

## Problem 1: Polynomial Factory

We want to have a tool for evaluating polynomials and computing their roots.

- (1) Write an interface called `Polynomial` that has two functions:
  - Evaluates a polynomial (input is a double, output is a double)
  - Evaluates the roots of a polynomial (no input, outputs an array of double)
  
- (2) Implement this interface for linear polynomials. Note that a linear polynomials store two values  $a, b$ , are evaluated by  $f(x) = ax + b$ , and their root is defined by  $-b/a$ .
  
- (3) Implement this interface for quadratic polynomials. Note that a linear polynomials store two values  $a, b, c$ , are evaluated by  $f(x) = ax^2 + bx + c$ , and their root is defined by  $\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ . Note that  $\sqrt{\cdot}$  is found at `java.lang.Math.sqrt`.

- (4) Implement a class called `PolynomialFactory` that creates a polynomial. You should use `switch/case`. It implements this interface:

```
interface PolynomialFactoryInterface {  
    // if two coefficients are passed in it returns a LinearPolynomial  
    // if three coefficients are passed it returns a QuadraticPolynomial  
    // otherwise it returns null  
    Polynomial getPolynomial(double[] coefficients);  
}
```

- (5) re-implement `getPolynomial` using `if/else`.

- (6) Implement a function that takes in a PolynomialFactory and a two dimensional array of polynomial coefficients (an array of double[]) and constructs an array of Polynomials.

- (7) Implement a function meanPolynomialValue that takes in an array of Polynomials and a double  $t$  and returns the average value of the polynomials passed in.

```
Polynomial[] polynomials =getPolynomials (...)  
double t = 34.0;  
double meanValue = meanPolynomialValue(polynomials,t);
```

- (8) Implement a function with the same prototype but returns the min value minPolynomialValue. Take care on how you initialize the minimum variable.

- (9) Implement a function that computes the average root meanRoot.

```
Polynomial[] polynomials =getPolynomials (...)  
double meanRoot = meanRoot(polynomials);
```

## Problem 2: Forward Euler canon

In this problem we will simulate the path of a two-dimensional canon ball shot on a flat plane. The goal is to capture when the canon ball lands.

- (1) Implement a class that represents a Ball's state. For this problem we need to store the  $x$  and  $y$  coordinate of the ball's position and its current velocity (which also has  $x$  and  $y$  components). It should follow the following interface:

```
interface EulerInterface {
    // simulates forward by the specified amount of time using Forward Euler.
    boolean step(double dt);
    // returns whether the ball is in the ground.
    // This should be when the y coordinate is at most $0$.
    boolean inGround();
}
```

Forward Euler updates the state of the ball by the following equations:

$$p = p + (dt)(v) \quad (1)$$

$$v_y = v_y - 9.8. \quad (2)$$

- (2) implement a function that moves a canonball forward until it hits the ground.

```
double findCollision(CanonBall ball) {

}

}
```

### Problem 3: Pigeonhole Principle

The pigeonhole principle states that if we have  $n$  pigeons in  $m$  holes, then if we have more pigeons than holes then at least one hole has more than one pigeon. In this problem we will help pigeons find holes.

```
public class Pigeon {
    private String name;
    Pigeon(String name) { this.name = name; }
    String getName() { return name; }
}
```

- (1) Create a checked exception called CannotPlacePigeonException that stores the Pigeon that could not be placed. If this error is printed it should show a message using the pigeon's name.

```
interface PigeonHolesInterface {

    // returns the number of holes available
    int size();

    // returns true if there is a pigeon in hole index
    boolean hasPigeon(int index);

    // places a pigeon in a particular hole
    void placePigeon(Pigeon pigeon, int index) throws CannotPlacePigeonException;

}
```

- (2) Implement a function that tries to place a pigeon in a hole. Assume all of the pigeons passed in had not been previously placed. Should this method throw an exception?

```
public static void placePigeon(PigeonHolesInterface holes, Pigeon pigeon) {
```

```
}
```

- (3) Implement a function that tries to stuff as many pigeons into holes as possible. Assume all of the pigeons passed in had not been previously placed. Should this method throw an exception? You may use the previous placePigeon.

```
public static void stuffPigeons(PigeonHolesInterface holes, Pigeon[] pigeons) {
```

```
}
```

- (4) Create a class called SinglePigeonHoles that represents a set of holes that pigeons can be placed in and satisfies the following interface:

```
interface SinglePigeonHolesInterface extends PigeonHolesInterface {
    // returns the pigeon in the hole index.
    // can return null if no pigeon is there
    Pigeon getPigeonInHole(int index);

    // count the number of holes that are empty
    int remainingHoleCount();
}
```

- (5) Implement a function that prints out the contents of every hole, either printing the pigeon's name or saying "Hole is empty":

```
public static void printContents(SinglePigeonHolesInterface holes) {
```

}

- (6) Write a class that implements `SinglePigeonHolesInterface` that uses a standard array of `Pigeon` to represent the pigeons. Note that if an entry in the array holds the value `null` then it does not have a pigeon in it.
- (7) Write a class that implements `PigeonHolesInterface` where each hole can hold a number of holes by using a two dimensional array of `Pigeon` to represent the pigeons. The constructor should take in two arguments: the number of holes and the number of pigeons that can fit in each hole.

## Problem 4: Tracking Statistics

Say we want to keep track of the average price that products are sold at. One way to do this is to store shared variables in the class that track the information need to evaluate an average.

- (1) Declare a class called `Product`. It will have a main function in it / will be run.

- (2) Specify shared members that can track the average

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- (3) Implement a function `getAverages` that does not require an instance of `Product` to be declared.
  - (4) Specify members to track the price and name of the package.
  - (5) Specify a constructor for the package to populate its members and the shared variables.
  - (6) Specify getters for the members of the class.
  - (7) Specify a setter for the price, but keep in mind that the values stored to compute the average will need to be adjusted as well.
  - (8) Specify a main function that creates three instances of `Package` and then prints out the average price.

## Problem 5: Dataset

Lets implement a class that stores an array of data and can compute some statistics on that data.

```
interface AbstractDataset {  
  
    // the number of values stored in the dataset  
    public int size();  
  
    // get the value stored at the corresponding index  
    public double get(int index);  
  
    // append a value to the dataset  
    public double append (double value);  
  
    // compute the average value  
    public double getAverage();  
  
    // compute the median value (use Collections.sort(List<T> list))  
    public double getMedian();  
  
    // compute the min and max value, returning an array of the form {min,max}  
    public double[] getMinMax();  
  
    // compute the range of values in the dataset (max - min)  
    public double getRange();  
  
}
```

(1) Declare a class called Dataset that implements AbstractDataset and will have a main function.

(2) Declare a member that can be easily resized that stores a bunch of double values.

(3) Specify a constructor that takes in no arguments.

(4) Specify a constructor that takes in a list of doubles.

(5) Finish implementing the interface

(6) Implement a main function that reads lines typed in by the user and outputs the above statistics after the user is done inputting data. The user is expected to only type in numbers or the word "exit". For example:

```
3.4
-2
3.45
20
16
exit
```