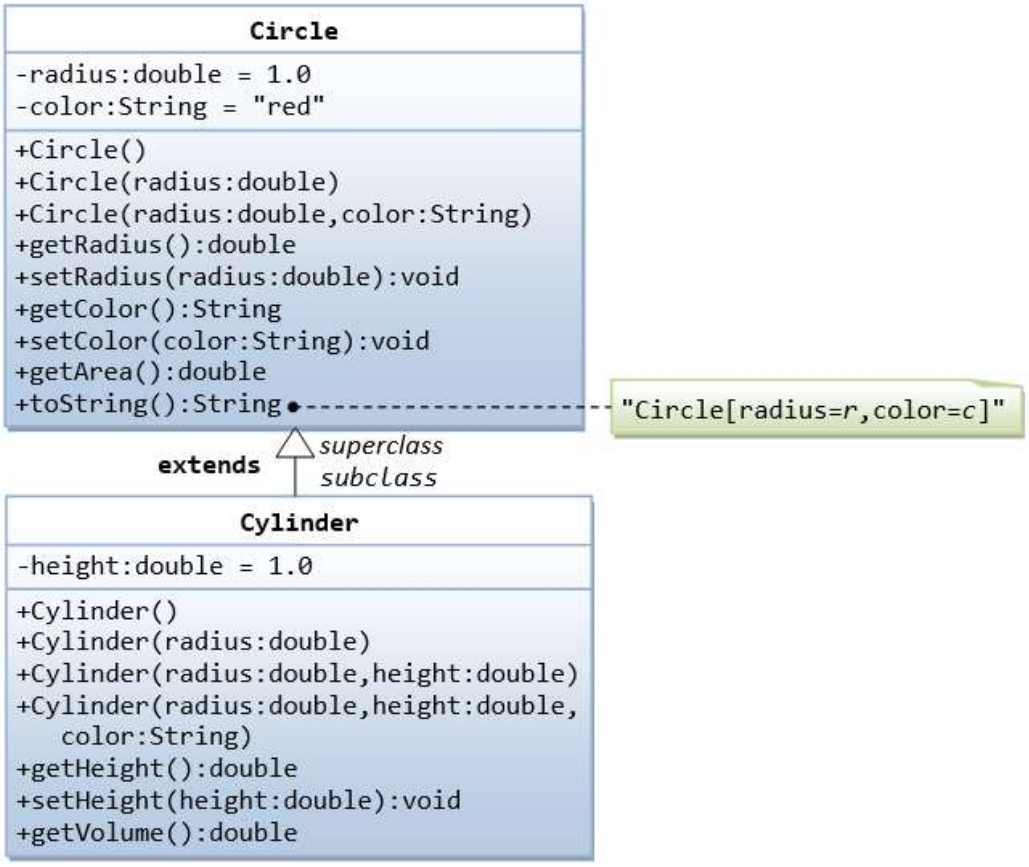
4. Exercises on Inheritance

4.1 An Introduction to OOP Inheritance by Example - The `Circle` and `Cylinder` Classes

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



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.

```
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;
```

```
}
```

Write a test program (says `TestCylinder`) to test the `Cylinder` class created, as follow:

```
public class TestCylinder {  // save as "TestCylinder.java"
   public static void main (String[] args) {
      // Declare and allocate a new instance of cylinder
      //   with default color, radius, and height
      Cylinder c1 = new Cylinder();
      System.out.println("Cylinder:"
            + " radius=" + c1.getRadius()
            + " height=" + c1.getHeight()
            + " base area=" + c1.getArea()
            + " volume=" + c1.getVolume());

      // Declare and allocate a new instance of cylinder
      //   specifying height, with default color and radius
      Cylinder c2 = new Cylinder(10.0);
      System.out.println("Cylinder:"
            + " radius=" + c2.getRadius()
            + " height=" + c2.getHeight()
            + " base area=" + c2.getArea()
            + " volume=" + c2.getVolume());

      // Declare and allocate a new instance of cylinder
      //   specifying radius and height, with default color
      Cylinder c3 = new Cylinder(2.0, 10.0);
      System.out.println("Cylinder:"
            + " radius=" + c3.getRadius()
            + " height=" + c3.getHeight()
            + " base area=" + c3.getArea()
            + " volume=" + c3.getVolume());
   }
}
```

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.,

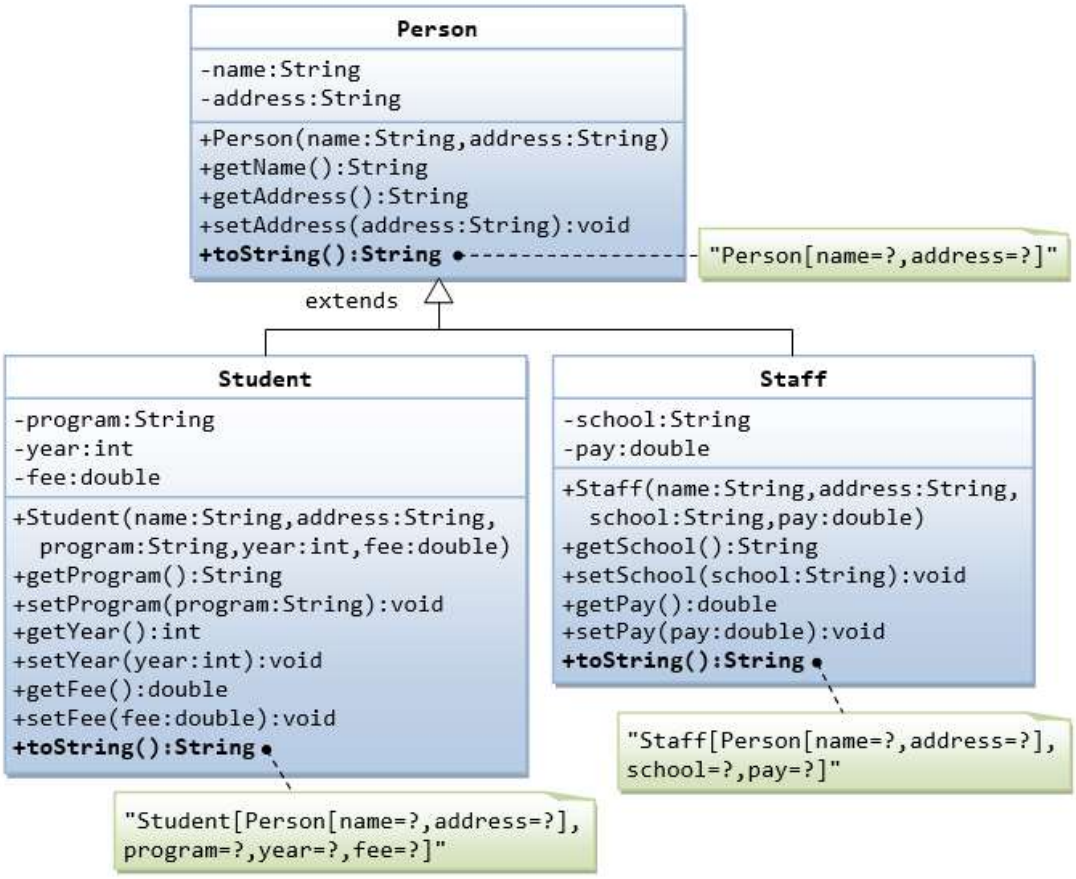
```
@Override
public String toString() {      // in Cylinder class
   return "Cylinder: subclass of " + super.toString()  // use Circle's toString()
         + " height=" + height;
}
```

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

Note: `@Override` is known as *annotation* (introduced in JDK 1.5), which asks compiler to check whether there is such a method in the superclass to be overridden. This helps greatly if you misspell the name of the `toString()`. If `@Override` is not used and `toString()` is misspelled as `ToString()`, it will be treated as a new method in the subclass, instead of overriding the superclass. If `@Override` is used, the compiler will signal an error. `@Override` annotation is optional, but certainly nice to have.

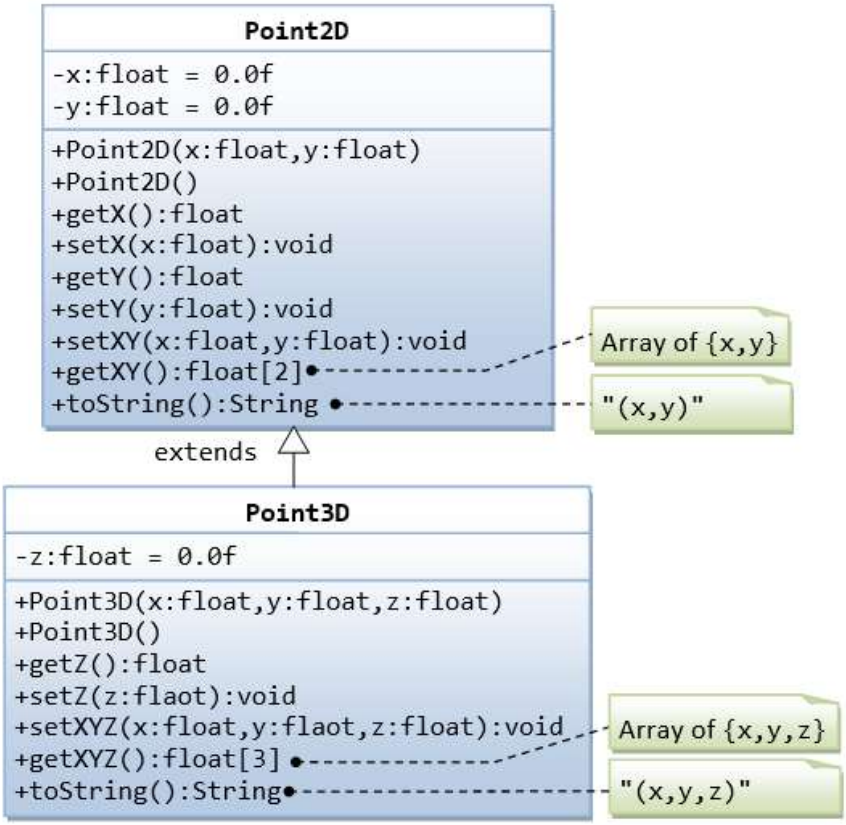
4.2 Ex: Superclass `Person` and its subclasses

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



4.3 Ex: `Point2D` and `Point3D`

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



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,

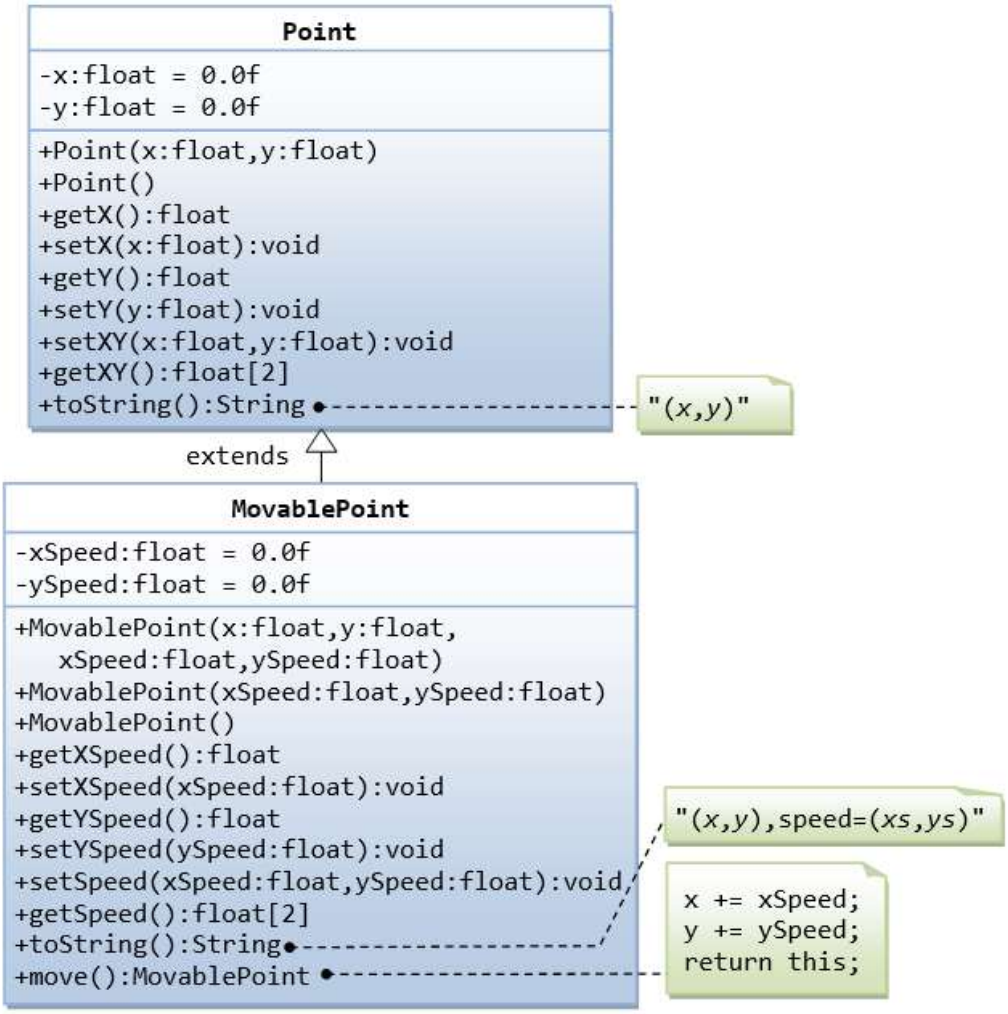
```
public void setXYZ(float x, float y, float z) {
   setX(x);     // or super.setX(x), use setter in superclass
   setY(y);
   this.z = z;
}
```

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
}
```

4.4 Ex: `Point` and `MovablePoint`

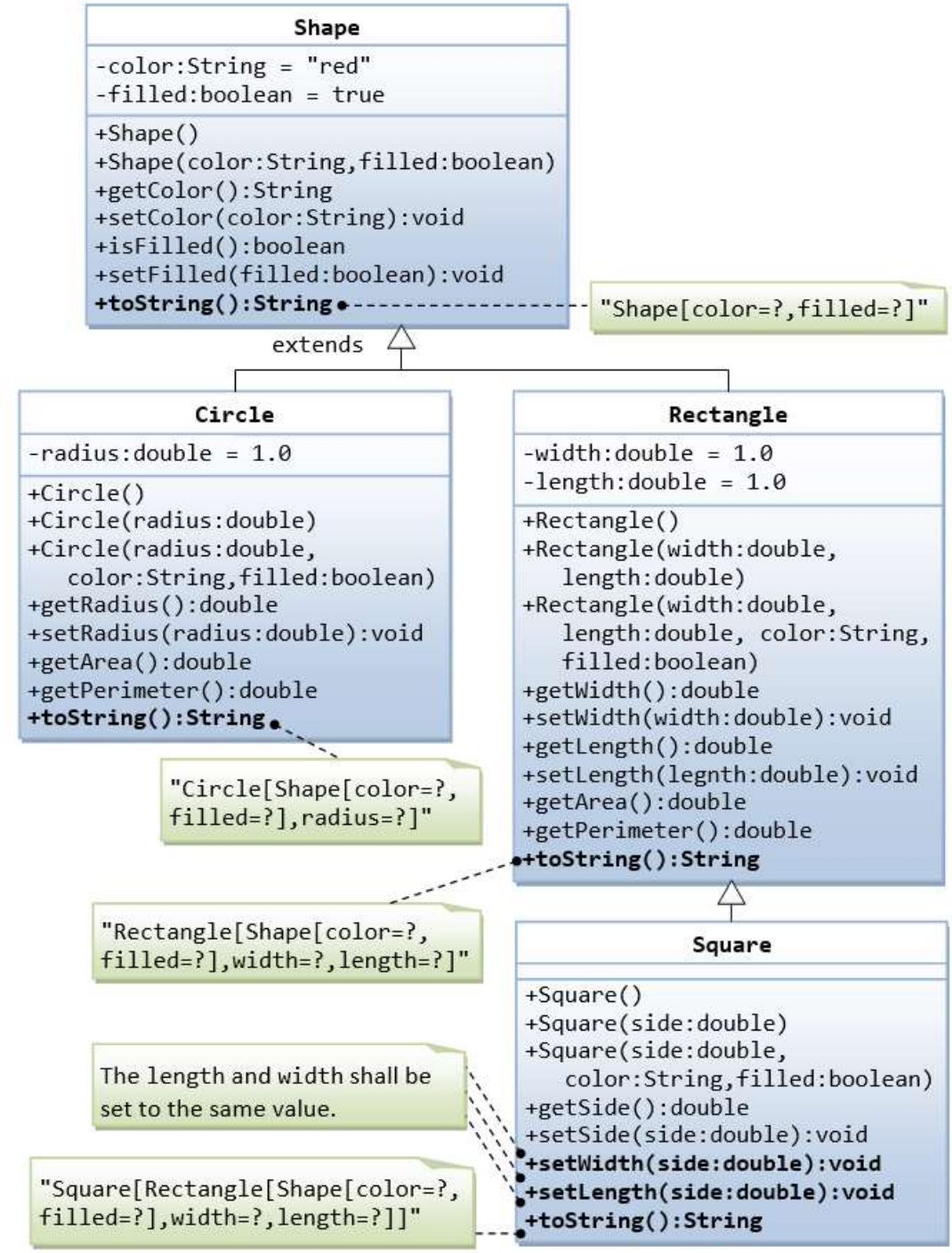
Write the classes as shown in the following class diagram. Mark all the overridden methods with annotation `@Override`.



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)`.

4.5 Ex: Superclass `Shape` and its subclasses `Circle`, `Rectangle` and `Square`



Write a superclass called `Shape` (as shown in the class diagram), which contains:

- Two instance variables `color` (`String`) and `filled` (`boolean`).
- Two constructors: a no-arg (no-argument) constructor that initializes the `color` to "green" and `filled` to `true`, and a constructor that initializes the `color` and `filled` to the given values.
- Getter and setter for all the instance variables. By convention, the getter for a `boolean` variable `xxx` is called `isXXX()` (instead of `getXxx()` for all the other types).
- A `toString()` method that returns "`A Shape with color of xxx and filled/Not filled`".

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.

The `Circle` class contains:

- An instance variable `radius` (`double`).
- Three constructors as shown. The no-arg constructor initializes the radius to `1.0`.

- Getter and setter for the instance variable `radius`.
- Methods `getArea()` and `getPerimeter()`.
- Override the `toString()` method inherited, to return "`A Circle with radius=xxx, which is a subclass of yyy`", where `yyy` is the output of the `toString()` method from the superclass.

The `Rectangle` class contains:

- Two instance variables `width` (`double`) and `length` (`double`).
- Three constructors as shown. The no-arg constructor initializes the `width` and `length` to `1.0`.
- Getter and setter for all the instance variables.
- Methods `getArea()` and `getPerimeter()`.
- Override the `toString()` method inherited, to return "`A Rectangle with width=xxx and length=zzz, which is a subclass of yyy`", where `yyy` is the output of the `toString()` method from the superclass.

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). Hint:

```
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.

4.6 Ex: Superclass `Animal` and its subclasses

Write the codes for all the classes as shown in the class diagram.