Solutions to the Review Problems for CS111 EXAM 1

October 12, 2007

October 13 Corrections: (1) The occurrence of "point" on page 7 has been changed to "location"; (2) In the JEM on p. 11, the object reference labeled RW has been changed to the label RRW.

The first CS111 exam will be held in class on Friday, October 19. The exam is open notes: you may refer to any handouts, your notes, and your assignments, but you may not refer to anyone else's materials. You may not use a computer during the exam.

The exam will cover material from Lectures 1–9, Labs 1–5, and Problem Sets 1–4. This includes material through conditionals and booleans. Recursion will *not* be covered on the exam.

This handout includes some problems adapted from previous exams that you may find helpful in studying for the exam. These problems are not necessarily indicative of the kinds of problems you may be given on your exam or the length of your exam, but they do cover much of the material you are expected to know for the exam.

Solutions to these problems have been posted. You will learn more if you refrain from consulting them until you have solved the problems on your own.

Problem 1: Buggle World Execution

Consider the two Java classes in Fig. 1.

```
public class DoItWorld extends BuggleWorld {

  public void run () {
    DoItBuggle dewey = new DoItBuggle();    // run statement 1
    int n = 5;                              // run statement 2
    dewey.setPosition(new Location(n,n-2)); // run statement 3 *
    dewey.brushUp();                        // run statement 4
    dewey.doit(Color.green, n-1);           // run statement 5 *
    dewey.doit(Color.blue, n+1);            // run statement 6 *
    dewey.forward();                        // run statement 7
    dewey.brushDown();                      // run statement 8
    dewey.forward(3);                       // run statement 9 *
  }
}

class DoItBuggle extends Buggle {

  public void doit (Color c, int n) {
    Color oldColor = this.getColor();
    this.setColor(c);
    this.forward(n);
    this.brushDown();
    this.backward(n-2);
    this.brushUp();
    this.backward(2);
    this.left();
    this.setColor(oldColor);
  }

}
```

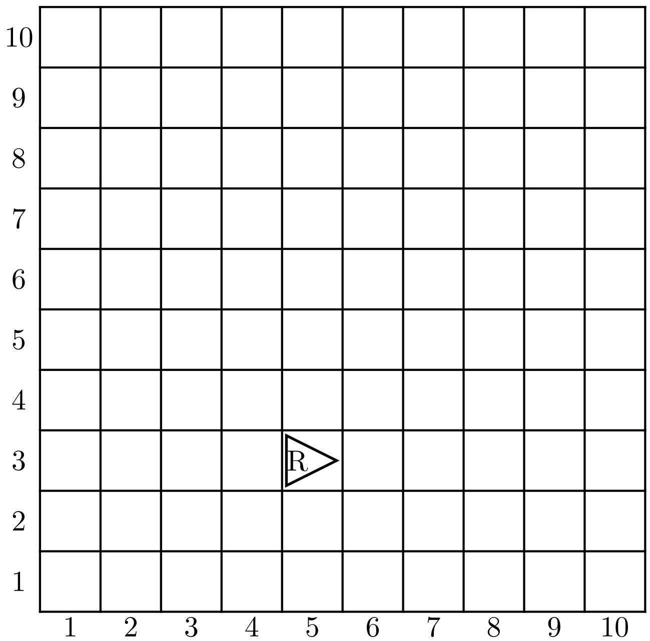
Figure 1: Two Java classes.

Suppose that the `run()` method is invoked on an instance of `DoItWorld` which has a 10×10 grid of cells. In the four grids on the following page, show the state of the grid directly *after* the execution of each of the statements in the `run()` method body marked with a `*`.

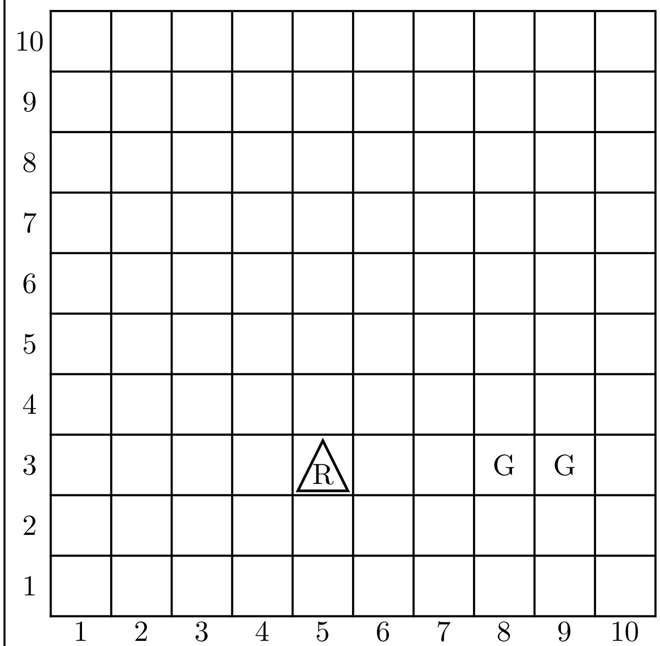
In each grid, you should show the following:

1. Draw buggle `dewey` as a triangle "pointing" in the direction that the buggle is facing.
2. Indicate the current color of the buggle by putting the *first letter* of the color name inside the triangle (e.g. `B` for blue, `G` for green, etc.).
3. Indicate the color of each non-white grid cell by putting the *first letter* of the color name inside the cell (e.g. `B` for blue, `G` for green, etc.).

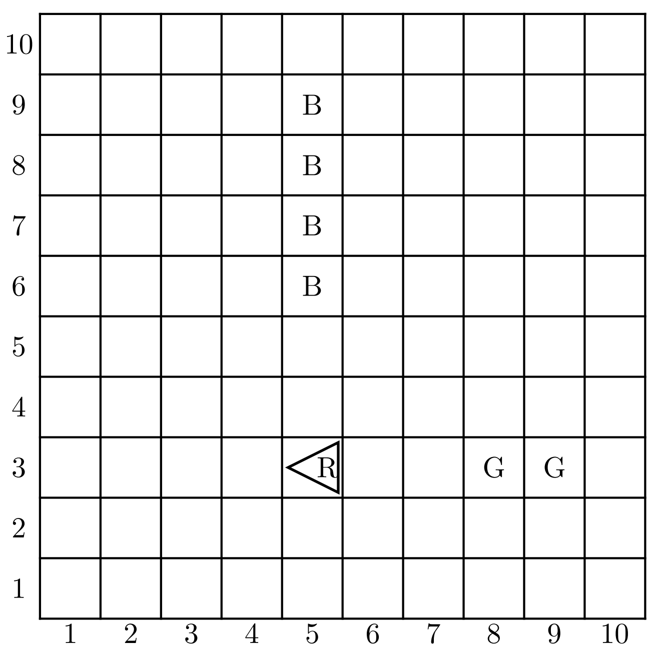
`DoItWorld` grid after the
execution of `run()` statement 3



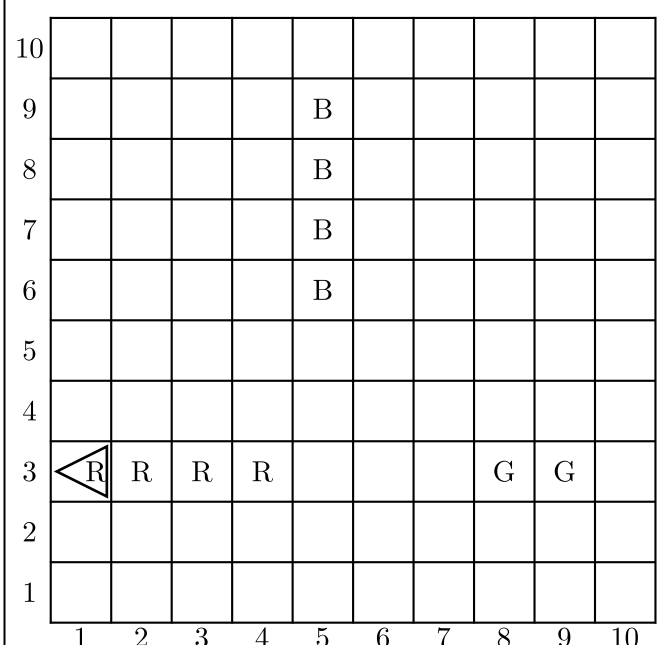
`DoItWorld` grid after the
execution of `run()` statement 5



`DoItWorld` grid after the
execution of `run()` statement 6



`DoItWorld` grid after the
execution of `run()` statement 9



Problem 2: Debugging

The class declarations in Fig. 2 contain (at least) **10 errors** (syntax errors and type errors).

```
public class ExamBuggleWorld extends BuggleWorld {  // line 1
                                                    // line 2
    public void run () {                            // line 3
        Color c = Color.cyan();                     // line 4
        int n = 4                                   // line 5
        ExamBuggle emma = ExamBuggle();             // line 6
        emma.mystery1(c,n);                         // line 7
        emma.mystery1(3,Color.red);                 // line 8
        boolean answer = emma.mystery2();           // line 9
        this.mystery3();                            // line 10
    }                                               // line 11
}                                                   // line 12
                                                    // line 13
class ExamBuggle extends Buggle {                   // line 14
                                                    // line 15
    public void mystery1(Color c, int n1) {         // line 16
        n2 = n1 + 1;                                // line 17
        this.setColor(Color.c);                     // line 18
        forward(n2);                                // line 19
        this.dropBagel();                           // line 20
                                                    // line 21
    public boolean mystery2() {                     // line 22
        this.isOverBagel();                         // line 23
    }                                               // line 24
                                                    // line 25
    public mystery3() {                             // line 26
        this.dropBagel();                           // line 27
    }                                               // line 28
                                                    // line 29
}                                                   // line 30
```

Figure 2:

In the table on the next page, for each of 10 errors in different lines of the above program give:

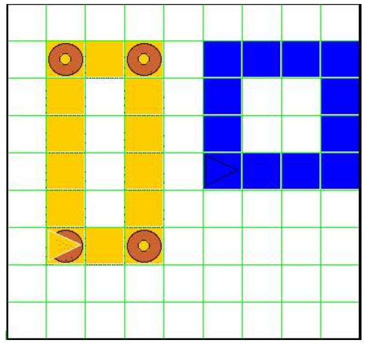
1. the line number of the error,
2. a *brief* description of the error, and
3. a corrected version of the line (i.e., with the error fixed).

You may list the errors in *any* order. You do *not* have to list them in the order in which they occur in the program.

Error #	Line #	Brief description of error	Corrected line
1	4	`Color.cyan()` is not a method invocation	`Color c = Color.cyan;`
2	5	The local variable declaration `int n = 4` is missing a semi-colon at the end	`int n = 4;`
3	6	There is a missing `new` in the constructor method invocation that creates an `ExamBuggle`	`ExamBuggle emma = new ExamBuggle();`
4	8	The two arguments of the instance method invocation `emma.mystery1(3,Color.red)` are in the wrong order	`emma.mystery1(Color.red,3);`
5	10	In `this.mystery3()`, `this` stands for an instance of `ExamBuggleWorld`, which does not understand the `mystery3` message; the recipient should be an instance of `ExamBuggle`	`emma.mystery3();`
6	17	The local variable declaration `n2 = n1 + 1;` is missing a type for the contents of the variable	`int n2 = n1 + 1;`
7	18	`Color.c` attempts to reference a non-existent class constant rather than the parameter `c`	`this.setColor(c);`
8	21	The instance method declaration for `mystery1` is missing a close squiggly brace.	`}`
9	23	The non-`void` method `mystery2` is missing a return statement.	`return this.isOverBagel();`
10	26	The method header for `mystery3` is missing the return type, `void`	`public void mystery3() {`

Problem 3: Buggle Methods

A class of Buggles enjoys doing window treatments. They call themselves `Windowers`. In `WindowWorld`, `wendy` and `winifred` each do a window treatment:



```
public class WindowWorld extends BuggleWorld {

    public void run() {
        Windower wendy = new Windower();          // line  1
        Windower winifred = new Windower();       // line  2

        wendy.setPosition(new Location(2, 3));    // line  3
        wendy.setColor(Color.orange);             // line  4
        wendy.forward(2);                         // line  5
        wendy.dropBagel();                        // line  6
        wendy.left();                             // line  7
        wendy.forward(5);                         // line  8
        wendy.dropBagel();                        // line  9
        wendy.left();                             // line 10
        wendy.forward(2);                         // line 11
        wendy.dropBagel();                        // line 12
        wendy.left();                             // line 13
        wendy.forward(5);                         // line 14
        wendy.dropBagel();                        // line 15
        wendy.left();                             // line 16

        winifred.setPosition(new Location(6, 5)); // line 17
        winifred.setColor(Color.blue);            // line 18
        winifred.forward(3);                      // line 19
        winifred.left();                          // line 20
        winifred.forward(3);                      // line 21
        winifred.left();                          // line 22
        winifred.forward(3);                      // line 23
        winifred.left();                          // line 24
        winifred.forward(3);                      // line 25
        winifred.left();                          // line 26
     }
}
```

a. Assume there is a `Windower` class, which extends `Buggle`. Capture the repeated pattern of code in the `run()` method above by creating a single method named `decorateWindow()` that produces the same window treatments that `wendy` and `winifred` created above in lines 3–16 and 17–26. You may assume that your `decorateWindow()` method is being defined in the `Windower` class. Your method should take 5 parameters that provide the following information:

- a location specifying the position of the window's lower left corner,
- color of the window,
- width of the window (number of cells),
- height of the window (number of cells),
- and a boolean value that says whether the window corners should be decorated with bagels.

Assume an infinite grid, i.e., you don't have to worry about whether your windows will fit in the `BuggleWorld` grid.

answer:

```
public void decorateWindow(Location startPos, Color c, int width,
                           int height, boolean bagelInCorners) {
    setPosition(startPos);
    setColor(c);
    forward(width - 1);  // Need -1 to convert between cells and steps forward
    if (bagelInCorners) {dropBagel();}
    left();
    forward(height - 1); // Need -1 to convert between cells and steps forward
    if (bagelInCorners) {dropBagel();}
    left();
    forward(width - 1);  // Need -1 to convert between cells and steps forward
    if (bagelInCorners) {dropBagel();}
    left();
    forward(height - 1); // Need -1 to convert between cells and steps forward
    if (bagelInCorners) {dropBagel();}
    left();
}
```

We can make this solution more compact by factoring out repeated parts of this code using the following `windowSide` helper method:

```
private void windowSide(int length, boolean bagelInCorners) {
     forward(length - 1); // Need -1 to convert between cells and steps forward
     if (bagelInCorners) {dropBagel();}
     left();
}

public void decorateWindow(Location startPos, Color c, int width,
                           int height, boolean bagelInCorners) {
    setPosition(startPos);
    setColor(c);
    windowSide(width,bagelInCorners);
    windowSide(height,bagelInCorners);
    windowSide(width,bagelInCorners);
    windowSide(height,bagelInCorners);
}
```

b. Below, write the two invocations of your `decorateWindow()` method that will replace lines 3–16 and lines 17–26 in the `run()` method:

- *invocation to replace lines 3–16:*
  answer:

  ```
  wendy.decorateWindow(new Location(2, 3), Color.orange, 3, 6, true);
  ```

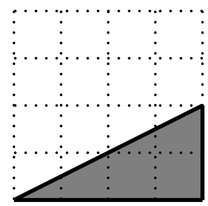
- *invocation to replace lines 17–26:*
  answer:

  ```
  winifred.decorateWindow(new Location(6, 5), Color.blue, 4, 4, false);
  ```

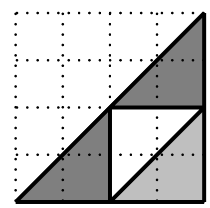
Problem 4: A Picture Method

Suppose that `TriangleWorld` is a subclass of `PictureWorld` that supplies you with a method named `wedge` with the following contract:

> `public Picture wedge (Color w)`
> Returns a picture of a black-bordered wedge of color `w`, as shown to the right. (The dotted lines indicate the grid of the unit square, and are *not* part of the picture.)



At the bottom of this page, your task is to write a method named `threeTriangles` that takes two color parameters and returns the picture to the right, which contains three black-bordered isosceles triangles: the lower-left and upper-right ones with a color specified by the first parameter and the lower-right one with the color specified by the second parameter. You may assume that the `threeTriangles` method is defined within the `TriangleWorld` class, and so may use the `wedge` method in addition to the methods in the `PictureWorld` contract (e.g., `empty`, `clockwise90`, `flipDiagonally`, `beside`, etc.). You must *not* use the `Poly` class for constructing polygons. You must *not* use `fourPics` or any methods (other than `wedge`) not defined in the `PictureWorld` contract.



Partial credit will be awarded for writing a correct skeleton of the `threeTriangles` method and for getting *some* of the triangles in the correct positions with the correct colors.

Hints: (1) Each of the isosceles triangles should be an appropriately transformed wedge picture; (2) You may define local variables of type `Picture` within your method; (3) *Think carefully* — the problem is trickier than it might first seem.

Put your definition of the `threeTriangles` *method here.*

answer:

```
// SOLUTION 1: Uses local Picture variables.
public Picture threeTriangles (Color c1, Color c2) {
  Picture LLiso = beside(wedge(c1), empty()); // Lower-left triangle in color 1
  Picture LRiso = beside(empty(),wedge(c2)); // Lower-right triangle in color 2
  Picture URiso = clockwise180(flipDiagonally(LLiso));
                  // Upper-right triangle in color 1
  return overlay(LLiso, overlay(LRiso, URiso));
}

// SOLUTION 2: Does not use local Picture variables.
public Picture threeTriangles (Color c1, Color c2) {
  return overlay(// Upper-right triangle in color 1
                 clockwise180(flipDiagonally(beside(wedge(c1), empty()))),
                 overlay(// Lower-left triangle in color 1
                         beside(wedge(c1), empty()),
                         // Lower-right triangle in color 2
                         beside(empty(),wedge(c2))));
}
```

Problem 5: Booleans and Conditionals

a. Bud Lojack has written the following method in a rather unclear programming style:

```
public boolean isColdAndHeadingNorth () {
    if (getColor().equals(Color.blue)) {
        if (getHeading().equals(Direction.NORTH)) {
          return true;
        } else {
          return false;
        }
    } else if (!getColor().equals(Color.blue)) {
      return false;
    } else if (!getHeading().equals(Direction.NORTH)) {
      return false;
    } else {
      return true;
    }
}
```

Rewrite Bud's method in a much clearer style.

answer:

The second test expression, `!getColor().equals(Color.blue)`, is only evaluated if the first test expression, `getColor().equals(Color.blue)`, evaluates to `false`. But this means that `!getColor().equals(Color.blue)` is equivalent to `!false` or `true`. So the method can be simplified to:

```
public boolean isColdAndHeadingNorth () {
    if (getColor().equals(Color.blue)) {
        if (getHeading().equals(Direction.NORTH)) {
          return true;
        } else {
          return false;
        }
    } else if (true) {
      return false;
    } else if (!getHeading().equals(Direction.NORTH)) {
      return false;
    } else {
      return true;
    }
}
```

The statement `if (true)` {*S1*} `else` {*S2*}; can always be replaced by *S1*, so the method can be simplified further to:

```
public boolean isColdAndHeadingNorth () {
    if (getColor().equals(Color.blue)) {
        if (getHeading().equals(Direction.NORTH)) {
          return true;
        } else {
          return false;
        }
    } else {
      return false;
    }
}
```

The pattern `if (E) {return true;} else {return false;}` can always be replaced by `return E;`, so we can simplify further to yield:

```
public boolean isColdAndHeadingNorth () {
    if (getColor().equals(Color.blue)) {
        return getHeading().equals(Direction.NORTH);
    } else {
      return false;
    }
}
```

Finally, the pattern `if (E1) {return E2;} else {return false;}` is equivalent to `return E1 && E2;`, so the original method can be simplified to:

```
public boolean isColdAndHeadingNorth () {
    return getColor().equals(Color.blue)
           && getHeading().equals(Direction.NORTH);
}
```

b. Define a `Buggle` method named `isBoxedIn()` that has no parameters and returns `true` if a buggle is in a cell surrounded by walls on all four sides, and otherwise returns `false`. The final state of the buggle when `isBoxedIn()` returns should be the same as the state of the buggle when `isBoxedIn()` is invoked. You may not use recursion or iteration in your solution, but you may define auxiliary methods if you wish.

answer: There are many different ways to define `isBoxedIn()`. Here we look at a few approaches.

One approach that is easy to read but is not particularly efficient is to use a separate predicate for each of the four positions:

```
public boolean isBoxedIn() {
  return isFacingWall() && isWallToLeft() && isWallInBack() && isWallToRight();
}

public boolean isWallToLeft() {
  left();
  boolean result = isFacingWall();
  right();
  return result;
}

public boolean isWallInBack() {
  left();
  boolean result = isWallToLeft();
  right();
  return result;
}

public boolean isWallToRight() {
  left();
  boolean result = isWallInBack();
  right();
  return result;
}
```

Note that `isWallToRight()` actually turns leftward three times, and could be made more efficient by turning right once instead:

```
public boolean isWallToRight() {
  right();
  boolean result = isFacingWall();
  left();
  return result;
}
```

Even so, the buggle repeats a lot of turning in the helper predicates. The repeated turning can be eliminated by performing all tests within `isBoxedIn()` itself. Although the result is more efficient, it is rather difficult to read and write:

```
public boolean isBoxedIn() {
  if (!isFacingWall()) { // No wall in front
    return false;
  } else {
    left(); // Check left wall
    if (!isFacingWall()) { // No wall to left
      right(); // Return to initial heading before return
      return false;
    } else {
      left(); // Check back wall
      if (!isFacingWall()) { // No wall in back
        right();
        right(); // Return to initial heading before return
        return false;
      } else {
        left(); // Check right wall
        if (!isFacingWall()) { // No wall to right
          left(); // Return to initial heading before return
                  // (three rights is a left)
          return false;
        } else { // Surrounded by four walls
          left(); // Return to initial heading before return.
          return true;
        }
      }
    }
  }
}
```

A more compact way to check all four sides is to maintain the result in a `boolean` variable (here named `result`) that is updated at every wall. This is simple to read and write, but is not as efficient as the above approach because it continues to visit all headings even after finding a missing wall.

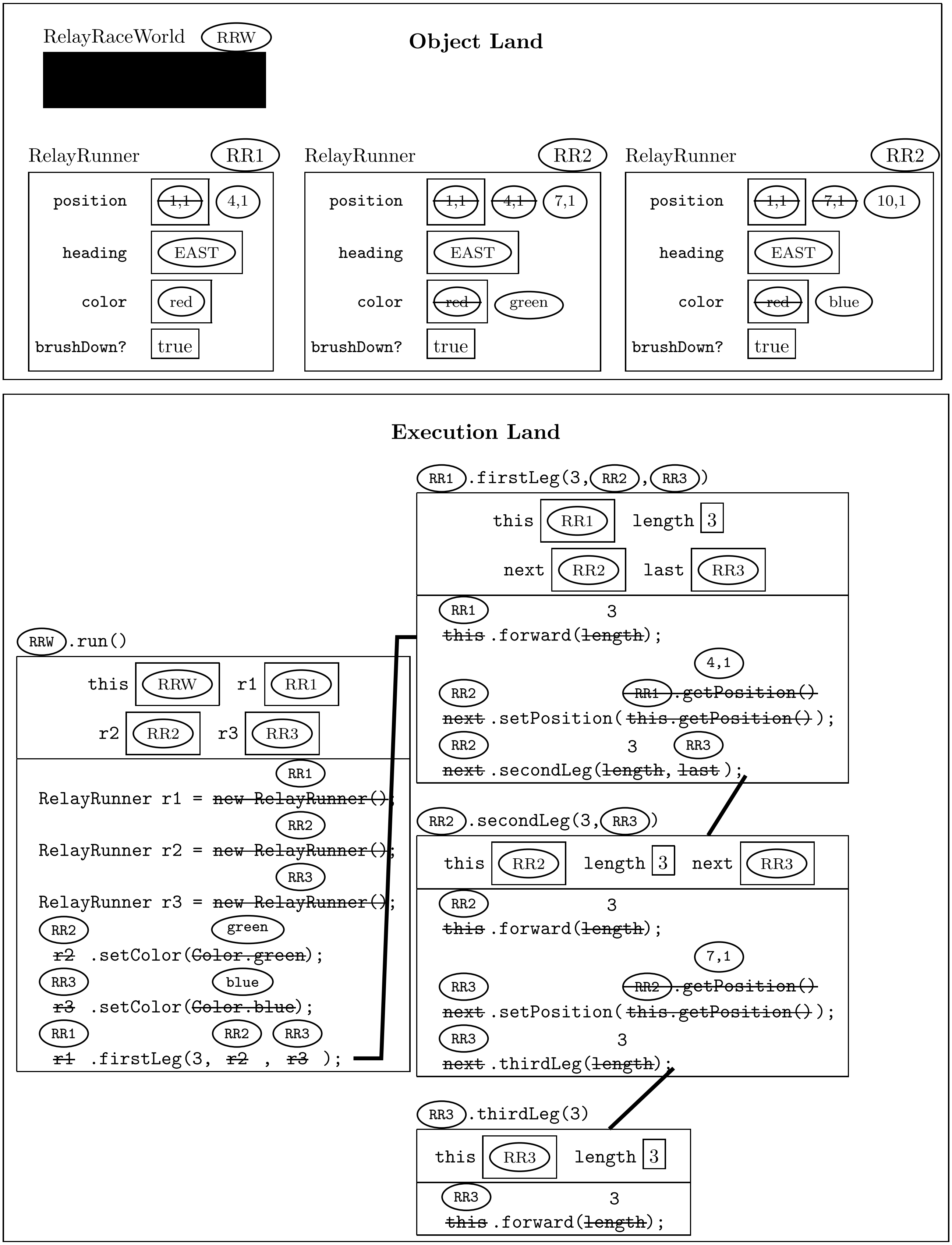
```
public boolean isBoxedIn() {
  boolean result = isFacingWall(); // Check front wall
  left();
  result = result && isFacingWall(); // Check left wall
  left();
  result = result && isFacingWall(); // Check back wall
  left();
  result = result && isFacingWall(); // Check right wall
  left();                            // Return to facing front wall
  return result:
}
```

Problem 6: Java Execution Model in BuggleWorld

Consider the following two class definitions:

```
public class RelayRaceWorld extends BuggleWorld {

    public void run() {
        RelayRunner r1 = new RelayRunner();
        RelayRunner r2 = new RelayRunner();
        RelayRunner r3 = new RelayRunner();

        r2.setColor(Color.green);
        r3.setColor(Color.blue);
        r1.firstLeg(3, r2,r3);
    }
}

class RelayRunner extends Buggle {

    public void firstLeg(int length, RelayRunner next, RelayRunner last) {
        this.forward(length);
        next.setPosition(this.getPosition());
        next.secondLeg(length, last);
    }

    public void secondLeg(int length, RelayRunner next) {
        this.forward(length);
        next.setPosition(this.getPosition());
        next.thirdLeg(length);
    }

    public void thirdLeg(int length) {
        this.forward(length);
    }
}
```

The final JEM is shown on the next page. This figure shows how each expression is evaluated to produce a value. You were asked only to show the final state of the JEM, so you were not required to show all this, however, it is very useful to do your JEMs this way so you can keep track of the computation. This problem tested your knowledge of parameters, variables, and method invocation in a very detailed way.

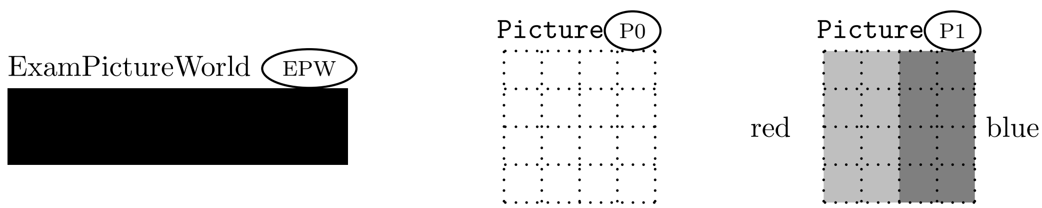

Object Land
RelayRaceWorld RRW
RelayRunner RR1
position 1,1 4,1
heading EAST
color red
brushDown? true
RelayRunner RR2
position 1,1 4,1 7,1
heading EAST
color red green
brushDown? true
RelayRunner RR2
position 1,1 7,1 10,1
heading EAST
color red blue
brushDown? true
Execution Land
RRW .run()
this RRW r1 RR1
r2 RR2 r3 RR3
RelayRunner r1 = new RelayRunner(); RR1
RelayRunner r2 = new RelayRunner(); RR2
RelayRunner r3 = new RelayRunner(); RR3
r2 .setColor(Color.green); RR2 green
r3 .setColor(Color.blue); RR3 blue
r1 .firstLeg(3, r2 , r3); RR1 RR2 RR3
RR1 .firstLeg(3, RR2 , RR3)
this RR1 length 3
next RR2 last RR3
this .forward(length); RR1 3
next .setPosition(this.getPosition()); RR2 RR1 .getPosition() 4,1
next .secondLeg(length, last); RR2 3 RR3
RR2 .secondLeg(3, RR3)
this RR2 length 3 next RR3
this .forward(length); RR2 3
next .setPosition(this.getPosition()); RR3 RR2 .getPosition() 7,1
next .thirdLeg(length); RR3 3
RR3 .thirdLeg(3)
this RR3 length 3
this .forward(length); RR3 3

Problem 7: Java Execution Model in PictureWorld

```
public class ExamPictureWorld extends PictureWorld {

    public Picture meth1 (Picture a) {
        Picture b = beside(a, empty());
        Picture c = meth2(b);
        return overlay(c, b);
    }

    public Picture meth2 (Picture a) {
        Picture b = above(a, empty(), 0.75);
        return clockwise90(b);
    }
}
```

Figure 3: A sublcass of `PictureWorld`.

Consider the subclass of `PictureWorld` shown in Fig. 3. Supose that: (EPW) is an instance of `ExamPictureWorld`, (P0) is a `Picture` instance denoting the empty picture, (P1) is a `Picture` instance denoting the rightmost picture below:



The dashed grid lines are *not* part of the pictures. They indicate coordinates within pictures. The colors names are *not* part of picture (P1). They indicate the color of the two rectangles. Each of the two rectangles is a solid color *without* any separately colored border.

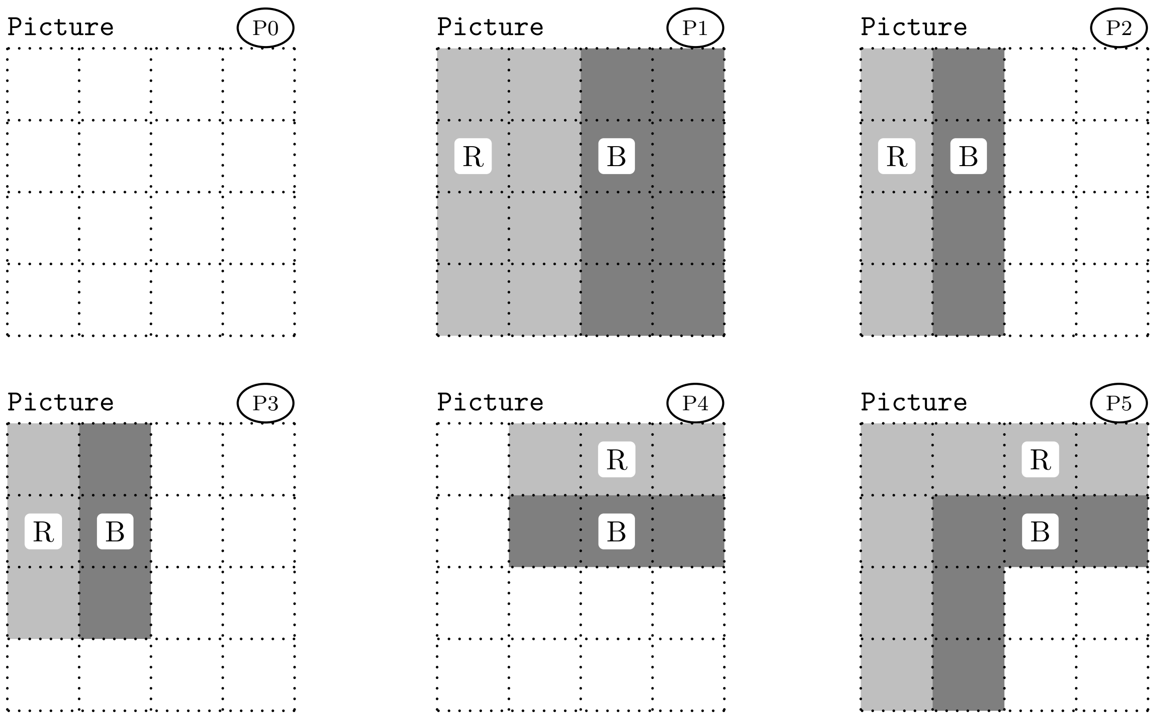
On the next page, you should flesh out the Java Execution Model for the method invocation (EPW)`.meth1(`(P1)`)`. In the area labeled **Execution Land**, you should flesh out the contents of the execution frame for this method invocation, as well as show the execution frame for the invocation of `meth2()`.

In the area labeled **Object Land** are the skeletons for the six `Picture` instances that are used during the execution. The pictures labeled (P0) and (P1) have already been drawn for you; you should draw pictures for the four new `Picture` instances (P2), (P3), (P4), and (P5) that will be created during the execution of (EPW)`.meth1(`(P1)`)`. In each picture, you should label red areas with the letter `R` and blue areas with the letter `B`. All other areas are presumed to be "clear".

Object Land

ExamPictureWorld EPW

[redacted]



Execution Land