

SandLab Underwater — based on a class project at Stanford University

In this project, you'll create what is called a *falling sand* program, but in this case the world will be underwater. 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 `SandLab.java` and `LabDisplay.class`. 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 you will create 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). Note that 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:

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

Do not add any more fields!

You can ignore the fields and code relating to saving and reading a file until later.

Now, 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;
public static final int SAVEFILE = 2;
```

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 `LabDisplay` with appropriate dimensions and tool names. Insert code to create a field called `sandGrid` that will be 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 `sandGrid` 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 `sandGrid` onto the display, using `LabDisplay`'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 LabDisplay
void setColor(int row, int col, Color color)

display.setColor(r,c,Color.gray); //setColor is a method in the LabDisplay program.
                                   // r = row, c = column, Color.gray is a java constant
```

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.

How the metal tool is coded is a pattern you can follow when adding sand to the program.

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.

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: Air

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

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

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

Exercise 7: Dropping Sand into Air or Water

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

Exercise 8: Saving and Reading a File

Now add some metal and other elements and click on the save file button. The screen will be saved to the file name in `NEW_FILE_NAME`. You will have to go rename that to the name in `FILE_NAME` to have it read in when you start the program next time. Give it a try!

Now implement other behaviors such as Oil, Generator, Destructor, Anti-gravity, Water vapor, and more! Get creative!