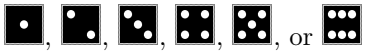
**Problem 1.** (*Comparable Six-sided Die*) Implement a comparable data type `Die` in `Die.java` that represents a six-sided die and supports the following API:

| method | description |
|---|---|
| `Die()` | construct a die |
| `void roll()` | roll the die |
| `int value()` | face value of the die |
| `boolean equals(Die that)` | does the die have the same face value as *that*? |
| `int compareTo(Die that)` | the signed difference between the face values of this die and *that* |
| `String toString()` | a string representation of the current face value of the die, ie,  , or  |

```
$ java Die 5 3 3
*   *
  *
*   *
false
true
2
0
```

**Problem 2.** (*US Phone Number*) Implement an immutable data type `PhoneNumber` in `PhoneNumber.java` that represents a US phone number, and supports the following API:

| method | description |
|---|---|
| `PhoneNumber(int area, int exch, int ext)` | construct a phone number given the area code, exchange, and extension |
| `boolean equals(PhoneNumber that)` | is the phone number same as *that*? |
| `String toString()` | a string representation of the phone number, in `"(area) exch-ext"` format (use `String.format()`) |

```
$ java PhoneNumber
(609) 258-4455
(609) 876-5309
(609) 003-5309
(215) 876-5309
(609) 876-5309
true
false
true
true
```

**Problem 3.** (*Comparable Geo Location*) Implement an immutable data type `Location` in `Location.java` that represents a location on Earth and supports the following API:

| method | description |
|---|---|
| `Location(String loc, double lat, double lon)` | construct a new location given its name, latitude, and longitude values |
| `double distanceTo(Location that)` | the great-circle distance† between this location and *that* |
| `boolean equals(Location that)` | is this location the same as *that*? |
| `int compareTo(Location that)` | -1, 0, or 1 depending on whether the distance of this location to the origin is less than, equal to, or greater than the distance of *that* location to the origin, where the origin is the center of the universe, ie, UMass Boston (42.3134, -71.0384) |
| `String toString()` | a string representation of the location, in `"loc (lat, lon)"` format |

† See Problem 4 of Homework 1 for formula

```
$ java Location 5 40.6769 117.2319
Chichen Itza (Mexico) (20.6829, -88.5686)
Christ the Redeemer (Brazil) (22.9519, -43.2106)
Machu Picchu (Peru) (-13.1633, -72.5456)
The Colosseum (Italy) (41.8902, 12.4923)
Petra (Jordan) (30.3286, 35.4419)
The Great Wall of China (China) (40.6769, 117.2319)
Taj Mahal (India) (27.175, 78.0419)
true
```

**Problem 4.** (*Comparable 3D Point*) Implement an immutable data type `Point3D` in `Point3D.java` that represents a point in 3D and supports the following API:

| method/class | description |
|---|---|
| `Point3D(double x, double y, double z)` | construct a point in 3D given its coordinates |
| `double distance(Point3D that)` | the Euclidean distance† between this point and *that* |
| `int compareTo(Point3D that)` | -1, 0, or 1 depending on whether this point's Euclidean distance to the origin is less than, equal to, or greater than *that* point's Euclidean distance to the origin, where the origin is $(0, 0, 0)$ |
| `static class XOrder` | a comparator for comparing points based on their $x$-coordinates |
| `static class YOrder` | a comparator for comparing points based on their $y$-coordinates |
| `static class ZOrder` | a comparator for comparing points based on their $z$-coordinates |
| `String toString()` | a string representation of the point, in `"(x, y, z)"` format |

† The Euclidean distance between the points $(x_1, y_1, z_1)$ and $(x_2, y_2, z_2)$ is given by $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$

```
$ java Point3D
5
-3 1 6
0 5 8
-5 -7 -3
-2 4 7
-6 8 6
(-3.0, 1.0, 6.0)
(0.0, 5.0, 8.0)
(-5.0, -7.0, -3.0)
(-2.0, 4.0, 7.0)
(-6.0, 8.0, 6.0)
(-3.0, 1.0, 6.0)
(-2.0, 4.0, 7.0)
(-5.0, -7.0, -3.0)
(0.0, 5.0, 8.0)
(-6.0, 8.0, 6.0)
(-6.0, 8.0, 6.0)
(-5.0, -7.0, -3.0)
(-3.0, 1.0, 6.0)
(-2.0, 4.0, 7.0)
(0.0, 5.0, 8.0)
(-5.0, -7.0, -3.0)
(-3.0, 1.0, 6.0)
(-2.0, 4.0, 7.0)
(0.0, 5.0, 8.0)
(-6.0, 8.0, 6.0)
(-5.0, -7.0, -3.0)
(-3.0, 1.0, 6.0)
(-6.0, 8.0, 6.0)
(-2.0, 4.0, 7.0)
(0.0, 5.0, 8.0)
```

**Problem 5.** (*Rational Number*) Implement a data type `Rational` in `Rational.java` that represents a rational number, ie, a number of the form $a/b$ where $a$ and $b \neq 0$ are integers. The data type must support the following API:

| method | description |
|---|---|
| `Rational(long x)` | construct a rational number whose numerator is the given number and denominator is 1 |
| `Rational(long x, long y)` | construct a rational number given its numerator and denominator† |
| `Rational add(Rational that)` | the sum of this and *that* rational number |
| `Rational multiply(Rational that)` | the product of this and *that* rational number |
| `String toString()` | a string representation of the rational number |

† Use the private method `gcd()` to ensure that the numerator and denominator never have any common factors. For example, the rational number 2/4 must be represented as 1/2.

```
$ java Rational 10
1023/512
```

**Problem 6.** (*Iterable Binary Strings*) Implement an immutable, iterable data type `BinaryStrings` in `BinaryStrings.java` to systematically iterate over length-$n$ binary strings. The data type must support the following API:

| method | description |
|---|---|
| `BinaryStrings(int n)` | construct an iterable `BinaryStrings` object given the length of binary strings needed |
| `Iterator<String> iterator()` | an iterator for binary strings of a given length |

```
$ java BinaryStrings 4
0000
0001
0010
0011
0100
0101
0110
0111
1000
1001
1010
1011
1100
1101
1110
1111
```

**Problem 7.** (*Iterable Primes*) Implement an immutable, iterable data type `Primes` in `Primes.java` to systematically iterate over the first $n$ primes. The data type must support the following API:

| method | description |
|---|---|
| `Primes(int n)` | construct an iterable `Primes` object given the number of primes needed |
| `Iterator<Integer> iterator()` | an iterator for the given number of primes |

```
$ java Primes 10
2
3
5
7
11
13
17
19
23
29
```

### Files to Submit

1. `Die.java`
2. `PhoneNumber.java`
3. `Location.java`
4. `Point3D.java`
5. `Rational.java`
6. `BinaryStrings.java`
7. `Primes.java`

**Before you submit:**

- Make sure your programs meet the input and output specifications by running the following command on the terminal:

  ```
  $ python run_tests.py -v [<problems>]
  ```

  where the optional argument `<problems>` lists the problems (`Problem1`, `Problem2`, etc.) you want to test; all the problems are tested if no argument is given.

- Make sure your programs meet the style requirements by running the following command on the terminal:

  ```
  $ check_style <program>
  ```

  where `<program>` is the `.java` file whose style you want to check.