Important

There are general homework guidelines you must always follow. If you fail to follow any of the following guidelines you risk receiving a **0** for the entire assignment.

1. All submitted code must compile under **JDK 8**. This includes unused code, so don't submit extra files that don't compile. Any compile errors will result in a 0.
2. Do not include any package declarations in your classes.
3. Do not change any existing class headers, constructors, or method signatures.
4. Do not add additional public methods.
5. Do not use anything that would trivialize the assignment. (e.g. don't import/use `java.util.LinkedList` for a Linked List assignment. Ask if you are unsure.)
6. Always be very conscious of efficiency. Even if your method is to be $O(n)$, traversing the structure multiple times is considered non-efficient unless that is absolutely required (and that case is extremely rare).
7. You must submit your source code, the `.java` files, not the compiled `.class` files.
8. After you submit your files redownload them and run them to make sure they are what you intended to submit. You are responsible if you submit the wrong files.

Graph Algorithms

For this assignment, you will be coding 4 different graph algorithms. This homework has quite a few files in it, so you should make sure to read ALL of the documentation given to you before asking a question.

Search Algorithms

Breadth-First Search is a search algorithm that visits vertices in order of "levels", visiting all vertices one away from the start, then two away, etc. Similar to levelorder traversal in BSTs, it depends on a Queue data structure to work.

Depth-First Search is a search algorithm that visits vertices in a depth based order. It depends on a Stack based data structure to work, which for your implementation will be recursion. It searches along one path of vertices from the start vertex and backtracks once it hits a dead end or a visited vertex until it finds another path to continue along. **Your implementation of DFS must be recursive to receive credit.**

Single-Source Shortest Path (Dijkstra's Algorithm)

The next algorithm is Dijkstra's algorithm. This algorithm finds the shortest path from one vertex to all of the other vertices in the graph. This algorithm only works for non-negative edge weights, so you may assume all edge weights for this algorithm will be non-negative.

There are two main variants of Dijkstra's Algorithm related to the termination condition of the algorithm. The classic variant is the version where you maintain a visited set to terminate early once you've visited all the vertices. The other variant is where you depend purely on the PriorityQueue to determine when to terminate the algorithm. You should implement the classic variant for this assignment.

Kruskal's Algorithm

Minimal Spanning Trees (MST)

An MST has two components. By definition, it is a tree, which means that it is a graph that is acyclic and connected. A spanning tree is a tree that connects the entire graph. It must also be minimal, meaning the sum of edge weights of the graph must be the smallest possible while still being a spanning tree.

By the properties of a spanning tree, any valid MST must have $|V| - 1$ edges in it. However, since all undirected edges are specified as two directional edges, a valid MST for your implementation will have $2(|V| - 1)$ edges in it.

Kruskal's algorithm takes in all of the edges of the graph and continually adds the cheapest to the MST as long as that edge does not form a cycle. To handle cycle detection, you will be using a disjoint-set/union-find data structure that we have provided for you.

Disjoint Set Data Structure (Union-Find)

For Kruskal's algorithm, you will be using the `DisjointSet` class implementation that we have provided to maintain which components are connected. This data structure has two primary functions, `union` and `find`. The idea here is that each disconnected component is maintained as a tree. If two pieces of data are in the same tree, then they are in the same connected component.

The DisjointSet will begin with all of the data in their own one node trees to begin since nothing is connected originally. As the algorithm progresses, the nodes that are connected in the graph will be linked into the same tree in the DisjointSet.

To see whether or not the two data are in the same tree, it suffices to see if their roots are the same since the root is unique. The `find` method finds the root of the component's tree.

If you add an edge to the MST in Kruskal's, then it will cause two previously disconnected components to become a single component. The `union` method does this for you, merging the two trees representing the two components into a single tree.

Grading

Here is the grading breakdown for the assignment. There are various deductions not listed that are incurred when breaking the rules listed in this PDF, and in other various circumstances.

Methods:	
BFS	15pts
DFS	15pts
Dijkstra's	25pts
Kruskal's	20pts
Other:	
Checkstyle	10pts
Efficiency	15pts
Total:	100pts

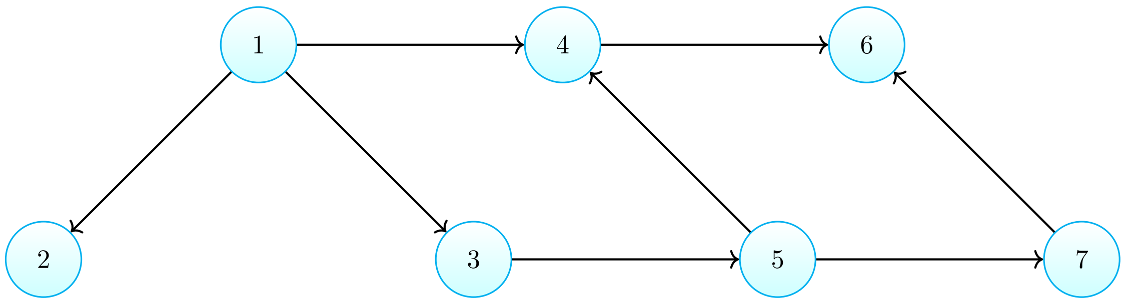
A note on JUnits

We have provided a **very basic** set of tests for your code, in `GraphAlgorithmsStudentTests.java`. These tests do not guarantee the correctness of your code (by any measure), nor does it guarantee you any grade. You may additionally post your own set of tests for others to use on the Georgia Tech GitHub as a gist. Do **NOT** post your tests on the public GitHub. There will be a link to the Georgia Tech GitHub as well as a list of JUnits other students have posted on the class Piazza.

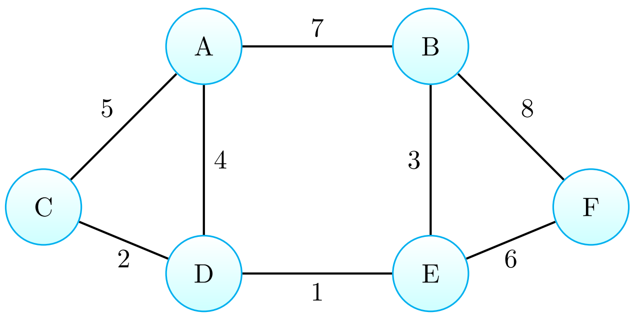
If you need help on running JUnits, there is a guide, available on T-Square under Resources, to help you run JUnits on the command line or in IntelliJ.

Visualizations of Graphs

The directed graph used in the student tests is:



The undirected graph used in the student tests is:



Style and Formatting

It is important that your code is not only functional but is also written clearly and with good style. We will be checking your code against a style checker that we are providing. It is located in T-Square, under Resources, along with instructions on how to use it. We will take off a point for every style error that occurs. If you feel like what you wrote is in accordance with good style but still sets off the style checker please email Raymond Ortiz (rortiz9@gatech.edu) with the subject header of "CheckStyle XML".

Javadocs

Javadoc any helper methods you create in a style similar to the existing Javadocs. Like the existing Javadocs, the Javadocs for your helper method(s) must describe well what the method does, what each parameter means (if any), and what the returned value is (if any). If a method is overridden or implemented from a superclass or an interface, you may use `@Override` instead of writing Javadocs.

Exceptions

When throwing exceptions, you must include a message by passing in a String as a parameter. **The message must be useful and tell the user what went wrong**. "Error", "BAD THING HAPPENED", and "fail" are not good messages. The name of the exception itself is not a good message.

For example:

```
throw new PDFReadException("Did not read PDF, will lose points.");
```

```
throw new IllegalArgumentException("Cannot insert null data into data structure.");
```

Generics

If available, use the generic type of the class; do **not** use the raw type of the class. For example, use `new LinkedList<Integer>()` instead of `new LinkedList()`. Using the raw type of the class will result in a penalty.

Forbidden Statements

You may not use these in your code at any time in CS 1332.

- `break` may only be used in switch-case statements
- `continue`
- `package`
- `System.arraycopy()`
- `clone()`
- `assert()`
- `Arrays` class
- `Array` class
- `Objects` class
- `Stack` class
- `Collections` class
- `Collection.toArray()`
- Reflection APIs
- Inner, nested, or anonymous classes

Debug print statements are fine, but nothing should be printed when we run them. We expect clean runs - printing to the console when we're grading will result in a penalty. If you use these, we will take off points.

Provided

The following file(s) have been provided to you. There are several, but you will only edit one of them.

1. `GraphAlgorithms.java`

   This is the class in which you will implement the different graph algorithms. Feel free to add private static helper methods but **do not add any new public methods, new classes, instance variables, or static variables**.

2. `GraphAlgorithmsStudentTests.java`

   This is the test class that contains a set of tests covering the basic operations on the `GraphAlgorithms` class. It is not intended to be exhaustive and does not guarantee any type of grade. Write your own tests to ensure you cover all edge cases. The graphs used for these tests are shown above in the pdf.

3. `Graph.java`

   This class represents a graph. **Do not alter this file.**

4. `Vertex.java`

   This class represents a vertex in the graph. **Do not modify this file**.

5. `Edge.java`

   This class represents an edge in the graph. It contains the vertices connected to this edge and its weight. **Do not modify this file**.

6. `DisjointSet.java`

   This class represents a union-find data structure to be used for Kruskal's algorithm, consisting of the operations find and union. **Do not modify this file**.

7. `DisjointSetNode.java`

   This class represents a node for `DisjointSet.java`. **Do not modify this file and do not use this file in your implementation**.

Deliverables

You must submit **all** of the following file(s). Please make sure the filename matches the filename(s) below, and that *only* the following file(s) are present. T-Square does **not** delete files from old uploads; you must do this manually. Failure to do so may result in a penalty.

After submitting, be sure you receive the confirmation email from T-Square, and then download your uploaded files to a new folder, copy over the interfaces, recompile, and run. It is your responsibility to re-test your submission and discover editing oddities, upload issues, etc.

1. `GraphAlgorithms.java`