CS111 EXAM 1
Spring Semester 2002
Thursday, February 28/Friday, March 1

YOUR NAME: Exam 1 Solutions

This exam has **five** problems. Each problem has several parts. The number of points for each problem is shown in square brackets next to the problem. There are 100 total points on the exam.

Write all your answers on the exam itself. Whenever possible, show your work so that partial credit can be awarded.

The exam is open book. You may refer to your notes, handouts from this semester (including the Fall'01 CS111 text), problem sets and solutions, and whatever additional materials would be helpful. **However, you may *not* use another person's notes, or any materials from previous semesters** (excluding the Fall'01 CS111 text).

By the Honor Code, you are not allowed to talk to anyone about the details of this exam before or after taking it, until after all members of the class have taken the exam.

Please keep in mind the following tips:

- *Briefly skim the entire exam before starting any problem.*
- *Work first on the problems on which you feel most confident.* You do **not** have to do the problems in order. All problems are independent from each other.
- *Try to do something on every problem so that you can potentially receive partial credit.* A guess is better than no answer at all!
- *Allocate your time carefully.* If you are taking too long on a problem, wrap it up and move on.
- *If you finish early, go back and check your answers.*

GOOD SKILL!

Problem	**Topic**	**Points**	**Score**
1	Java Syntax	15	
2	BuggleWorld Execution	20	
3	Writing Methods	25	
4	Invocation Trees	20	
5	Debugging	20	
Total		100	

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(except for this self-referential sentence).

Problem 1 [15]: Java Syntax
For each of the following Java code fragments, indicate:

1. whether the code fragment is an expression or a statement;
2. the kind of expression or statement;
3. if the code fragment is an expression, indicate the type of value to which it evaluates. (You need not indicate anything for a statement).

In the code fragments, assume that `bob` is an instance of the `Buggle` class and that `StringChooser` is the class studied in Lab 1. As examples, parts **a** and **b** are done for you.

Part	Code Fragment	Expression or Statement	Kind of Expression or Statement	Type (for expressions only)
a	`new Buggle()`	expression	constructor method invocation	`Buggle`
a	`String hi = "Hello";`	statement	local variable declaration	N/A (not applicable)
c	`bob.getPosition()`	expression	instance method invocation	`Point`
d	`bob.setColor(Color.blue);`	statement	instance method invocation	N/A (not applicable)
e	`bob`	expression	variable reference	`Buggle`
f	`Direction.EAST`	expression	class variable (class constant)	`Direction`
g	`StringChooser.chooseLine("nouns.txt")`	expression	class method invocation	`String`

Problem 2 [20]: 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 Point(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 *
  }
}

public 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);
  }

}
```

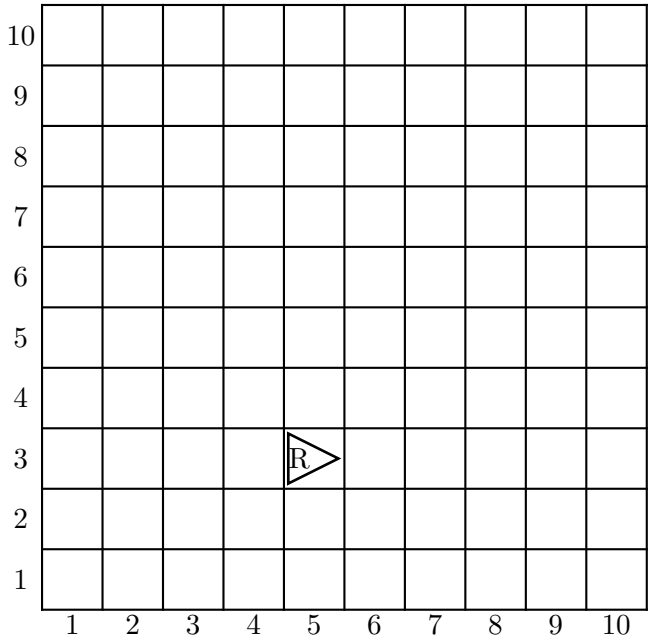
Figure 1: Two Java classes.

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 `*`.

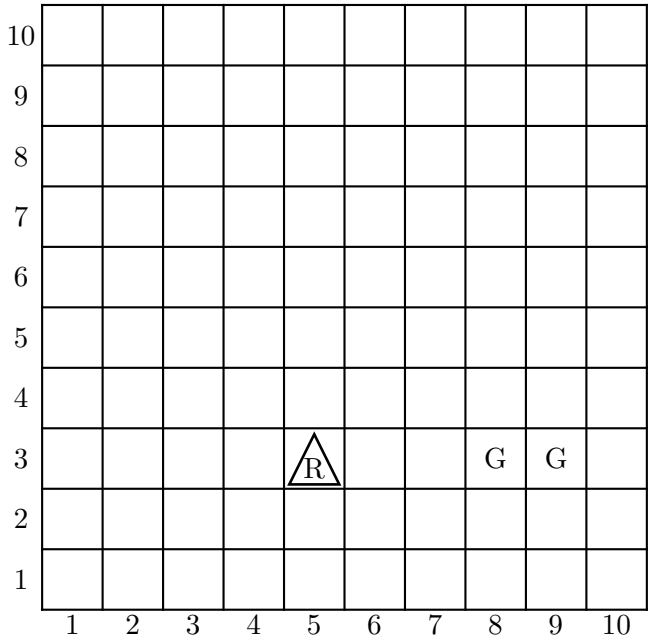
In each grid, you should show the following:

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.).

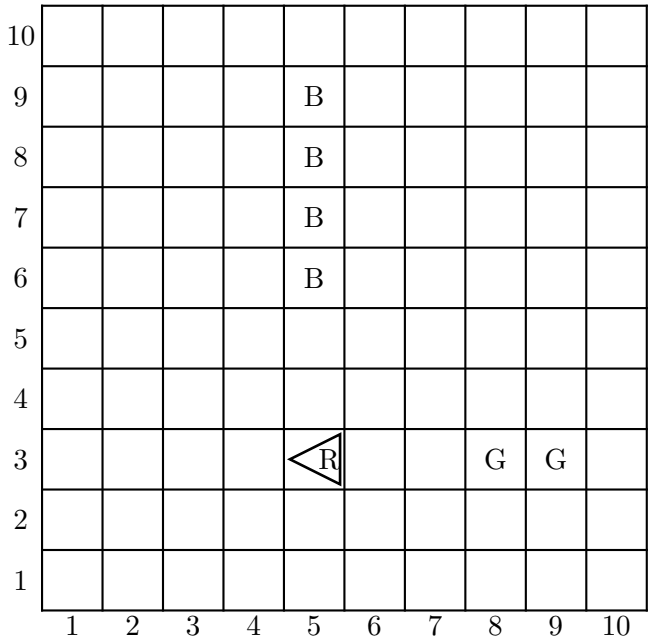
`DoItWorld` grid after the execution of `run()` statement 3



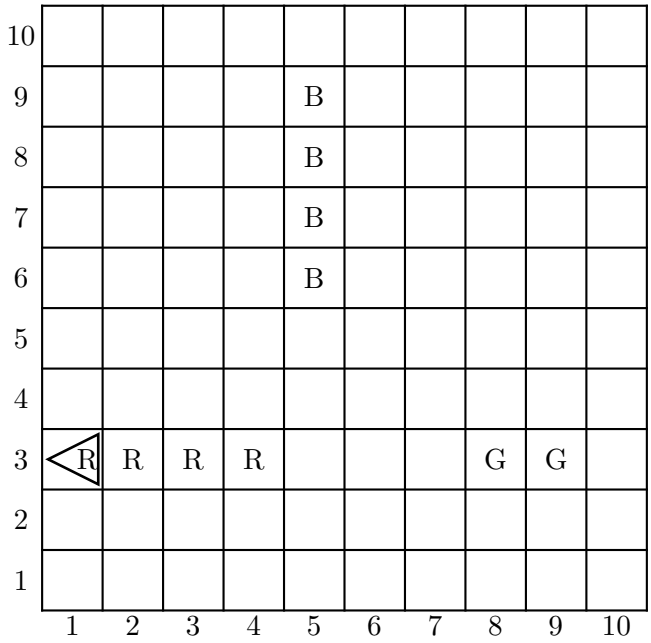
`DoItWorld` grid after the execution of `run()` statement 5



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

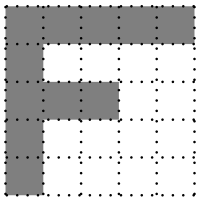


`DoItWorld` grid after the execution of `run()` statement 9



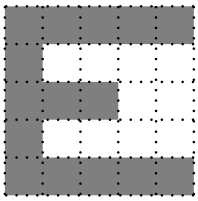
Problem 3 [25]: Writing Methods

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

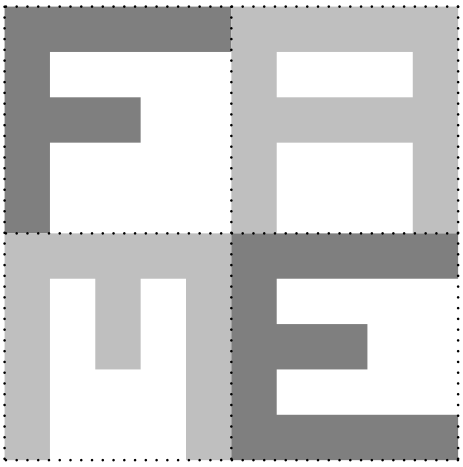
> `public Picture f (Color c)`
> Returns a picture of the letter "F" in color `c`, as shown below.
>
> 
>
> The dotted lines indicate the boundaries of the unit square, and are *not* part of the picture. The letter is a solid color `c` and does *not* have any boundary line drawn in a separate color.

On the next page your task is to write *two* methods:

1. A method named `e` that takes a single color parameter and returns the following picture of the letter "E" in that color.

2. A method named `fame` that takes two color parameters and returns the following picture:

   The "F" and "E" have the color of the first parameter, while the "A" and "M" have the color of the second parameter.

You may assume that both methods are defined within the `LetterWorld` class, and so may use the `f` method in addition to the methods in the `PictureWorld` contract (e.g., `clockwise90`, `flipDiagonally`, `above`, etc.). You may assume that the `fourPics`, `fourSame`, and `fourOverlay` methods defined in class and on the problem sets are also available. Your `fame` method may use your `e` method, which you may assume works correctly (even if your definition of `e` is actually incorrect or missing).

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

Here is one solution, which does not name any intermediate pictures:

```
// The letter "E" can be formed by overlaying an "F"
// and a copy of "F" flipped across the horizontal axis.
public void Picture e (Color c) {
  return overlay(f(c), flipHorizontally(f(c)));
}
```

Here is another solution, which names some intermediate pictures:

```
public void Picture e (Color c) {
  Public picture f_c = f(c);
  Public picture f_c_flipH = flipHorizontally(f_c);
  return overlay(f_c, f_c_flipH);
}
```

A surprising number of students tried to draw the "E" shape with buggles. As we have seen on problem sets, buggles can indeed draw letters in `BuggleWorld`*, but there is no way for a buggle to somehow turn what it has drawn into a* `Picture` *instance within* `PictureWorld`*.*

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

Here is one solution, which does not name any intermediate pictures:

```
// Create a picture consisting of quadrants "F","A", 'M',"E"
// where "F" and "E" are in color c1 and "A" and 'M" are in color c2
public void Picture fame (Color c1, Color c2) {
  return fourPics(f(c1),                          // F
                  overlay(f(c2),
                          flipVertically(f(c2))), // make A out of 2 Fs
                  clockwise90(e(c2)),             // M is rotated E
                  e(c1));                         // E
}
```

Here is another solution, which names some intermediate pictures:

```
public void Picture fame (Color c1, Color c2) {
  Picture f_c1 = f(c1);
  Picture f_c2 = f(c2);
  Picture a_c2 = overlay(f_c2, flipVertically(f_c2));
  Picture m_c2 = clockwise90(e(c2));
  Picture e_c1 = e(c1);
  return fourPics(f_c1, a_c2, m_c2, e_c1); }
```

Problem 4 [20]: Invocation Trees

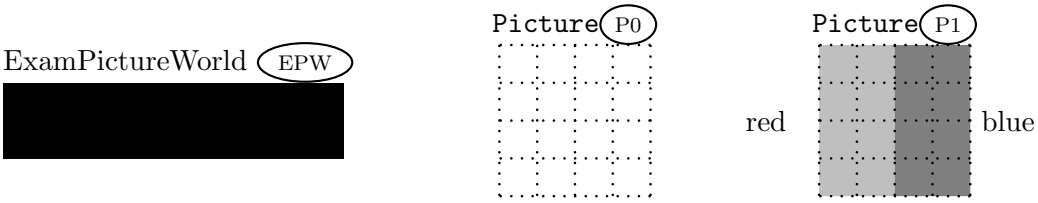
```
public class ExamPictureWorld extends PictureWorld {

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

    public Picture meth2 (Picture c) {
        return clockwise90(above(c, empty(), 0.75));
    }
}
```

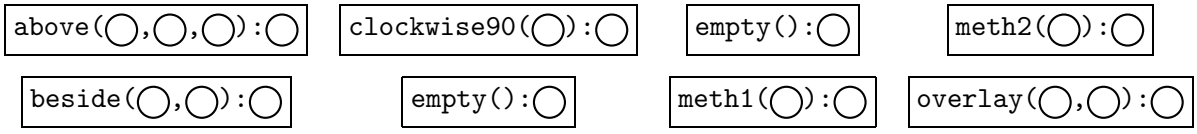
Figure 2: A sublcass of `PictureWorld`.

Consider the subclass of `PictureWorld` shown in Fig. 2. 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.

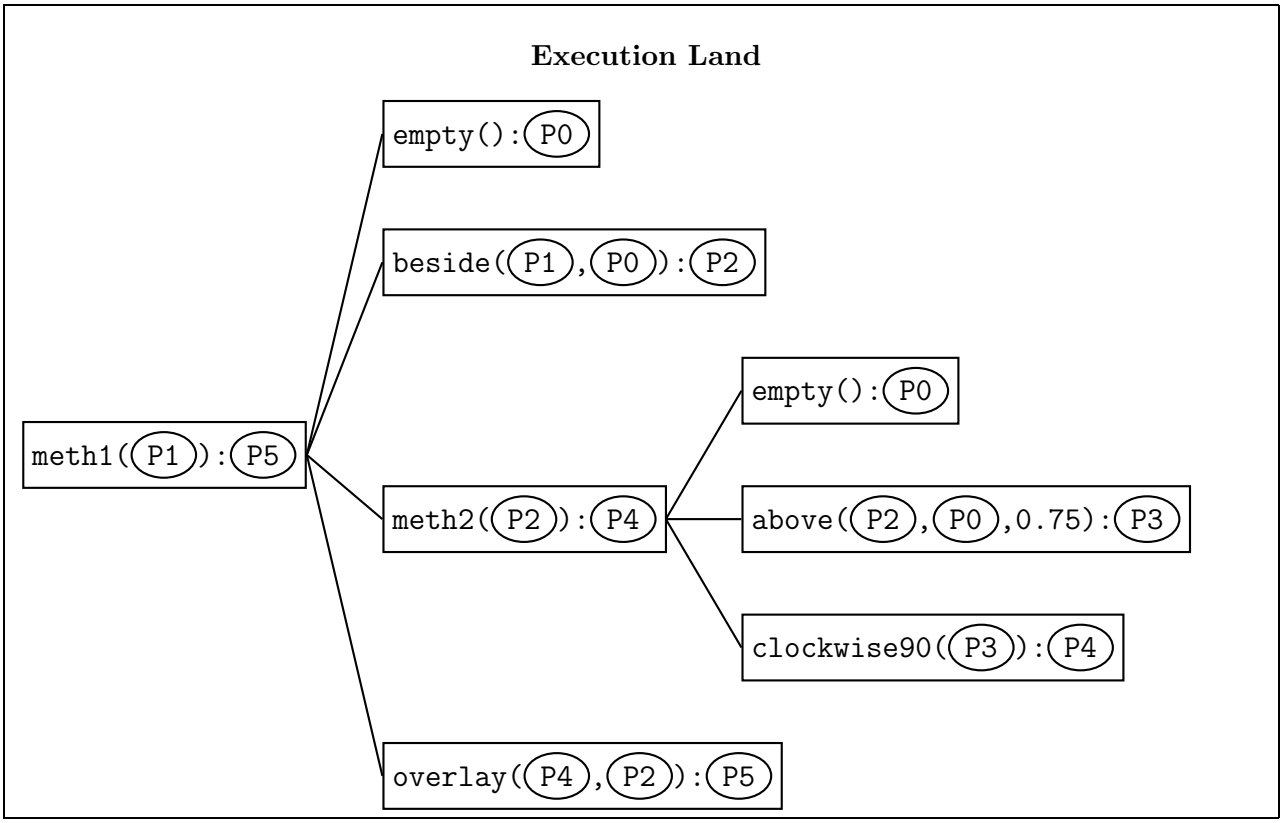
On the next page, you are to draw an invocation tree that models the instance method invocation (EPW).meth1((P1)). In the area labeled **Execution Land**, you should draw an invocation tree that contains the following eight nodes, arranged appropriately into a tree. You should use each node exactly once.

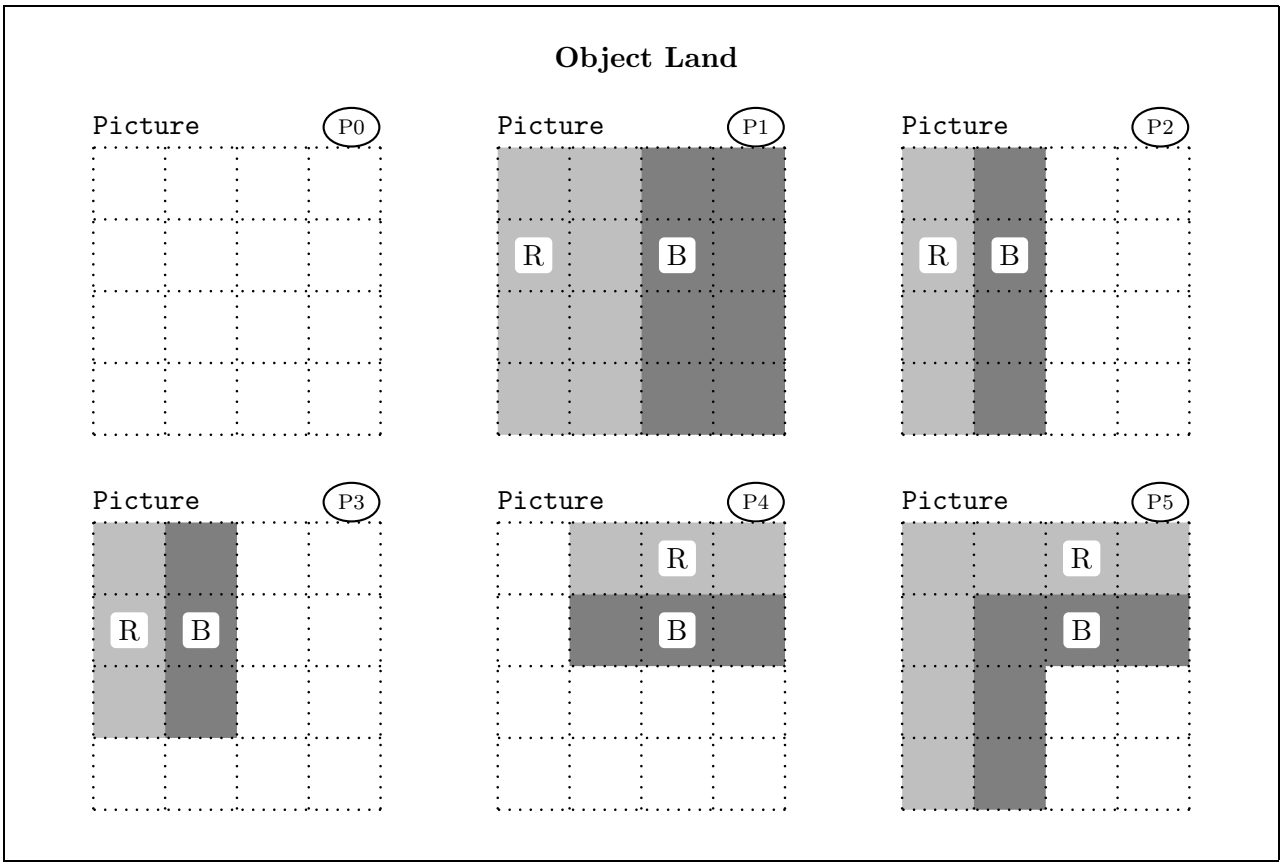


The empty circles in the nodes are skeletons for object references that you should fill in with one of the labels P0, P1, P2, P3, P4, or P5 to refer to the appropriate Picture instance in Object Land (see below). A circle enclosed by parentheses is a reference to an actual argument of the method invocation. A circle appearing after a colon is a reference to the result of the method invocation. The root of the invocation tree is the `meth1()` node, which has already been drawn for you, and whose actual argument has been filled in (you need to fill in its result).

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 the pictures for (P2), (P3), (P4), and (P5). 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 white.

(Note: for simplicity, the receiver object (EPW) for each of the method invocations has been omitted. This instance has also been omitted from Object Land.)


Execution Land
empty():P0
beside(P1,P0):P2
meth1(P1):P5
empty():P0
meth2(P2):P4
above(P2,P0,0.75):P3
clockwise90(P3):P4
overlay(P4,P2):P5


Object Land
Picture P0
Picture P1
R
B
Picture P2
R
B
Picture P3
R
B
Picture P4
R
B
Picture P5
R
B

Problem 5 [20]: Debugging

The class declarations in Fig. 3 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 3:

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.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()`

Notes:

- *Another (unintended) error was that the wrong symbol (\\) was used to introduce comments in the problem. The correct symbol is* `//`.
- *Some students said there was a missing* `public class ExamBuggle extends Buggle` *on line 14. It turns out that this is not an error, but we did not take off for it because we haven't explained this in class. It turns out that a single Java file can declare only* one `public` *class. If the two class declarations in Fig. 3 were in two separate files, each could be declared* `public`.

THIS IS THE END OF THE EXAM.