**Falling Sand**

In this lab, you'll create a *falling sand* program. The software resembles a paint program, except that the user is painting particles into the world. The software simulates the physical behavior of those particles, which may move (perhaps falling like grains of sand), change, clone, disappear, interact, etc.

**Exercise 0: Getting Started**

Download [FallingSand.zip](http://nifty.stanford.edu/2017/feinberg-falling-sand/FallingSand.zip). Compile and run SandLab.java. (This will run SandLab's main method, which constructs a new SandLab and calls its run method.) You should see a window pop up. On the left side is a black rectangular canvas which will soon be inhabited by particles. On the right side there is one button for each tool you will be able to paint with: *Empty*(for erasing) and *Metal* (for creating metal particles). You can't actually paint now, because you haven't written the code yet.

Look in the SandLab.java file, and you'll see that a SandLab remembers two things:

* grid - a 2-dimensional array of int values that represent the type of particle found at each location
* display - the SandDisplay used to show the particles on the screen

**Do not add any more fields!**

Notice that we're using int values to represent particle types, with 0 representing *empty*, 1 representing *metal*, and higher values representing the additional particle types you'll be adding. To avoid confusion, **we never want to see these particle type numbers (0, 1, etc.) in our code!** Instead, we've declared variables for each of these types. You'll see these listed near the top of SandLab.java.

public static final int EMPTY = 0;

public static final int METAL = 1;

This lets us use meaningful variable names instead of confusing type numbers in our code. For example:

if (type == METAL)

These variables are marked final to indicate that they are constants. (Attempts to re-assign to these variables will not compile.) By convention in Java, we use all-caps names for constants. (Traditionally, constants are also declared as public and static, so that we can access them from outside the file by writing SandLab.METAL, for example.)

**Exercise 1: Constructor**

The SandLab constructor already initializes the display field to refer to a new SandLabDisplay with appropriate dimensions and tool names. Insert code to initialize the grid field to refer to a 2-dimensional array of the same dimensions. (You won't be able to test this code yet.)

**Exercise 2: locationClicked**

The locationClicked method is called (by the run method) whenever the user clicks on some part of the canvas. The selected tool (*empty*, *metal*, etc.) is passed to the method. Store this value in the corresponding position of the grid array. (You won't be able to test this code yet.)

**Exercise 3: updateDisplay**

The updateDisplay method is called (by the run method) at regular intervals. Its job is to draw each particle (and empty space) found in grid onto the display, using SandDisplay's setColor method. Complete this method so that empty locations are shown in one color (probably black) and metal locations are shown in another color (probably gray).

**class java.awt.Color**

Color(int red, int green, int blue) // values range from 0 - 255 inclusive

**class SandDisplay**

void setColor(int row, int col, Color color)

Test that you can now paint metal particles and erase them.

**Exercise 4: Sand**

Modify your program so that you can also paint with *sand* particles (probably in yellow). For now, these particles won't actually move.

**Exercise 5: step**

The step method is called (by the run method) at regular intervals. This method should choose a *single random valid location*. (Do not use a loop.) If that location contains a sand particle and the location below it is empty, the particle should move down one row. (Metal particles will never move.) This code should only modify the array. Do not set any colors in the display. Test that your sand particles fall now.

**Tip:** If particles fall too quickly or too slowly, the speed can be adjusted by adjusting the slider in the display or by changing the dimensions passed to the SandLab constructor (from main).

**Note:** Because the step method picks a single random particle to move (or act in some way) each time it is called, it is possible that some sand particles will move several times before others have the chance to move at all. In practice, the step method is called so rapidly that you are unlikely to notice this effect when you run the code.

**Exercise 6: Water**

Modify your program so that you can also paint with *water* particles, which move in one of three randomly chosen directions: down, left, or right.

In the step method, when the randomly chosen location contains a water particle, pick one of three random directions. If the location in that randomly chosen direction is empty, the water particle moves there. (Look for ways to minimize duplicate code in your step method.)

Test that the water behaves roughly like a liquid, taking the shape of a container.

**Exercise 7: Dropping Sand Into Water**

What happens now when you drop sand particles into water? Right now, sand is only allowed to move into empty spaces. Modify your code so that a sand particle can also move into a space containing a water particle (by trading places with the water particle). (Look for ways to minimize duplicate code in your step method.) Test that you can drop sand into water now (without destroying the water).

**Now implement other behaviors for additional credit. Get creative!**