

Deliverables

Your project files should be submitted to the grading system by the due date and time specified. Note that there is also an optional Skeleton Code assignment (ungraded) which will ensure that you have classes and methods named correctly and also that you have the correct return types and parameter types. This ungraded assignment will also indicate level of coverage your tests have achieved. The files you submit to skeleton code assignment may be incomplete in the sense that method bodies have at least a return statement if applicable or they may be essentially completed files. In order to avoid a late penalty for the project, you must submit your files to the Completed Code assignment no later than 11:59 PM on the due date. Your grade will be determined, in part, by the tests that you pass or fail in your test file and by the level of coverage attained in your source file, as well as our usual correctness tests.

Files to submit to the grading system:

- Tetrahedron.java, TetrahedronTest.java
- TetrahedronList.java, TetrahedronListTest.java

Specifications – **Use arrays in this project; ArrayLists are not allowed!**

Overview: This project consists of four classes: (1) Tetrahedron is a class representing a Tetrahedron object; (2) TetrahedronTest class is a JUnit test class which contains one or more test methods for each method in the Tetrahedron class; (3) TetrahedronList is a class representing a Tetrahedron list object; and (4) TetrahedronListTest class is a JUnit test class which contains one or more test methods for each method in the TetrahedronList class. *Note that there is no requirement for a class with a main method in this project.*

You should create a new folder to hold the files for this project and add your files from Part 2 (Tetrahedron.java file and TetrahedronTest.java). You should create a new jGRASP project for Part 3 and add Tetrahedron.java file and TetrahedronTest.java to the project; you should see the two files in their respective categories – Source Files and Test Files. If TetrahedronTest.java appears in source File category, you should right-click on the file and select “Mark As Test” from the right-click menu. You will then be able to run the test file by clicking the JUnit run button on the Open Projects toolbar. After TetrahedronList.java and TetrahedronListTest.java are created as specified below, these should be added to your jGRASP project for Part 3 as well.

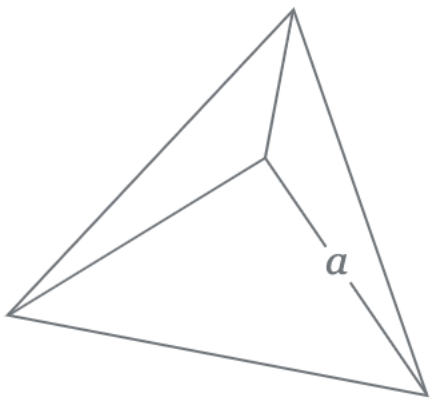
If you have successfully completed Tetrahedron.java and TetrahedronTest.java in Part 2, you should go directly to TetrahedronList.java on page 5.

- **Tetrahedron.java** (The specification of the Tetrahedron class is repeated below for your convenience from Part 2; there are no modifications for this class in Part 3)

Requirements: Create a Tetrahedron class that stores the label and edge, where edge is non-negative (≥ 0). The Tetrahedron class also includes methods to set and get each of these fields, as well as methods to calculate the height, surface area, and volume of a Tetrahedron object, and a method to provide a String value that describes a Tetrahedron object. The Tetrahedron class includes a one static field (or class variable) to track the number of Tetrahedron objects that have

been created, as well appropriate static methods to access and reset this field. And finally, this class provides a method that JUnit will use to test Tetrahedron objects for equality as well as a method required by Checkstyle. In addition, Tetrahedron must implement the Comparable interface for objects of type Tetrahedron.

A **regular tetrahedron** is a tetrahedron in which all four faces are equilateral triangles with edge length a . When lying on one face, the tetrahedron is a pyramid with height h .
(Source: <https://en.wikipedia.org/wiki/Tetrahedron>)

	<p><i>The variables are abbreviated as follows:</i></p> <p>a is edge length</p> <p>h is height</p> <p>A is surface area</p> <p>V is volume</p>	$h = \sqrt{\frac{2}{3}} a$ $A = \sqrt{3} a^2$ $V = \frac{a^3}{6\sqrt{2}}$
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Design: The Tetrahedron class implements the Comparable interface for objects of type Tetrahedron and has fields, a constructor, and methods as outlined below (last method is new).

- (1) **Fields:** Instance Variables - label of type String and edge of type double. Initialize the String to "" and the double variable to 0 in their respective declarations. These instance variables should be private so that they are not directly accessible from outside of the Tetrahedron class, and these should be the only instance variables (fields) in the class. Class Variable - count of type int should be private and static, and it should be initialized to zero.
- (2) **Constructor:** Your Tetrahedron class must contain a public constructor that accepts two parameters (see types of above) representing the label and edge length. Instead of assigning the parameters directly to the fields, the respective set method for each field (described below) should be called since they are checking the validity of the parameter. For example, instead of using the statement `label = labelIn;` use the statement `setLabel(labelIn);` The constructor should increment the class variable count each time a Tetrahedron is constructed.

Below are examples of how the constructor could be used to create Tetrahedron objects. Note that although String and numeric literals are used for the actual parameters (or arguments) in these examples, variables of the required type could have been used instead of

the literals.

```
Tetrahedron example1 = new Tetrahedron("Small Example", 0.5);  
Tetrahedron example2 = new Tetrahedron(" Medium Example ", 12.8);  
Tetrahedron example3 = new Tetrahedron("Large Example", 97.36);
```

(3) **Methods:** Usually a class provides methods to access and modify each of its instance variables (known as get and set methods) along with any other required methods. The methods for Tetrahedron, which should each be public, are described below. See the formulas in the figure above and the Code and Test section below for information on constructing these methods.

- `getLabel`: Accepts no parameters and returns a `String` representing the label field.
- `setLabel`: Takes a `String` parameter and returns a `boolean`. If the `String` parameter is not null, then the “trimmed” `String` is set to the label field and the method returns `true`. Otherwise, the method returns `false` and the label is not set.
- `getEdge`: Accepts no parameters and returns a `double` representing the edge field.
- `setEdge`: Takes a `double` parameter and returns a `boolean`. If the `double` parameter is non-negative, then the parameter is set to the edge field and the method returns `true`. Otherwise, the method returns `false` and the edge field is not set.
- `height`: Accepts no parameters and returns the `double` value for the height of the Tetrahedron. *[Be sure to avoid integer division in your expression.]*
- `surfaceArea`: Accepts no parameters and returns the `double` value for the total surface area of the Tetrahedron.
- `volume`: Accepts no parameters and returns the `double` value for the volume of the Tetrahedron. *[Be sure to avoid integer division in your expression.]*
- `toString`: Returns a `String` containing the information about the Tetrahedron object formatted as shown below, including decimal formatting (“#,##0.0###”) for the `double` values. Newline and tab escape sequences should be used to achieve the proper layout within the `String` but it should not begin or end with a newline. In addition to the field values (or corresponding “get” methods), the following methods should be used to compute appropriate values in the `toString` method: `height()`, `surfaceArea()`, and `volume()`. Each line should have no trailing spaces (e.g., there should be no spaces before a newline (`\n`) character). The `toString` value for `example1`, `example2`, and `example3` respectively are shown below (the blank lines are not part of the `toString` values).

```
Tetrahedron "Small Example" with six edges of length 0.5 has:  
  height = 0.408 units  
  surface area = 0.433 square units  
  volume = 0.015 cubic units
```

```
Tetrahedron "Medium Example" with six edges of length 12.8 has:  
  height = 10.451 units  
  surface area = 283.779 square units  
  volume = 247.152 cubic units
```

```
Tetrahedron "Large Example" with six edges of length 97.36 has:  
height = 79.494 units  
surface area = 16,418.057 square units  
volume = 108,761.565 cubic units
```

- `getCount`: A static method that accepts no parameters and returns an `int` representing the static count field.
- `resetCount`: A static method that returns nothing, accepts no parameters, and sets the static count field to zero.
- `equals`: An instance method that accepts a parameter of type `Object` and returns `false` if the `Object` is not a `Tetrahedron`; otherwise, when cast to a `Tetrahedron`, if it has the same field values as the `Tetrahedron` upon which the method was called, it returns `true`. Otherwise, it returns `false`. Note that this `equals` method with parameter type `Object` will be called by the JUnit `Assert.assertEquals` method when two `Tetrahedron` objects are checked for equality.

Below is a version you are free to use.

```
public boolean equals(Object obj) {  
  
    if (!(obj instanceof Tetrahedron)) {  
        return false;  
    }  
    else {  
        Tetrahedron d = (Tetrahedron) obj;  
        return (label.equalsIgnoreCase(d.getLabel())  
            && Math.abs(edge - d.getEdge()) < .000001);  
    }  
}
```

- `hashCode()`: Accepts no parameters and returns zero of type `int`. This method is required by Checkstyle if the `equals` method above is implemented.
- `compareTo`: Accepts a parameter of type `Tetrahedron` and returns an `int` as follows: a negative value if `this.volume()` is less than the parameter's volume; a positive value if `this.volume()` is greater than the parameter's volume; zero if the two volumes are essentially equal. For a hint, see the activity for this module.

Code and Test: As you implement the methods in your `Tetrahedron` class, you should compile it and then create test methods as described below for the `TetrahedronTest` class.

- **TetrahedronTest.java**

Requirements: Create a `TetrahedronTest` class that contains a set of *test* methods to test each of the methods in `Tetrahedron`. The goal for Part 2 is method, statement, and condition coverage.

Design: Typically, in each test method, you will need to create an instance of `Tetrahedron`, call the method you are testing, and then make an assertion about the expected result and the actual result (note that the actual result is commonly the result of invoking the method unless it has a void return type). You can think of a test method as simply formalizing or codifying what you

could be doing in jGRASP interactions to make sure a method is working correctly. That is, the sequence of statements that you would enter in interactions to test a method should be entered into a single test method. You should have sufficient test methods so that each method, statement, and condition in Tetrahedron are covered. Collectively, these test methods are a set of test cases that can be invoked with a single click to test all of the methods in your Tetrahedron class.

Code and Test: A good strategy would be to begin by writing test methods for those methods in Tetrahedron that you “know” are correct. By doing this, you will be able to concentrate on the getting the test methods correct. That is, if the test method *fails*, it is most likely due to a defect in the test method itself rather than the Tetrahedron method being tested. As you become more familiar with the process of writing test methods, you will be better prepared to write the test methods as new methods are developed. Be sure to call the Tetrahedron `toString` method in one of your test cases so that the grading system will consider the `toString` method to be “covered” in its coverage analysis. Remember that you can set a breakpoint in a JUnit test method and run the test file in Debug mode. Then, when you have an instance in the Debug tab, you can unfold it to see its values or you can open a canvas window and drag items from the Debug tab onto the canvas. You can also step-in to the method being called by the test method and then single-step through it, looking for the error.

- **TetrahedronList.java (new for Part 3)** – Consider implementing this file in parallel with its test file, `TetrahedronListTest.java`, which is described after this class.

Requirements: Create a `TetrahedronList` class that stores the name of the list and an array of `Tetrahedron` objects. It also includes methods that return the name of the list, number of `Tetrahedron` objects in the `TetrahedronList`, total surface area, total volume, average surface area, and average volume for all `Tetrahedron` objects in the `TetrahedronList`. The `toString` method returns summary information about the list (see below).

Design: The `TetrahedronList` class has three fields, a constructor, and methods as outlined below.

- (1) **Fields** (or instance variables): (1) a `String` representing the name of the list, (2) an array of `Tetrahedron` objects, and (3) an `int` representing the number of `Tetrahedron` objects in the array, which be less than the length of the array of Tetrahedron objects. These instance variables should be private so that they are not directly accessible from outside of the `TetrahedronList` class. These should be the only fields (or instance variables) in this class, and they should be initialized in the constructor described below.
- (2) **Constructor:** Your `TetrahedronList` class must contain a constructor that accepts three parameters: (1) a parameter of type `String` representing the name of the list, (2) a parameter of type `Tetrahedron[]`, representing the list of `Tetrahedron` objects, and (3) a parameter of type `int` representing the number of `Tetrahedron` objects in the array. These parameters should be used to assign the fields described above (i.e., the instance variables).

(3) Methods: The methods for TetrahedronList are described below.

- `getName`: Returns a String representing the name of the list.
- `numberOfTetrahedrons`: Returns an int representing the number of Tetrahedron objects in the TetrahedronList. If there are zero Tetrahedron objects in the list, zero should be returned.
- `totalSurfaceArea`: Returns a double representing the total surface areas for all Tetrahedron objects in the list. If there are zero Tetrahedron objects in the list, zero should be returned.
- `totalVolume`: Returns a double representing the total volumes for all Tetrahedron objects in the list. If there are zero Tetrahedron objects in the list, zero should be returned.
- `averageSurfaceArea`: Returns a double representing the average surface area for all Tetrahedron objects in the list. If there are zero Tetrahedron objects in the list, zero should be returned.
- `averageVolume`: Returns a double representing the average volume for all Tetrahedron objects in the list. If there are zero Tetrahedron objects in the list, zero should be returned.
- `toString`: Returns a String (does not begin with `\n`) containing the name of the list (which can change depending on the name of the list passed as a parameter to the constructor) followed by various summary items: number of Tetrahedrons, total surface area, total volume, average surface area, and average volume. Use `"#,##0.0###"` as the pattern to format the double values. Below is an example of the formatted String returned by the `toString` method, where the name of the list (name field) is **Tetrahedron Test List** and the array of Tetrahedron objects contains the three examples described above (top of page 2).

```
----- Summary for Tetrahedron Test List -----
Number of Tetrahedrons: 3
Total Surface Area: 16,702.269 square units
Total Volume: 109,008.731 cubic units
Average Surface Area: 5,567.423 square units
Average Volume: 36,336.244 cubic units
```
- `getList`: Returns the array of Tetrahedron objects (the second field above).
- `addTetrahedron`: Returns nothing but takes two parameters (label and edge), creates a new Tetrahedron object, and adds it to the TetrahedronList object. Be sure to increment the int field containing the number of Tetrahedron objects in the TetrahedronList object.
- `findTetrahedron`: Takes a label of a Tetrahedron as the String parameter and returns the corresponding Tetrahedron object if found in the TetrahedronList object; otherwise returns null. Case should be ignored when attempting to match the label.
- `deleteTetrahedron`: Takes a String as a parameter that represents the label of the Tetrahedron and returns the Tetrahedron if it is found in the TetrahedronList object and deleted; otherwise returns null. Case should be ignored when attempting to match the label. When an element is deleted from an array, elements to the right of the deleted element must be shifted to the left. After shifting the items to the left, the last Tetrahedron element in the array should be set to null. Finally, the number of elements field must be decremented.

- `editTetrahedron`: Takes two parameters (label and edge), uses the label to find the corresponding the Tetrahedron object in the list. If found, sets the edge to the value passed in as the parameter, and returns true. If not found, returns false. (*Note that the label should not be changed by this method.*)
- `findTetrahedronWithLargestVolume`: Returns the Tetrahedron with the largest volume; if the list contains no Tetrahedron objects, returns null.

Code and Test: Some of the methods above require that you use a loop to go through the objects in the array. You should implement the class below in parallel with this one to facilitate testing. That is, after implementing one to the methods above, you can implement the corresponding test method in the test file described below.

- **`TetrahedronListTest.java`** (new for Part 3) – Consider implementing this file in parallel with its source file, `TetrahedronList.java`, which is described above this class.

Requirements: Create a `TetrahedronListTest` class that contains a set of *test* methods to test each of the methods in `TetrahedronList`.

Design: Typically, in each test method, you will need to create an instance of `TetrahedronList`, call the method you are testing, and then make an assertion about the expected result and the actual result (note that the actual result is usually the result of invoking the method unless it has a void return type). You can think of a test method as simply formalizing or codifying what you have been doing in interactions to make sure a method is working correctly. That is, the sequence of statements that you would enter in interactions to test a method should be entered into a single test method. You should have at least one test method for each method in `TetrahedronList`. However, if a method contains conditional statements (e.g., an *if* statement) that results in more than one distinct outcome, you need a test method for each outcome. For example, if the method returns boolean, you should have one test method where the expected return value is false and another test method that expects the return value to be true. Also, each condition in boolean expression must be exercised true and false. Collectively, these test methods are a set of test cases that can be invoked with a single click to test all of the methods in your `TetrahedronList` class.

Code and Test: A good strategy would be to begin by writing test methods for those methods in `TetrahedronList` that you “know” are correct. By doing this, you will be able to concentrate on the getting the test methods correct. That is, if the test method *fails*, it is most likely due to a defect in the test method itself rather the `TetrahedronList` method being testing. As you become more familiar with the process of writing test methods, you will be better prepared to write the test methods for the new methods in `TetrahedronList`. Be sure to call the `TetrahedronList` `toString` method in one of your test cases so that the grading system will consider the `toString` method to be “covered” in its coverage analysis. Remember that when a test method fails, you can set a breakpoint in a JUnit test method and run the test file in Debug mode. Then, when you have an instance in the Debug tab, you can unfold it to see its values or you can open a canvas

window and drag items from the Debug tab onto the canvas. You can also step-in to the method being called by the test method and then single-step through it, looking for the error.

Finally, when comparing two arrays for equality in JUnit, be sure to use `Assert.assertArrayEquals` rather than `Assert.assertEquals`. `Assert.assertArrayEquals` will return true only if the two arrays are the same length and the elements are equal based on an element by element comparison using the equals method.

The Grading System

When you submit your files (`Tetrahedron.java`, `TetrahedronTest.java`, `TetrahedronList.java`, and `TetrahedronListTest.java`), the grading system will use the results of your test methods and their level of coverage of your source files as well as the results of our reference correctness tests to determine your grade. In this project, your test files should provide method, statement, and condition coverage. Each condition in your source file must be exercised both true and false.