

Assignment A5 CS1110 Fall 2008 See CMS for deadline

This assignment introduces you to graphics. You will write procedures that draw interesting designs, bouncing balls, and a recursive design in a JFrame. You may work with one other person. If you do so, form your group on the CMS WELL BEFORE YOU SUBMIT YOUR FILES. Remember, partners should work together and not independently.

You need not use a JUnit testing class. You will (partly) be looking at visual output (graphics) to determine correctness.

Please keep track of the time you spend on this assignment. You will be asked to put it in a comment at the top of file A5.java.

To save time and effort, we give you complete specifications of most of the methods you write. Please study them carefully. Note how precise and thorough they are. You should aim for this quality of specification when you write your own specifications. At the end of this document, we tell you what to submit.

Download file [A5.zip](#), unzip it, and put everything in it into a new directory. It contains:

1. A file `A5.java`, which extends class `Turtle`.
2. Several `.class` files. These are machine language versions of `.java` files. Do NOT load them into DrJava. The only thing you should load into DrJava is file `A5.java`. It will automatically use the `.class` files.
3. A directory `doc`, which contains specifications of classes `Turtle` and `HSV`. You will use these specs when writing method calls to make turtles do what you want.

A `Turtle` is a pen of a certain color at a pixel (x, y) that is pointing in some direction given by an angle (0 degrees is to the right, or east; 90 degrees, north; 180 degrees, west; and 270 degrees, south). When the turtle is moved to another spot using procedure `moveAhead` or `moveBack`, a line is drawn if its pen is currently "down" and nothing is drawn if its pen is "up". The pen is initially black, but its color, of class `java.awt.Color`, can be changed. A footnote on page 1.5 of the ProgramLive CD contains information about class `Color`.

Open `doc/index.html` in your favorite browser and study the specifications of methods in class `Turtle` (the javadoc files). Here are some important points:

- Class `Turtle` uses the `Graphics` object that is attached to a `JPanel`. It builds on class `Graphics` by maintaining the "turtle", which has a position and an angle and holds a pen of a color; the pen is up or down. You can use many turtles at the same time; they all use the same `JPanel`.
- The coordinates and angle of the turtle are maintained using type **double**. This is needed for maximum accuracy. If we used **int**, errors might crop up after many calculations. However, whenever a point is to be placed in the window, its x- and y-coordinates are rounded to the nearest integer because the graphics space works with **ints**.
- Class `Color` is in package `java.awt`. Its objects are colors in the RGB model. Take a look at its API spec. It has various constants that you can use, e.g. `put java.awt.Color.red` in the DrJava interactions pane, hit key Enter-return, and see what happens.
- Manually resizing the `JFrame` window also changes the size of the panel on which the drawing occurs. But you have to move the mouse inside the panel to see this.
- Procedure `jumpTo(ang, x, y)` can be used to move the turtle, without drawing, to (x, y) and face it

at angle `ang`.

- Call `pause(p)` to pause execution for `p` milliseconds. Judicious use of this method will allow you to watch something being drawn in slow motion.

Class `A5.java` contains procedure `drawTwoLines` to show you how graphics works. After compiling class `A5`, in DrJava's interaction pane, create an instance of class `A5` and execute a call on `drawTwoLines`. A `JFrame` should be created and two lines should be drawn on it. Notice how the body of the procedure saves the initial color of the pen and ends by changing the pen back to its initial color. Generally, methods will attempt to leave things the way they were when they started, and this indicates how to do that.

In the interactions pane (or in a method in class `A5`), draw some lines, rectangles, circles, etc, to familiarize yourself with class `Turtle`. After that, perform the tasks given below.

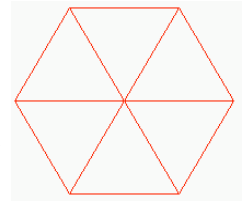
Task 1. Complete function `A5.toString`. Follow the instructions given in the function itself. You will see why in Task 2. Here is an example of what our `toString` function produces, and yours should be similar:

pos. (250, 250), facing 0.0 degrees, color java.awt.Color[r=0,g=0,b=0], pen down.

Your output does not have to be *precisely* like this, but it should contain the same information, and in this order. Note: class `Color` has its own `toString` function.

Task 2 . Complete procedure `drawRedTriangle`. Then follow the instructions in the comment in the body to learn about rounding errors when using type `double` and why they don't really matter here. Note that the comment asks you to put some information at the top of file `A5.java` (as a comment).

Task 3. Complete `drawRedHex` to draw a red hexagon, as shown to the right of this paragraph. It should call procedure `drawRedTriangle` 6 times. Some lines will be drawn twice, but that is OK. Of course, when the procedure call terminates, the turtle's properties (position, angle, pen color, and whether the pen is up or down) should be the same as when the procedure call began.

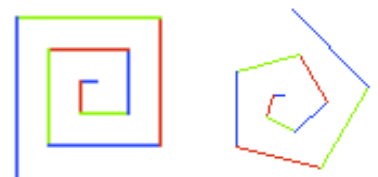


The procedure should draw the shape at the turtle's current position and at the turtle's current angle. Don't move the turtle before beginning.

Also, note that THIS PROCEDURE DOESN'T HAVE TO DRAW ANY EXTRA LINES OR JUMP AROUND AT ALL. Just use calls on `drawRedTriangle` and `addAngle`.

Task 4. Do TWO (repeat, 2) of 4A, 4B, or 4C. After you have completed the assignment, if you are interested, do the other one! It is fun, seeing how easy it is to do these neat things.

Task 4A: Draw a spiral. The first picture to the right is done by drawing 10 lines. The first line has length 5; the second, 10; the third, 15, etc. After each line, 90 degrees is added to the angle. The second diagram to the right shows a similar spiral but with 75 degrees added to the angle after each line.



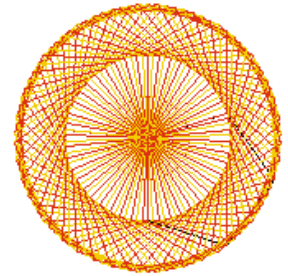
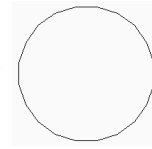
Complete procedure `spiral`. When you first test your method, use 5 for `d` and 0 for `sec`. Try different angles, like 90 degrees, 92 degrees, 88 degrees, etc. You can also use `msec = 500` or `msec = 1000` (which is 1 second) in order to see the lines drawn one at a time.

You will be amazed at what method `spiral` does. Find out by trying these calls, assuming that `x` is an instance of `A5`. Use procedure `moveToCenter()` to erase the panel and place the turtle in the middle before

each one:

```
x.spiral(500, 90, 1, 0);    x.spiral(500, 135, 1, 0);    x.spiral(500, 60, 1, 0);  
x.spiral(500, 121, 1, 10); x.spiral(500, 89, 1, 0);    x.spiral(500, 150, 1, 5);  
x.spiral(500, 120, 1, 0);  x.spiral(500, 119, 1, 10);
```

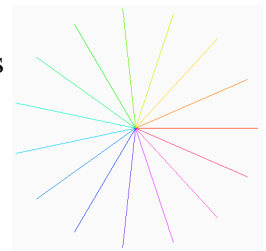
Task 4B: Draw many polygons. The first image to the right is a 20-sided polygon, drawn using procedure `drawPolygon`, which we give you. The second image to the right is a series of 90 5-sided polygons of side length 50, the first started at angle 270, the second started at angle 274, the third at angle 278, and so on. The polygon colors alternate between red and orange.



Complete procedure `multiPolygons` so that your program can draw such designs.

When finished, experiment, to see what neat designs come out. Try, for example, `multiPolygons(4, 200, 20)` and `multiPolygons(7, 50, 30)`.

Task 4C: Draw radiating lines. The picture to the right is done by drawing 15 lines of the same length, radiating out from the current turtle position. The angle between the lines is the same. If n lines are drawn, the angle between them is $360.0/n$. Note the colors of the lines. Each line is drawn in the HSV color (hue, 1, 1) [translated, of course, to the RGB system; we give you `HSV.class`, which contains our function `HSVtoRGB` from assignment A4], where hue is the hue given by the angle at which it is drawn. So, what you see is part of the color disk of the HSV system!



Complete procedure `radiate`. As you write it, test it with small values of n , like 4 or 8. After the procedure is completely tested, try it with 360 lines of length 200, pausing 50 milliseconds between each. Isn't that neat? Also, do it with 3,000 lines, pausing 5 milliseconds between each, and notice how much more filled in the disk becomes.

Task 5: Bouncing balls. Procedure `Turtle.fillCircle` draws a disk — a filled-in circle. You can use this procedure to draw a bouncing ball. Suppose the ball is at some position (x, y) . To make it look like the ball is moving, repeat the following process over and over again:

1. Move the ball: (1) Draw the ball at its current position using color white, thus erasing it, (2) change the position of the turtle, and (3) draw the ball in its own color.
2. Pause for 100 milliseconds.

(a) Add to class `A5` three private **double** fields: `radius` gives the radius of the ball and fields `vx` and `vy` describe the speed of the ball; when the ball is moved, it moves `vx` pixels in the horizontal direction and `vy` pixels in the vertical direction. Write getter methods for these fields.

(b) Complete constructor `A5(x, y, r, c, vx, vy)`, which initializes a new `A5` object. You know the constructor works properly when you see the ball in the panel. Be sure you follow the principle to initialize inherited fields first, using a call on as superclass constructor.

To make things easier, also complete constructor `A5(vx, vy, r)`, which creates a black ball at the midpoint of the panel with speed (vx, vy) and radius r . Then, create several balls, with different starting points, radii, and colors, before going on to the next step.

(c) Complete procedure `moveOnce()`, following these directions:

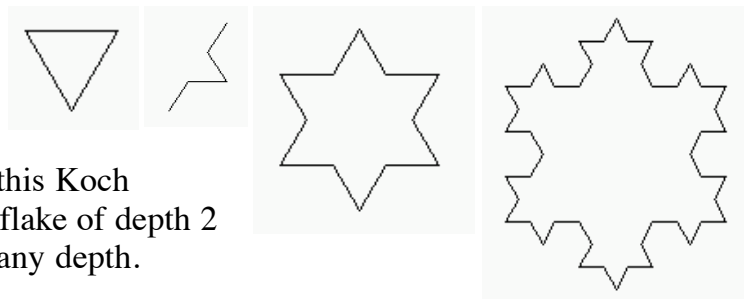
1. Move the ball, as follows: (1) draw the ball with a white pen; (2) move the turtle; and (3) draw the ball in its original color. (So, the program must remember the original color. Have a local variable `origColor` to contain the original color and, after drawing the ball white, set the turtle color back to the value of variable `origColor`.)
2. *After* moving the ball: negate the y-coordinate speed (using `vy = -vy`;) **IF** either (1) the vertical motion is negative and the ball just touches or goes partially over the top of the panel or (2) the vertical motion is positive and the ball just touches or goes partially over the bottom of the panel. You have to do the same kind of thing for the horizontal direction.

Test method `moveOnce()` carefully, as follows. In the interactions pane, create a ball of radius 45 that starts in the middle of the panel and has velocity $(0, -35)$. Then, repeatedly execute `d.moveBallOnce()` and watch what happens. Makes sure that it bounces properly off the top and bottom walls. Then do the same kind of test for the left and right walls. You will notice that, because of the way `moveOnce` works, the ball may partially go through a wall and then come out. That is alright. That is the way we want it.

(d) Complete procedure `perpetua1()`. Its body should be a loop that does not terminate and that has a `repetend` that (1) moves balls `b1` and `b2` once and then (2) pauses for 100 milliseconds. In the interactions pane, create two new Ball `d1` and `d2`, call `A5.perpetua12(d1, d2)`; and watch the balls move. Stop this execution by hitting the DrJava reset button.

Task 6. Recursive graphics. We now ask you to develop a recursive procedure to draw some graphics, recursively. We discuss one example, the Koch snowflake. Then, we ask you to develop a recursive procedure. We give you some examples.

Directly to the right is a triangle. It is called a "Koch snowflake" of level 0. Replacing each line of this Koch snowflake by four lines as drawn in the second diagram gives the Koch snowflake of depth 1, which is the third figure. And, replacing each of the lines of this Koch snowflake by the same four lines gives the Koch snowflake of depth 2 shown on the extreme right. This can be continued to any depth.



Doing this is extremely easy using recursion! This is done using procedures `koch` and `kochL`, which appear in the class `A5` that we give you. Procedure `koch` is always the one to call (`kochL` is private), for it clears the window, etc., in preparation for drawing the Koch flake. `koch` calls `kochL`.

We can explain in a simple way what `koch` and `kochL` using the following two *patterns*:

- Koch: L - - L - - L
- KochL: L + L - - L + L

Here's how to interpret each of them. Each symbol is a command to do something, as follows.

- L: If `d` (depth of recursion) is 0, draw a line of length `F`; otherwise, call `kochL(d-1, F, s)`.
- +: add 60 degrees to the turtle's angle.
- : subtract 60 degree from the turtle's angle.

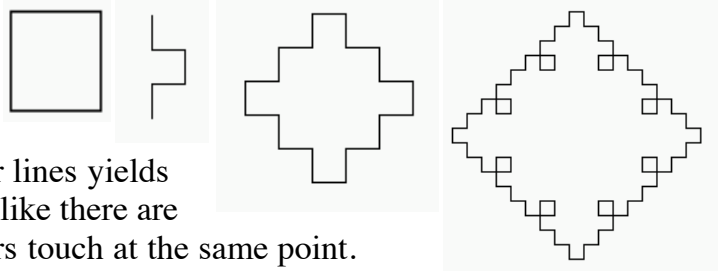
So, the patterns are simply a simple, terse, way of describing what each of the method bodies should do. Compare these sequences of commands to the bodies of the method bodies, and you will see what we mean. Such a system of patterns is called a "Lindenmayer System", after Aristid Lindenmayer, who co-authored a book titled *The Algorithmic Beauty of Plants* (Springer Verlag, 1990).

In this task 6, your job is to write a procedure that draws a recursive graphical design. You can choose from a few alternatives given below.

Before we begin, make careful note of these ground rules:

1. Following the Koch-snowflake pattern, write two procedures, a public one that will initialize as procedure `koch` does and a private one, which is recursive.
2. Give complete and precise specifications of both procedures.
3. Our examples below show you output for depths 0, 1, and 2. We expect you to test your procedures with greater depth than that! And we are sure you will, because it's fun to see the graphic output appear.
3. Do not search the web to find procedures already written in other languages; that is dishonest. Instead, use the material given below to help you and do some problem solving of our own. Ask Gries, a TA, or a consultant for help if you need it.

1. Square flakes. Directly to the right is a square. It is called a "flake" of depth 0. Replacing each line of this flake by four lines as drawn in the second diagram



yields a flake of depth 1, which is the third figure.

Replacing each of the lines of this flake by the same four lines yields the flake of depth 2 shown on the extreme right. It looks like there are loops in this diagram, but that is only because two corners touch at the same point.

2. Sierpinski triangles. Directly to the right is a filled-in equilateral triangle. We call it a Sierpinski triangle of size s (the length of a side) and depth 0. Next to it is a Sierpinski triangle of size s and depth 1. It is created by filling in 3 Sierpinski triangles of size $s/2.0$ and depth 0, in each of the corners of what would be a Sierpinski triangle of size s and depth 0. All the way on the right is a Sierpinski triangle of size s and depth 2; it is created by drawing 3 Sierpinski triangles of size $s/2.0$ and depth 1. In the same way, draw a Sierpinski triangle of size s and depth d by drawing three Sierpinski triangles of size $s/2.0$ and depth $d-1$ in appropriate places.



Here are some hints. (1) You can write the Sierpinski procedures with (at least) two parameters (x, y) that give the position of the left point of the base line of the triangle. Or, you can let the turtle indication this position. It is up to you. (2) Use procedure `fillTriangle` (in class A5) to draw a triangle —it is needed only at depth 0! (3) The most difficult part may be finding the height of the triangle with side length s . Knowing that the triangle is an equilateral triangle, you can make use of the pythagorean theorem to figure this out. Using h for the height, you should be able to visualize a triangle that is $1/2$ of the equilateral triangle, with side lengths $s, s/2.0$, and h . Solve the formula $s^{**2} = (s/2)^{**2} + h^{**2}$ for h .

3. Sierpinski carpet. To the right are three Sierpinski carpets of depth 0, 1, and 2. Here's how you draw them: (0) Draw a black filled-in square of side length s .



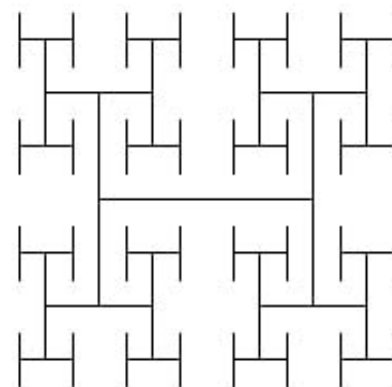
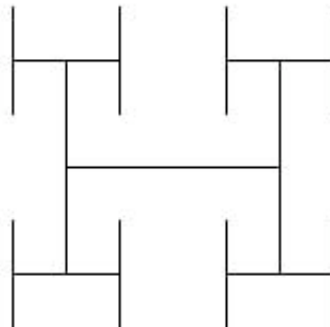
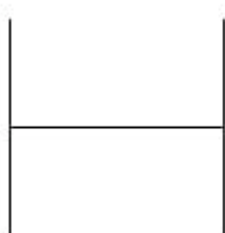
(1) To change it into a Sierpinski carpet of depth 0, *don't do anything*.



(2) To change it into a Sierpinski carpet of depth d ($d > 0$), think of the square of size s as a grid of 9 black squares of size $s/3$. Make the middle square white. In each of the other 8 black squares of size $s/3$, draw a Sierpinski carpet of depth $d-1$.

Here are some hints. (1) You can write the Sierpinski procedures with (at least) two parameters (x, y) that give the position of the top left point of the carpet to draw —yes, work with the top-left point as defining where the square is. Or, you can let the turtle indicate this position. It is up to you. (2) Turtle procedure `fillRect(w, h)` can be used to fill a square. However, the turtle's position gives the *center* of the square, not its top-left position. So, before you can call `fillRect`, you have to move the turtle to the middle of the square. It may be best to write your own procedure `fillSquare(s)`, which will draw a square of length s with its top-left position given by the turtle —this procedure will call `fillRect`.

4. H-trees. To the right are three H-trees of size s and depths 0, 1, and 2. Here's how you draw them:



(1) Draw an H, with all three lines being of length s .

(2) If $d > 0$, draw four H-trees of size $s/2$ and depth $d-1$. The centers of the four H-trees are at the top and bottom of the two vertical lines drawn in step (1).

H-trees are useful in designing microprocessor chips. The lines are wires that connect circuit components in a tree of interconnections, without wires crossing.

Here are some hints. (1) We suggest having as parameters of your procedures the center (x,y) of the H-tree to be created, the depth d , and the length s of each line in the H-tree. Draw the lines drawn using procedure `jumpTo` (to move the turtle) and `moveAhead` (to actually draw the line).

What to submit. Put a comment at the top of `A4.java` that contains the following information.

1. your name and netid;
2. Your information from task 2;
3. The name of your public recursive procedure;
4. What you thought of this assignment (an integer in 1..10, with 10 being "outstanding"; you can give a comment as well); and
5. The time you spent on this assignment.

Make sure class `A5` is indented properly. Submit file `A5.java` on the CMS.