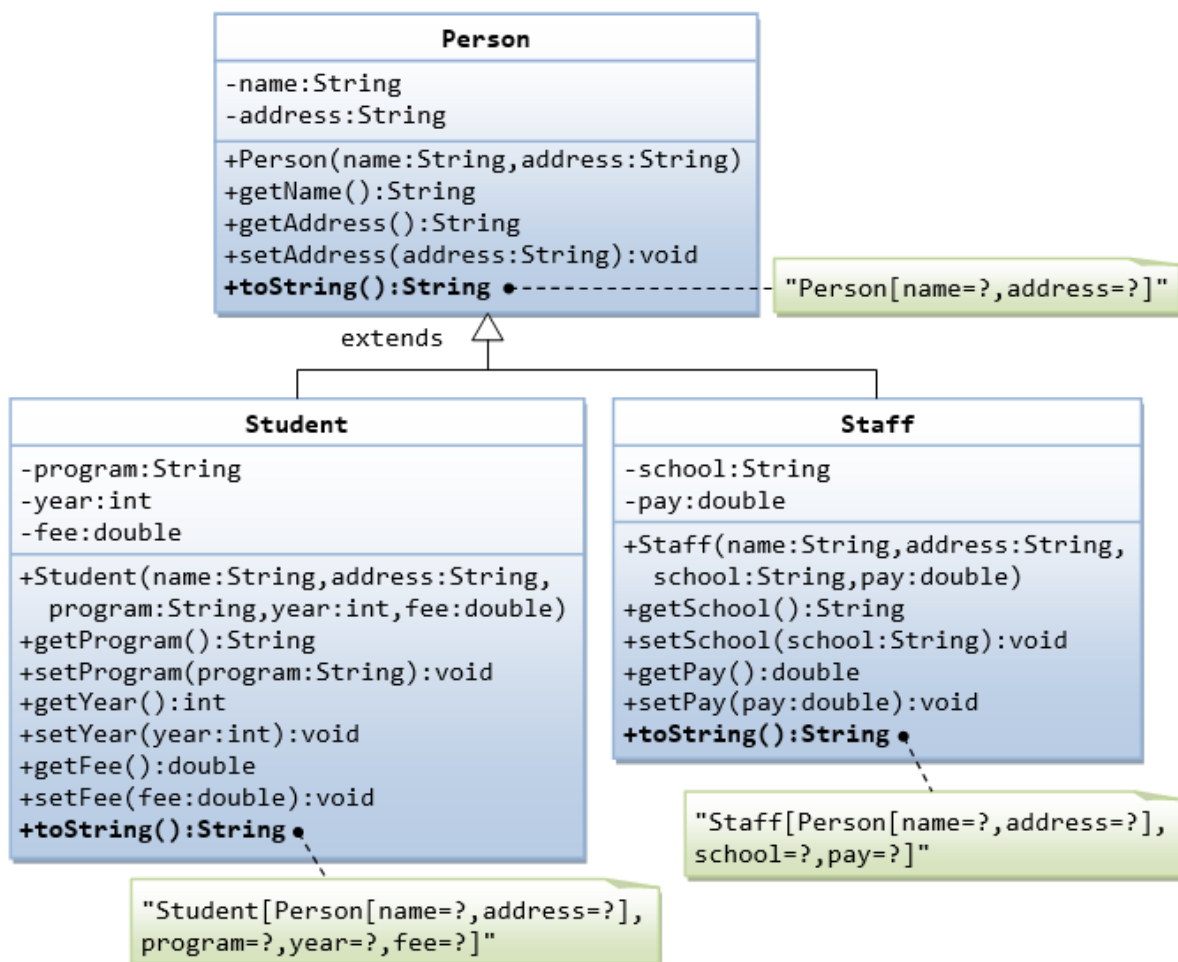
13.3 *Point2D* and *Point3D*

Write the classes as shown in the following class diagram. Mark all the overridden methods with annotation @Override.

```
                    Point2D
-x:float = 0.0f
-y:float = 0.0f
+Point2D(x:float,y:float)
+Point2D()
+getX():float
+setX(x:float):void
+getY():float
+setY(y:float):void
+setXY(x:float,y:float):void ------- Array of {x,y}
+getXY():float[2] -------------
+toString():String -------------- "(x,y)"

                extends △
                    Point3D
-z:float = 0.0f
+Point3D(x:float,y:float,z:float)
+Point3D()
+getZ():float
+setZ(z:flaot):void
+setXYZ(x:float,y:flaot,z:float):void -- Array of {x,y,z}
+getXYZ():float[3] -------------
+toString():String -------------- "(x,y,z)"
```
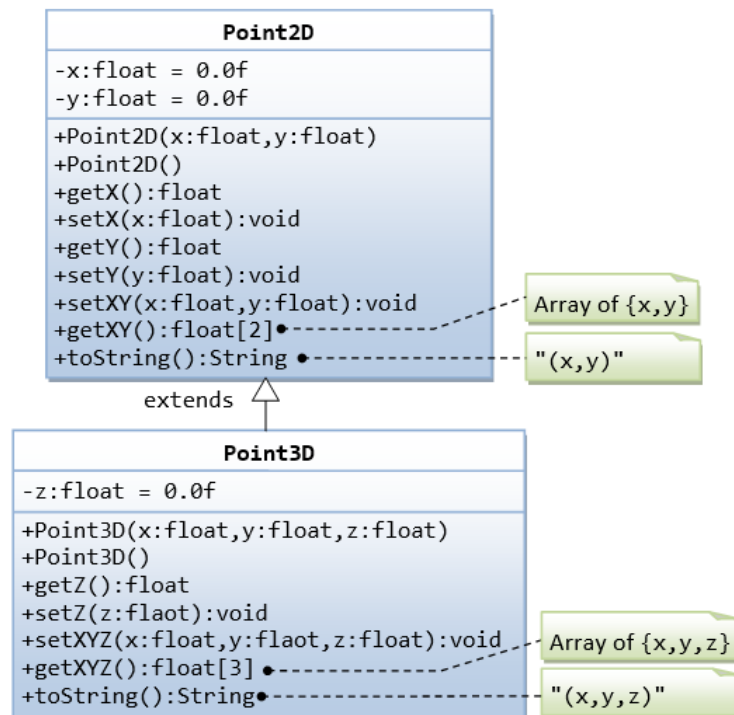
Hints:

1. You cannot assign floating-point literal say 1.1 (which is a double) to a float variable, you need to add a suffix f, e.g. 0.0f, 1.1f.
2. The instance variables x and y are private in Point2D and cannot be accessed directly in the subclass Point3D. You need to access via the public getters and setters. For example,

```
public void setXYZ(float x, float y, float z) {
      setX(x);       // or super.setX(x), use setter in superclass
      setY(y);
      this.z = z;
   }
```
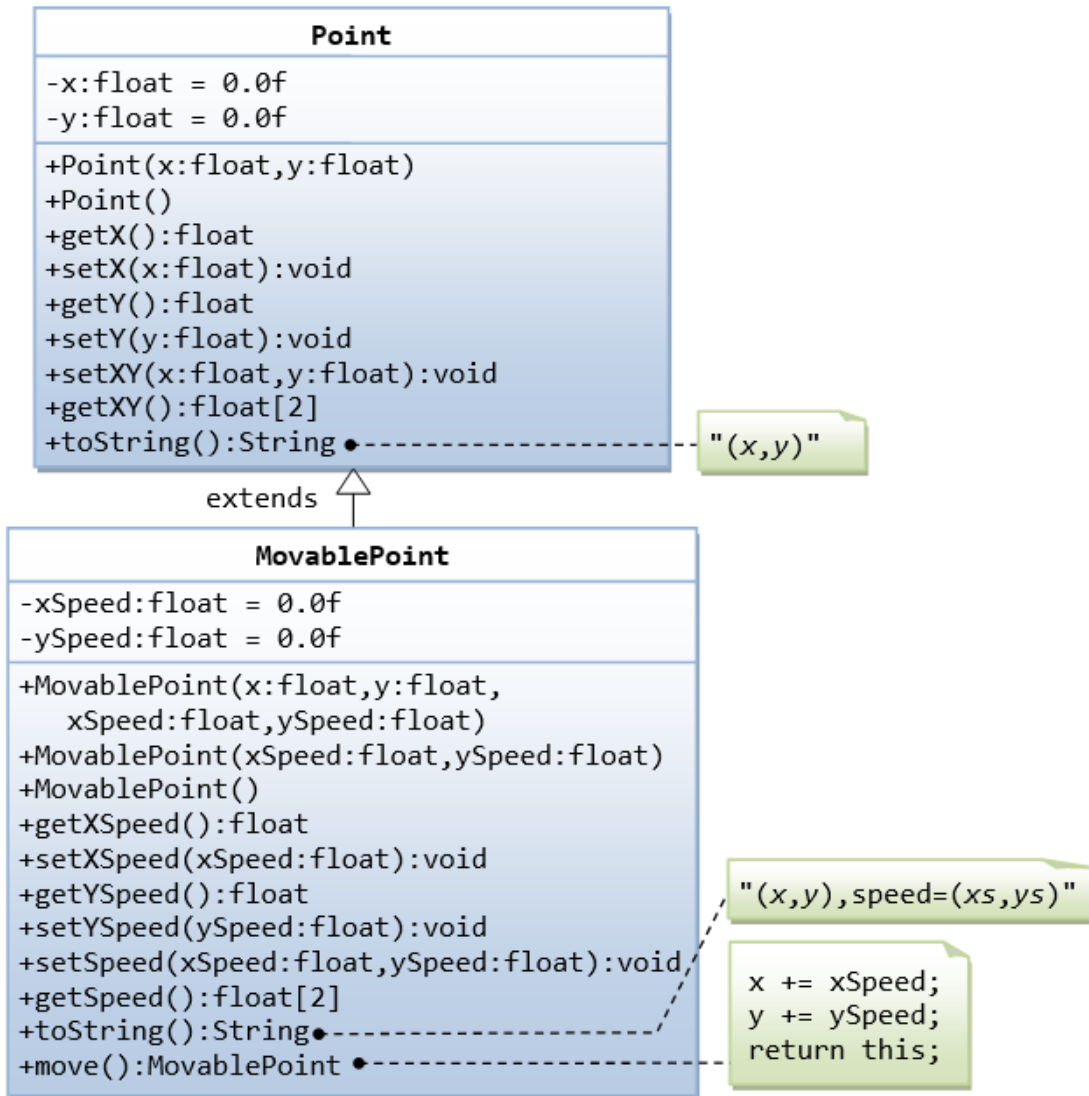
3. The method getXY() shall return a float array:

```
public float[] getXY() {
      float[] result = new float[2];  // construct an array of 2 elements
      result[0] = ...
      result[1] = ...
      return result;  // return the array
   }
```
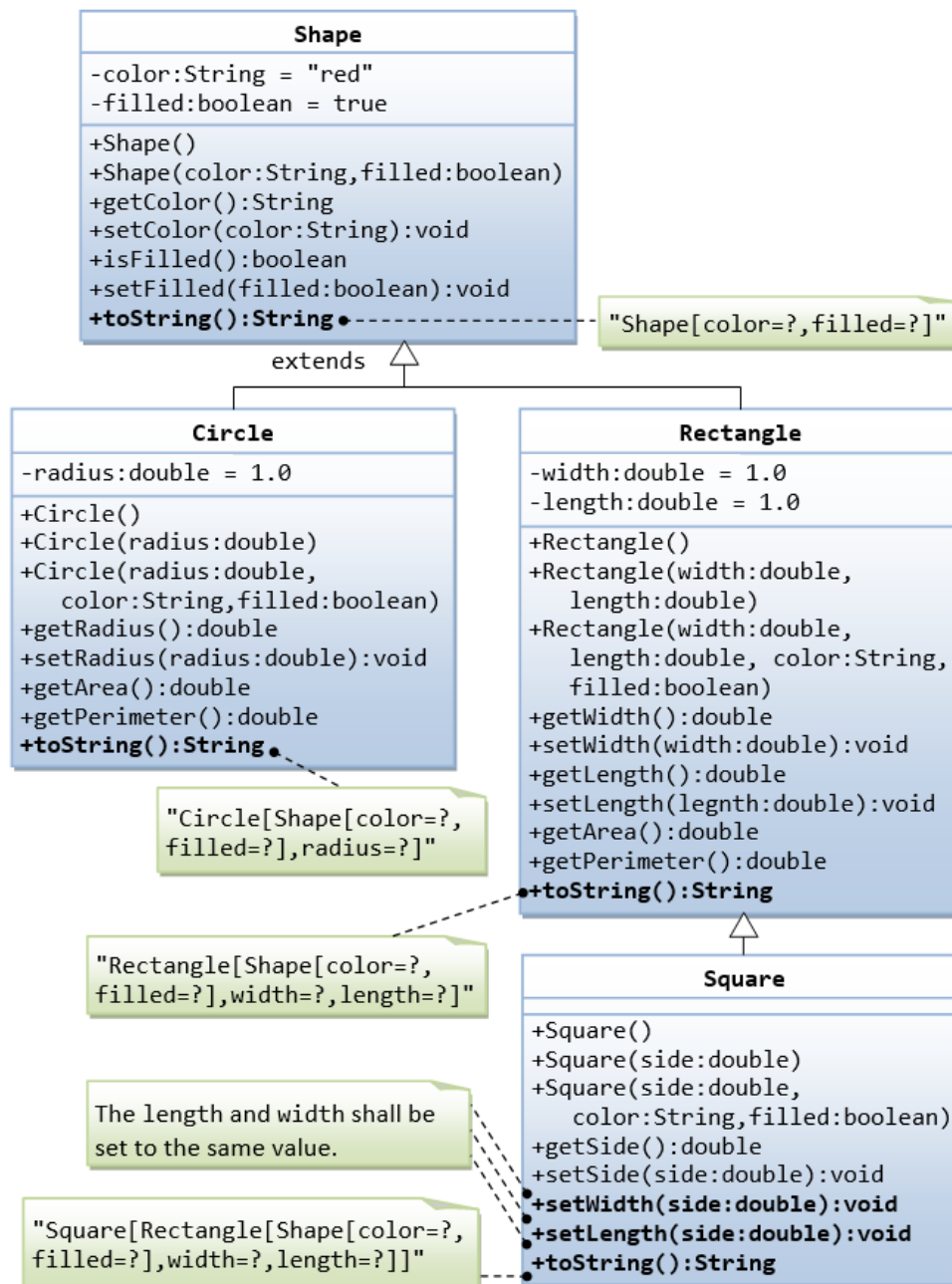
13.4 *Point and MovablePoint*

Write the classes as shown in the following class diagram. Mark all the overridden methods with annotation @Override.

```
                     Point
-x:float = 0.0f
-y:float = 0.0f
+Point(x:float,y:float)
+Point()
+getX():float
+setX(x:float):void
+getY():float
+setY(y:float):void
+setXY(x:float,y:float):void
+getXY():float[2]
+toString():String •------------------- "(x,y)"
```

extends △

```
                 MovablePoint
-xSpeed:float = 0.0f
-ySpeed:float = 0.0f
+MovablePoint(x:float,y:float,
    xSpeed:float,ySpeed:float)
+MovablePoint(xSpeed:float,ySpeed:float)
+MovablePoint()
+getXSpeed():float
+setXSpeed(xSpeed:float):void
+getYSpeed():float                              "(x,y),speed=(xs,ys)"
+setYSpeed(ySpeed:float):void
+setSpeed(xSpeed:float,ySpeed:float):void       x += xSpeed;
+getSpeed():float[2]                            y += ySpeed;
+toString():String •-------------------         return this;
+move():MovablePoint •-------------------
```

Hints

1. You cannot assign floating-point literal say 1.1 (which is a double) to a float variable, you need to add a suffix f, e.g. 0.0f, 1.1f.
2. The instance variables x and y are private in Point and cannot be accessed directly in the subclass MovablePoint. You need to access via the public getters and setters. For example, you cannot write x += xSpeed, you need to write setX(getX() + xSpeed).

13.5 Superclass *Shape* and its subclasses *Circle, Rectangle* and *Square*

Shape

```
-color:String = "red"
-filled:boolean = true
```

```
+Shape()
+Shape(color:String,filled:boolean)
+getColor():String
+setColor(color:String):void
+isFilled():boolean
+setFilled(filled:boolean):void
+toString():String •
```

"Shape[color=?,filled=?]"

extends △

Circle

```
-radius:double = 1.0
```

```
+Circle()
+Circle(radius:double)
+Circle(radius:double,
    color:String,filled:boolean)
+getRadius():double
+setRadius(radius:double):void
+getArea():double
+getPerimeter():double
+toString():String•
```

"Circle[Shape[color=?,
filled=?],radius=?]"

Rectangle

```
-width:double = 1.0
-length:double = 1.0
```

```
+Rectangle()
+Rectangle(width:double,
    length:double)
+Rectangle(width:double,
    length:double, color:String,
    filled:boolean)
+getWidth():double
+setWidth(width:double):void
+getLength():double
+setLength(legnth:double):void
+getArea():double
+getPerimeter():double
+toString():String
```

"Rectangle[Shape[color=?,
filled=?],width=?,length=?]"

△

Square

```
+Square()
+Square(side:double)
+Square(side:double,
    color:String,filled:boolean)
+getSide():double
+setSide(side:double):void
+setWidth(side:double):void
+setLength(side:double):void
+toString():String
```

The length and width shall be
set to the same value.

"Square[Rectangle[Shape[color=?,
filled=?],width=?,length=?]]"

Write a superclass called Shape (as shown in the class diagram)

Write a test program to test all the methods defined in Shape.

Write two subclasses of Shape called Circle and Rectangle, as shown in the class diagram.

Write a class called Square, as a subclass of Rectangle. Convince yourself that Square can be modeled as a subclass of Rectangle. Square has no instance variable, but inherits the instance variables width and length from its superclass Rectangle.

- Provide the appropriate constructors (as shown in the class diagram).

Hints:

```
public Square(double side) {
    super(side, side);  // Call superclass Rectangle(double, double)
}
```

- Override the `toString()` method to return "A Square with side=xxx, which is a subclass of yyy", where yyy is the output of the `toString()` method from the superclass.
- Do you need to override the `getArea()` and `getPerimeter()`? Try them out.
- Override the `setLength()` and `setWidth()` to change both the `width` and `length`, so as to maintain the square geometry.

14. Exercises on Polymorphism, Abstract Classes and Interfaces

14.1 Ex: Abstract Superclass *Shape* and Its Concrete Subclasses

Rewrite the superclass Shape and its subclasses `Circle`, `Rectangle` and `Square`, as shown in the class diagram.

Shape is an abstract class containing 2 abstract methods: `getArea()` and `getPerimeter()`, where its concrete subclasses must provide its implementation. All instance variables shall have `protected` access, i.e., accessible by its subclasses and classes in the same package. Mark all the overridden methods with annotation `@Override`.
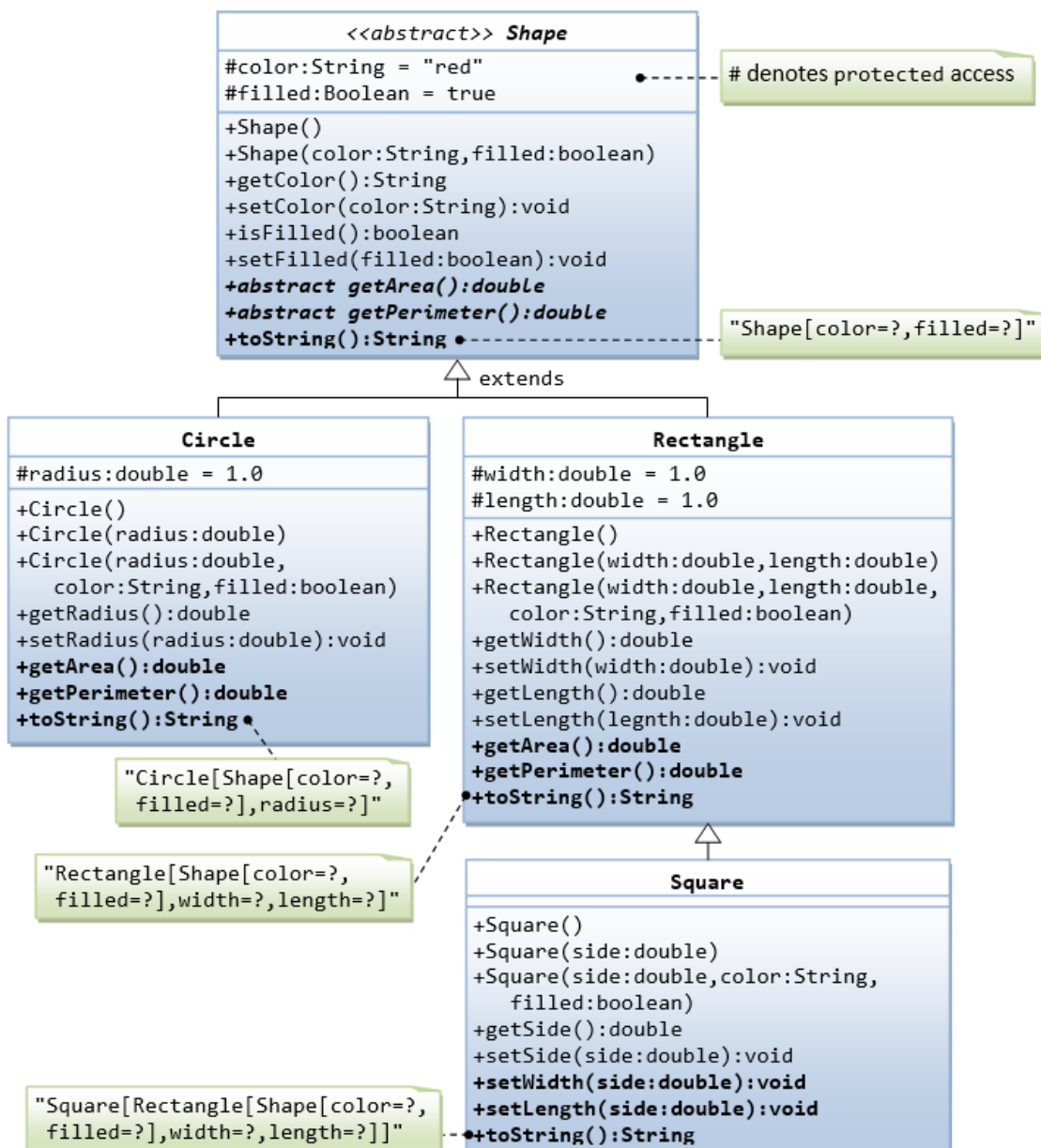
In this exercise, Shape shall be defined as an `abstract` class, which contains:

- Two protected instance variables **color(String)** and **filled(boolean).** The `protected` variables can be accessed by its subclasses and classes in the same package. They are denoted with a `'#'` sign in the class diagram.
- Getter and setter for all the instance variables, and `toString()`.
- Two abstract methods `getArea()` and `getPerimeter()` (shown in italics in the class diagram).
- Subclasses `Circle` and `Rectangle` shall *override* the `abstract` methods `getArea()` and `getPerimeter()` and provide the proper implementation. They also *override* the `toString()`.

Write a test class to test these statements involving polymorphism and explain the outputs. Some statements may trigger compilation errors. Explain the errors, if any.

```
Shape s1 = new Circle(5.5, "red", false);  // Upcast Circle to Shape
System.out.println(s1);                     // which version?
System.out.println(s1.getArea());           // which version?
System.out.println(s1.getPerimeter());      // which version?
System.out.println(s1.getColor());
System.out.println(s1.isFilled());
System.out.println(s1.getRadius());

Circle c1 = (Circle)s1;                     // Downcast back to Circle
System.out.println(c1);
System.out.println(c1.getArea());
System.out.println(c1.getPerimeter());
System.out.println(c1.getColor());
System.out.println(c1.isFilled());
System.out.println(c1.getRadius());

Shape s2 = new Shape();

Shape s3 = new Rectangle(1.0, 2.0, "red", false);    // Upcast
System.out.println(s3);
System.out.println(s3.getArea());
System.out.println(s3.getPerimeter());
System.out.println(s3.getColor());
System.out.println(s3.getLength());

Rectangle r1 = (Rectangle)s3;    // downcast
System.out.println(r1);
System.out.println(r1.getArea());
System.out.println(r1.getColor());
System.out.println(r1.getLength());

Shape s4 = new Square(6.6);      // Upcast
System.out.println(s4);
System.out.println(s4.getArea());
System.out.println(s4.getColor());
System.out.println(s4.getSide());

// Take note that we downcast Shape s4 to Rectangle,
//  which is a superclass of Square, instead of Square
Rectangle r2 = (Rectangle)s4;
System.out.println(r2);
System.out.println(r2.getArea());
System.out.println(r2.getColor());
System.out.println(r2.getSide());
System.out.println(r2.getLength());
```

```
// Downcast Rectangle r2 to Square
Square sq1 = (Square)r2;
System.out.println(sq1);
System.out.println(sq1.getArea());
System.out.println(sq1.getColor());
System.out.println(sq1.getSide());
System.out.println(sq1.getLength());
```

Try:

Explain the usage of the abstract method and abstract class?

14.2 *GeometricObject Interface and its Implementation Classes Circle and Rectangle*

Write an interface called GeometricObject, which contains 2 abstract methods: getArea() and getPerimeter(), as shown in the class diagram. Also write an implementation class called Circle. Mark all the overridden methods with annotation @Override.
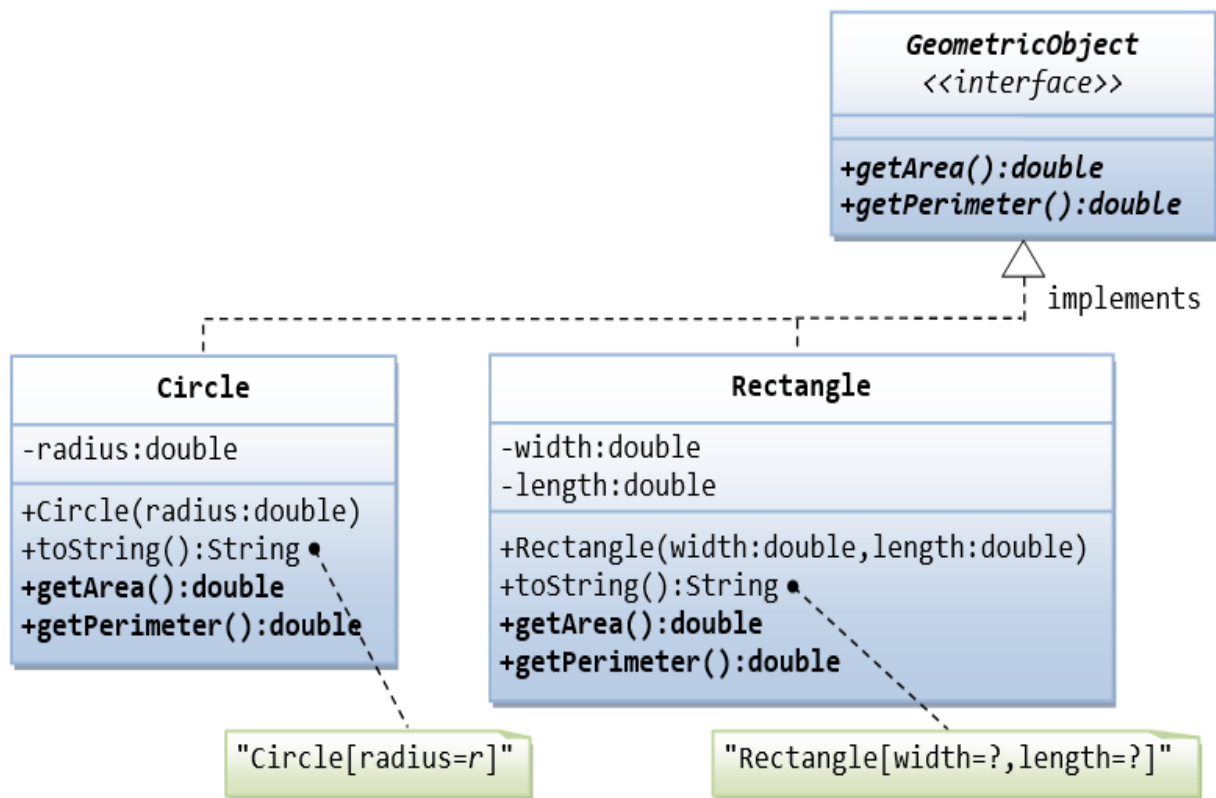
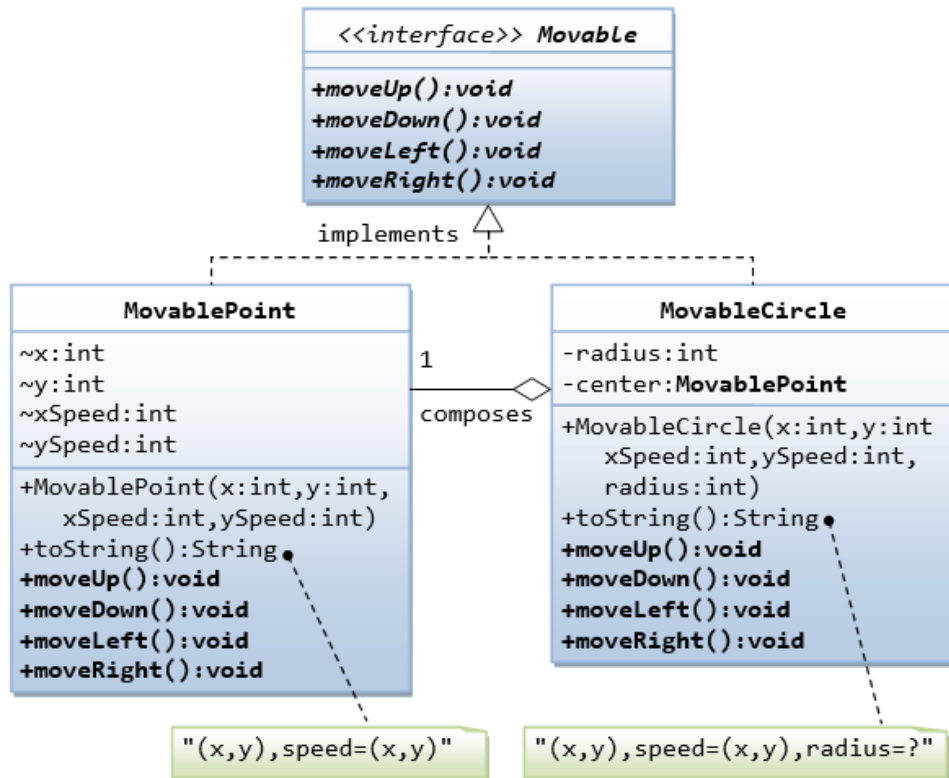## 14.3 Ex: *Movable* Interface and its Implementation *MovablePoint* Class

Write an interface called Movaable, which contains 4 abstract methods moveUp(), moveDown(), moveLeft() and moveRight(), as shown in the class diagram. Also write an implementation class called MovablePoint. Mark all the overridden methods with annotation @Override.
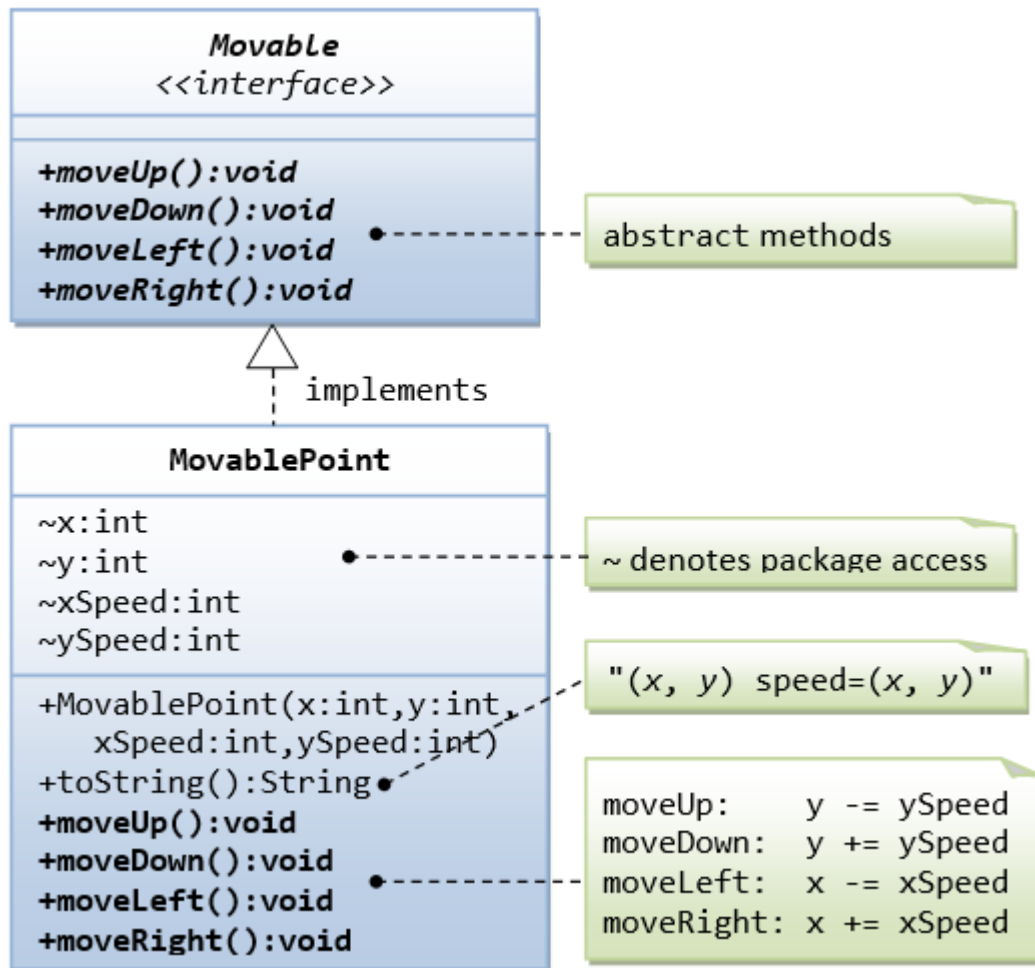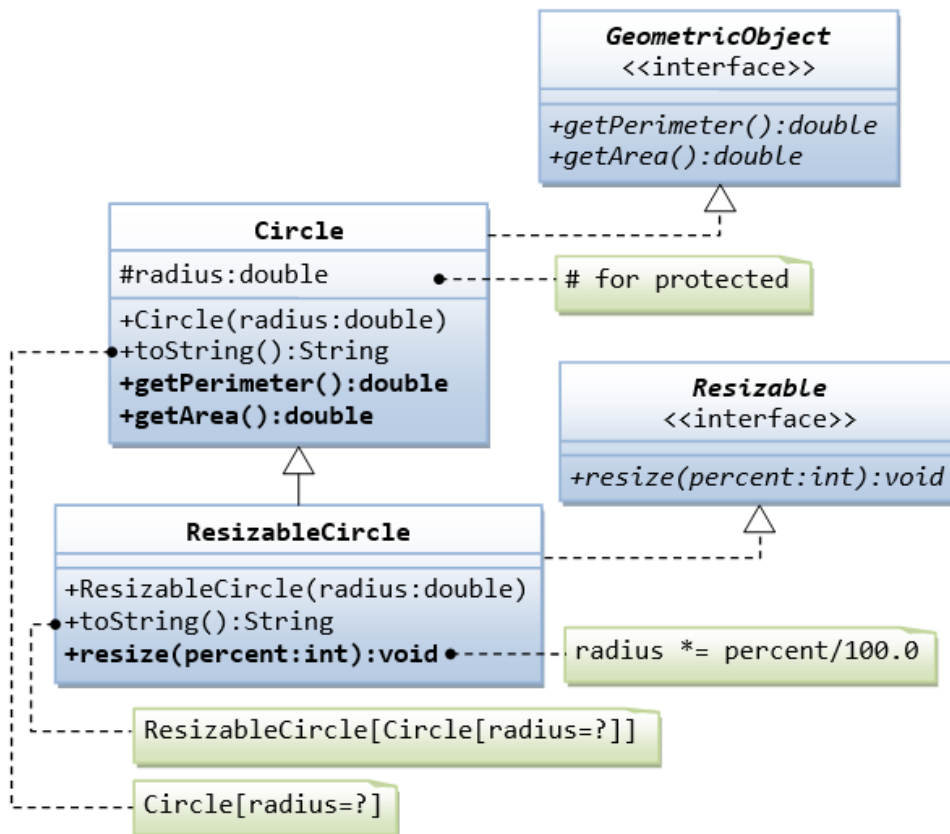

14.4 *Movable* Interface and Classes *MovablePoint* and *MovableCircle*

Write an interface called Movaable, which contains 4 abstract methods moveUp(), moveDown(),
moveLeft() and moveRight(),
as shown in the class diagram.

Write the implementation classes called MovablePoint and MovableCircle. Mark all the overridden methods with annotation @Override.

<<interface>> *Movable*

+*moveUp():void*
+*moveDown():void*
+*moveLeft():void*
+*moveRight():void*

implements

MovablePoint

~x:int
~y:int
~xSpeed:int
~ySpeed:int

+MovablePoint(x:int,y:int,
    xSpeed:int,ySpeed:int)
+toString():String
+moveUp():void
+moveDown():void
+moveLeft():void
+moveRight():void

1

composes

MovableCircle

-radius:int
-center:**MovablePoint**

+MovableCircle(x:int,y:int
    xSpeed:int,ySpeed:int,
    radius:int)
+toString():String
+moveUp():void
+moveDown():void
+moveLeft():void
+moveRight():void

"(x,y),speed=(x,y)"

"(x,y),speed=(x,y),radius=?"

14.5 Interfaces `Resizable` and `GeometricObject`

GeometricObject
<<interface>>

+*getPerimeter():double*
+*getArea():double*

Circle

#radius:double

+Circle(radius:double)
+toString():String
+getPerimeter():double
+getArea():double

for protected

Resizable
<<interface>>

+*resize(percent:int):void*

ResizableCircle

+ResizableCircle(radius:double)
+toString():String
+resize(percent:int):void

radius *= percent/100.0

ResizableCircle[Circle[radius=?]]

Circle[radius=?]

Write the interface called `GeometricObject`, which declares two abstract methods: getParameter() and getArea(), as specified in the class diagram.

Hints:

```java
public interface GeometricObject {
    public double getPerimeter();
    ......
}
```

Write the implementation class `Circle`, with a protected variable `radius`, which implements the interface `GeometricObject`.

Hints:

```java
public class Circle implements GeometricObject {
    // Private variable
    ......

    // Constructor
    ......

    // Implement methods defined in the interface GeometricObject
    @Override
    public double getPerimeter() { ...... }


    ......
}
```

Write a test program called `TestCircle` to test the methods defined in `Circle`.

The class `ResizableCircle` is defined as a subclass of the class `Circle`, which also implements an interface called `Resizable`, as shown in class diagram. The interface `Resizable` declares an `abstract` method `resize()`, which modifies the dimension (such as `radius`) by the given percentage. Write the interface `Resizable` and the class `ResizableCircle`.

Hints:

```java
public interface Resizable {
    public double resize(...);
}
```

```java
public class ResizableCircle extends Circle implements Resizeable {

    // Constructor
    public ResizableCircle(double radius) {
        super(...);
    }

    // Implement methods defined in the interface Resizable
    @Override
    public double resize(int percent) { ...... }
}
```
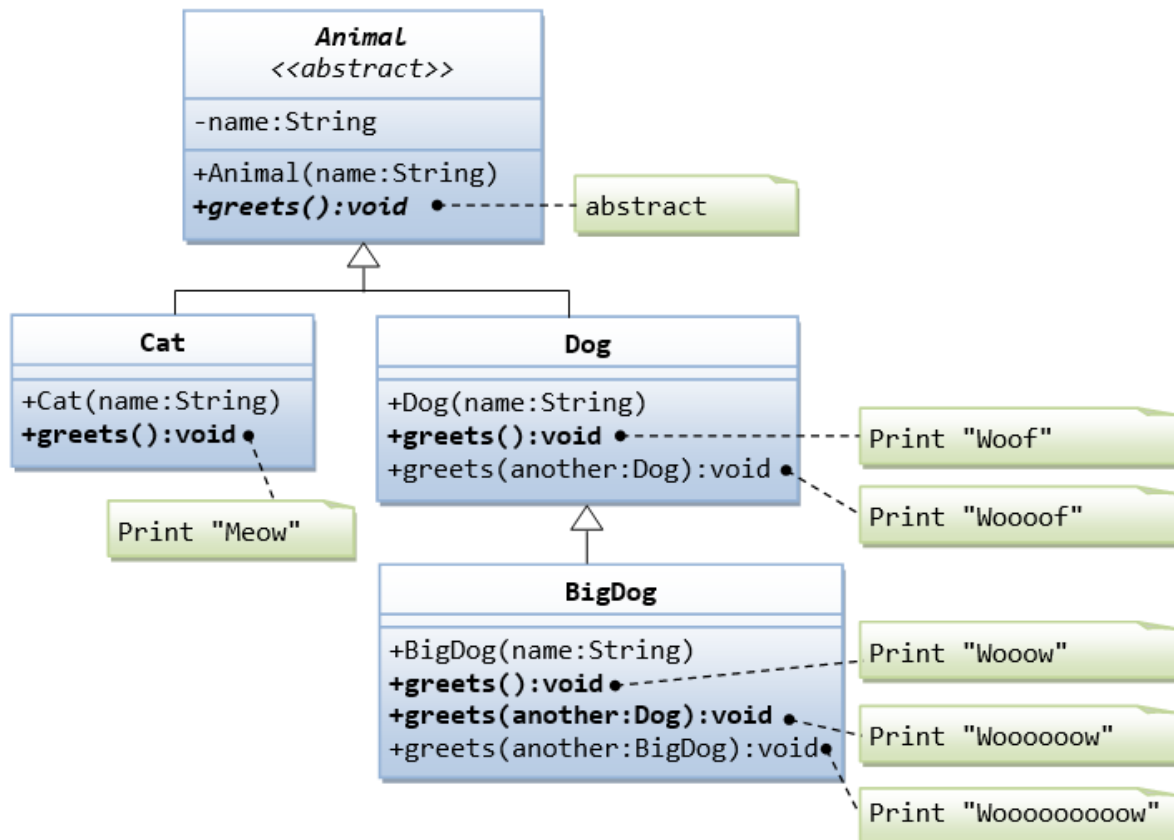
Try:

Write a test program called `TestResizableCircle` to test the methods defined in `ResizableCircle`.

14.6 Abstract Superclass Animal and its Implementation Subclasses

Write the codes for all the classes shown in the class diagram. Mark all the overridden methods with annotation @Override.

14.7 Another View of Abstract Superclass Animal and its Implementation Subclasses

Examine the following codes and draw the class diagram.

```
abstract public class Animal {
    abstract public void greeting();
}
```

```
public class Cat extends Animal {
    @Override
    public void greeting() {
        System.out.println("Meow!");
    }
}
public class Dog extends Animal {
    @Override
    public void greeting() {
        System.out.println("Woof!");
```

```
    }

    public void greeting(Dog another) {
        System.out.println("Woooooooooof!");
    }
}
```

```
public class BigDog extends Dog {
    @Override
    public void greeting() {
        System.out.println("Woow!");
    }

    @Override
    public void greeting(Dog another) {
        System.out.println("Woooooowwwww!");
    }
}
```

Try:
Explain the outputs (or error) for the following test program.

```
public class TestAnimal {
    public static void main(String[] args) {
        // Using the subclasses
        Cat cat1 = new Cat();
        cat1.greeting();
        Dog dog1 = new Dog();
        dog1.greeting();
        BigDog bigDog1 = new BigDog();
        bigDog1.greeting();

        // Using Polymorphism
        Animal animal1 = new Cat();
        animal1.greeting();
        Animal animal2 = new Dog();
        animal2.greeting();
        Animal animal3 = new BigDog();
        animal3.greeting();
        Animal animal4 = new Animal();

        // Downcast
        Dog dog2 = (Dog)animal2;
        BigDog bigDog2 = (BigDog)animal3;
        Dog dog3 = (Dog)animal3;
        Cat cat2 = (Cat)animal2;
        dog2.greeting(dog3);
        dog3.greeting(dog2);
        dog2.greeting(bigDog2);
        bigDog2.greeting(dog2);
        bigDog2.greeting(bigDog1);
    }
}
```

15. Final Notes

The only way to learn programming is program, program and program on challenging problems. The problems in this tutorial are certainly NOT challenging. There are tens of thousands of challenging problems available – used in training for various programming contests (such as International Collegiate Programming Contest (ICPC), International Olympiad in Informatics (IOI)). Check out these sites:

- The ACM - ICPC International collegiate programming contest (https://icpc.global/)
- The Topcoder Open (TCO) annual programming and design contest (https://www.topcoder.com/)
- Universidad de Valladolid's online judge (https://uva.onlinejudge.org/).
- Peking University's online judge (http://poj.org/).
- USA Computing Olympiad (USACO) Training Program @ http://train.usaco.org/usacogate.
- Google's coding competitions (https://codingcompetitions.withgoogle.com/codejam, https://codingcompetitions.withgoogle.com/hashcode)
- The ICFP programming contest (https://www.icfpconference.org/)
- BME International 24-hours programming contest (https://www.challenge24.org/)
- The International Obfuscated C Code Contest (https://www0.us.ioccc.org/main.html)
- Internet Problem Solving Contest (https://ipsc.ksp.sk/)
- Microsoft Imagine Cup (https://imaginecup.microsoft.com/en-us)
- Hewlett Packard Enterprise (HPE) Codewars (https://hpecodewars.org/)
- OpenChallenge (https://www.openchallenge.org/)

Coding Contests Scores

Students must solve problems and attain scores in the following coding contests:

Name of the contest	Minimum number of problems to solve	Required score
CodeChef	20	200
Leetcode	20	200
GeeksforGeeks	20	200
SPOJ	5	50
InterviewBit	10	1000
Hackerrank	25	250
Codeforces	10	100
BuildIT	50	500
Total score need to obtain		2500

Student must have any one of the following certifications:

- HackerRank – Java Basic Skills Certification
- Oracle Certified Associate Java Programmer OCAJP
- CodeChef - Learn Java Certification
- NPTEL – Programming in Java
- NPTEL – Data Structures and Algorithms in Java

V. TEXT BOOKS:

1. Farrell, Joyce.*Java Programming*, Cengage Learning B S Publishers, 8th Edition, 2020
2. Schildt, Herbert. *Java: The Complete Reference* 11th Edition, McGraw-Hill Education, 2018.

VI. REFERENCE BOOKS:

1. Deitel, Paul and Deitel, Harvey. *Java: How to Program*, Pearson, 11th Edition, 2018.
2. Evans, Benjamin J. and Flanagan, David. *Java in a Nutshell*, O'Reilly Media, 7th Edition, 2018.
3. Bloch, Joshua. *Effective Java*, Addison-Wesley Professional, 3rd Edition, 2017.

4. Sierra, Kathy and Bates, Bert. *Head First Java*, O'Reilly Media, 2nd Edition, 2005

VII. ELECTRONICS RESOURCES:

1. https://docs.oracle.com/en/java/
2. https://www.geeksforgeeks.org/java
3. https://www.tutorialspoint.com/java/index.htm
4. https://www.coursera.org/courses?query=java

VIII. MATERIALS ONLINE;

1. Syllabus
2. Lab manual