

This assignment, including much of the wording of this document, is taken from an assignment from Stanford University, by Professor Eric Roberts. Your task is to write the classic arcade game *Breakout*. You can download our solution as a jar-file application and get a real taste for the game.

Please keep track of the time you spent on this assignment. We will ask for it when it is time to submit.

The assignment is easily within your grasp —as long as you start early, break the problem up into manageable pieces, and program/test incrementally. Below, we discuss stages of implementation and give suggestions for staying on top of the project. If you follow our advice and test each piece thoroughly before proceeding to the next, you should be successful. Our solution is ~335 lines long and has 11–12 methods.

Breakout

The initial configuration of the game *Breakout* is shown above on the right. The colored rectangles in the top part of the screen are bricks, and the slightly larger rectangle at the bottom is the paddle. The paddle is in a fixed position in the vertical dimension; it moves back and forth horizontally across the screen along with the mouse—unless the mouse goes past the edge of the window.

A complete game consists of three turns. On each turn, a ball is launched from the center of the window toward the bottom of the screen at a random angle. The ball bounces off the paddle and the walls of the world, in accordance with the physical principle generally expressed as “the angle of incidence equals the angle of reflection” (it’s easy to implement). The start of a possible trajectory, bouncing off the paddle and then off the right wall—is shown to the right. (The dotted line is there only to show the ball’s path and won’t actually appear on the screen.)

In the second diagram, the ball is about to collide with a brick on the bottom row. When that happens, the ball bounces just as it does on any other collision, but the brick disappears. The third diagram shows the game after that collision and after the player has moved the paddle to put it in line with the oncoming ball.

The play on a turn continues in this way until one of two conditions occurs:

1. The ball hits the lower wall, which means that the player missed it with the paddle. In this case, the turn ends. If the player has a turn left, the next ball is served; otherwise, the game ends in a loss for the player.
2. The last brick is eliminated: the player wins, and the game ends.

Clearing all the bricks in a particular column opens a path to the top wall. When this delightful situation occurs, the ball may bounce back and forth several times between the top wall and the upper line of bricks without the user having to worry about hitting the ball with the paddle. This condition, a reward for “breaking out”, gives meaning to the name of the game. The fourth diagram on the right shows the situation shortly after the first ball has broken through the wall. The ball goes on to clear several more bricks before it comes back down the open channel.

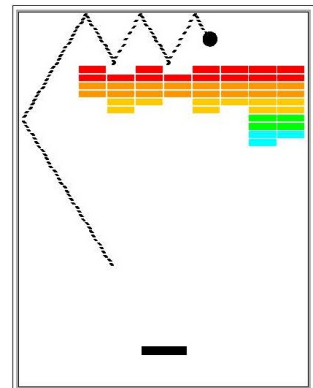
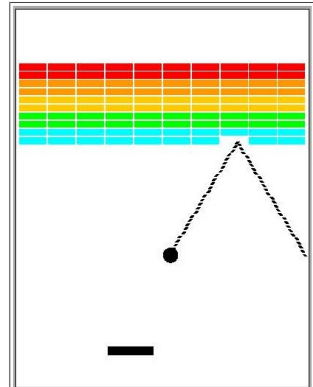
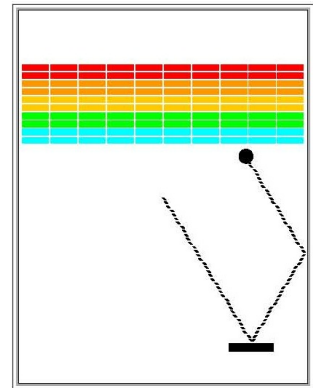
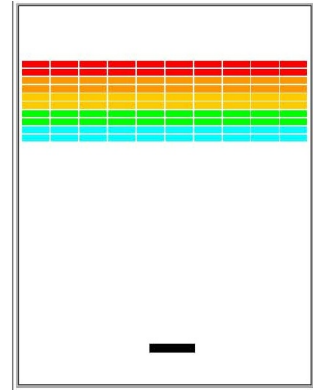
Breaking out is an exciting part of the game, but you don’t have to do anything in your program to make it happen. The game is operating by the same rules it always applies: bouncing off walls, clearing bricks, and obeying the “laws of physics”.

Partners

You may work with one partner. Both of you should do what is necessary on the CMS to form a group several days before the submission deadline. It is dishonest and against the code of academic integrity to split the work so that each does half of the work. You must work together the whole time.

Academic integrity

This assignment is similar to one given in previous offerings of CS1110. *It is a violation of the Code of Academic Integrity for you to be in possession of or to look at code (in any format) for this assignment of anyone in this class or in previous classes of CS1110 or to show another student your program.* Please do not violate the Code; penalties for this will be severe. We will try hard to give you all the help you need for this assignment.



Getting help

Do not spend hours and hours trying to solve a single problem. Get help. Piazza will contain discussions of general issues that arise. Look there before calling/emailing someone.

File Breakout.java

We give you file Breakout.java. A partial skeleton of it appears to the right. The class includes:

- The import statements needed in writing the game.
- Constants that control the game parameters, e.g. the height of a paddle. Your code should use these constants internally so that changing them in your file changes the behavior of your program accordingly.
- A static method `main` that starts the application program, fixes bricks, and sets the window to the appropriate size. Run the program by clicking button Run or by executing this in the interactions pane:

```
java Breakout
```

The acm package

You used this package in A5, so we don't say much about it. Here are API specs for the package: <http://jtf.acm.org/javadoc/student/index.html>. So you can study the package while you are not on the internet, we provide the html files in downloadable form on the course website, but not all the images are included.

Class `Breakout` is a subclass of class `GraphicsProgram`, which is associated with the window on which the graphics takes place. Method `main` creates an instance of the class and then calls method `start` of the instance, which is inherited from `GraphicsProgram`.

`GraphicsProgram` also declares procedure `run`, which is overridden in class `Breakout`. Execution of `start(sizeArgs)` constructs the basic GUI window and then calls procedure `run`. You have to write the body of `run` (and any other methods you need) to initialize the GUI with bricks, paddle, and ball and play the game. You have to write class `Brick`.

An important part of your programming will be to develop new methods whenever you need them, in order to keep each method small and manageable. Your grade will depend partly on the design of your program. As one guideline, points will be deducted for methods that are more than 50 lines long (including the specification).

You must provide a class invariant. You must specify each method precisely and thoroughly. You need not write loop invariants, although doing so will help you. If you show your code to an instructor, TA, or consultant and they see a method that is not specified, they will ask you to go away, fix it, and come back at another time.

What to download

Download file `Breakout.java` from the course website and put it in a new directory. In the same directory, put a copy of directory `acm` that you used for assignment A5.

1. Set up the bricks

The first step is to write the code that puts the various pieces on the playing board. Thus, it probably makes sense to implement procedure `run` as two method calls: one that sets up the game and one that plays it. An important part of the setup consists of creating rows of bricks at the top of the game, which are shown on the next page.

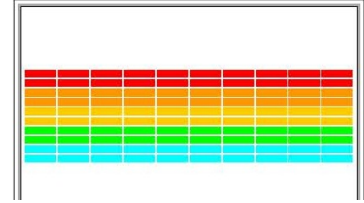
The number, dimensions, and spacing of the bricks, as well as the distance from the top of the window to the first line of bricks, are specified using named constants given in class `Breakout`. The only value you need to compute is the x coordinate of the first column, which should be chosen so that the bricks are centered in the window, with the leftover space divided equally on the left and right sides. Hint: the leftmost brick should be placed at x -

```
import acm.graphics.*;
...
/** The game breakout. Start it by executing
    java Breakout; */
public class Breakout extends GraphicsProgram {
    /** Width of the game display */
    private static final int GAME_WIDTH= 480;
    /** Height of the game display */
    private static final int GAME_HEIGHT= 620;
    /** Width of the paddle */
    private static final int PADDLE_WIDTH= 58;
    /** Height of the paddle */
    private static final int PADDLE_HEIGHT = 11;
    /**Distance of the (...) paddle up from the bottom */
    private static final int PADDLE_OFFSET= 30;
    ...
    /** Run program as an application. ... */
    public static void main(String[] args) {
        String[] sizeArgs= { "width=" + GAME_WIDTH,
                             "height=" + GAME_HEIGHT };
        fixBricks(args);
        new Breakout().start(sizeArgs);
    }
    /** Run the Breakout program. */
    public void run() { ... }
}
```

coordinate `BRICK_SEP_H/2`. The colors of the bricks remain constant for two rows and run in the following sequence: RED, ORANGE, YELLOW, GREEN, CYAN—if there are more than 10 rows, start over with RED, etc.

All objects placed on the playing board are instances of subclasses of abstract class `GObject`. The bricks and paddle are objects of subclass `GRect`.

Complete subclass `Brick` of `GRect` (given at the end of `Breakout.java`) and use objects of class `Brick` for the bricks. The reason for this will be given later. Class `Brick` has no fields and needs only two methods: (1) a constructor for a new brick of a given width and height and (2) a constructor for a new brick at a point (x, y) and of a given width and height. Class `GRect` has similar constructors.



To add `GRect` object `r` (say) to the playing board, call inherited procedure `add(r)`. To begin, you might want to create a single `Brick` object of some position and size and add it to the playing board, just to see what happens. Then think about how you can place the 8 rows of bricks.

You need to fill a `Brick` (which is a `GRect`) with a particular color and also to set its color so that its outline is the same color (instead of black). Look for `GRect` methods to do this. In order to allow the object to be filled with a color, you need to use a procedure call like `rect.setFill(true);`

Here is an *important* point. *Do not use an array or Vector to keep track of the bricks.* Just add the bricks to the playing board as they are created. Do not be concerned about keeping track of them. Later, you will see why you don't need to keep them in an array or Vector.

Here is another important point. Make sure your creation of the rows of bricks works with any number of rows and any number bricks in each row—1, 2, ..., 10, and perhaps more.

Here's a suggestion: Get this part of the program working by 19 November, so that you can produce just the diagram shown above to the right. This will give you considerable confidence that you can get the rest done.

2. Write method `fixBricks`

In checking out the program, to save time, it would be nice to play it with just 3-4 bricks per row and 1-2 rows of bricks. This will let you more quickly see whether the program works correctly when the ball breaks out (gets through to the top of the canvas) and when someone wins or loses. But this would require changing the values of the static constants that give the number of rows and number of bricks in a row. Instead of that, we can use the fact that this is an application and give the application some values when it starts out.

Breakout is an application, so you can call it from the interactions pane. In fact, you can use this in the interactions pane:

```
java Breakout 3 2
```

This is equivalent to writing `Breakout.main(new String[]{"3", "2"});` That is, it calls method `main` with the given `String` array as argument.

Look at method `Breakout.main`. Its first statement calls `fixBricks`. Your task is to write the body of `fixBricks`, following its specification (and the hint given as a comment) carefully. You will then be able to start the program as shown above and have just 3 bricks per row and 2 rows.

Shoot for getting this done by 21 November.

3. Create the paddle

Now create the black paddle. You will need to reference the paddle often, so declare it as a private field of type `GRect`. A public static variable of class `Breakout` gives its vertical position relative to the bottom of the window.

An important point: making the paddle move in response to mouse movements means that something has to be registered as a "listener" to the mouse. We talked about how to do this in general in lecture, but the acm classes handle this a bit differently. **Read the ACM documentation (webpage URL given above) to find out how to make the "appropriate something" in the ACM-package framework listen to the mouse.** *The whole window associated with the `GraphicsProgram` should listen to mouse movement, not the paddle.*

Once you've done that, here's how to make the paddle track the mouse (horizontally only). Declare a procedure like this:

```

/** Move the horizontal middle of the paddle to the x-coordinate of the
    mouse position --but keep the paddle completely on the board. */
public void mouseMoved(MouseEvent e) {
    GPoint p= new GPoint(e.getPoint());
    ...
}

```

So, you are overriding inherited procedure `mouseMoved`. This procedure is called whenever the mouse is moved. Parameter `e` has a function `getPoint`, and the assignment statement we give you in the body stores in `p` the coordinates of the point where the mouse currently is. Replace the three dots by code that changes the `x`-coordinate of the paddle as indicated in the specification, using the `x`-coordinate of point `p`. Be careful that the paddle stays completely on the board even if the mouse moves off the board. Our code for this is 3 lines long; it uses function `Math.min` and `Math.max`.

Try to get this done by 23 November.

4. Create a ball and make it bounce off the walls

You are now past the “setup” phase and into the “play” phase of the game, where a ball is created and moves and bounces appropriately. A ball is just a filled `GOval`. To start, create a ball and put it in the center of the window. You probably want a private field `ball` of type `GOval` to contain the ball, since you will have to refer to it often. Keep in mind that the coordinates of the `GOval` specify the upper left corner and not the center of the ball.

The play phase of the game should contain a loop, each iteration of which (1) moves the ball a bit, (2) changes direction if it hits a wall, and (3) pauses for 10 milliseconds, using `pause(10);`. The program needs to keep track of the velocity of the ball, which consists of its horizontal (`x`) component and its vertical (`y`) component, which you declare as fields like this:

```
private double vx, vy; // give their meanings in a comment!
```

These velocity components represent the change in position that occurs on each time step (each loop iteration).

Initially, the ball should head downward, so use a starting velocity of +3.0 for `vy`. The game would be boring if every ball took the same course, so choose component `vx` randomly. You can read about random numbers in the text, but for now, simply do the following:

1. Declare a field `rgen`, which will serve as a random-number generator:

```
private RandomGenerator rgen= new RandomGenerator();
```

2. Initialize variable `vx` as follows:

```
vx= rgen.nextDouble(1.0, 3.0);
if (!rgen.nextBoolean(0.5)) vx= -vx;
```

This code sets `vx` to be a random **double** in the range 1.0 to 3.0 and then makes it negative half the time.

Your next challenge is to get the ball to bounce off the walls of the playing board, ignoring entirely the paddle and the bricks. To do this, *after* moving the ball one step, by (vx, vy) , do the following. Suppose the ball is going up. Then, if *any part of the ball* has a `y`-coordinate ≤ 0 , the ball has reached the top and its direction has to be changed so that it goes down, by setting `vy` to $-vy$. Check the other three sides in the same fashion. When you have finished this, the ball will bounce around the playing board forever —until you stop it.

You have to figure out whether the ball has reached (or gone over) the top. Remember that the location of a `GOval` is the top-left corner of its bounding box.

Complete this by 28 November.

5. Checking for collisions

Now comes the interesting part. In order to make `Breakout` into a real game, you have to be able to tell when the ball collides with another object in the window. As scientists often do, we make a simplifying assumption and then relax the assumption later. Suppose the ball were a single point (x, y) rather than a circle. The call

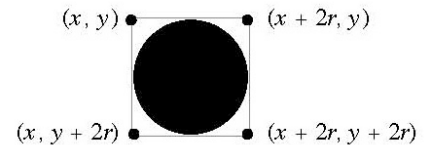
```
getElementAt(x, y)
```

of inherited function `getElementAt` does this: (1) return **null** if no graphical object covers point (x, y) and (2) return (the name on the tab of) the `GObject` that covers point (x, y) , if some `GObject` actually covers the point. (If several `GObjects` cover the point, the one that appears to be in front on the display is returned.)

Suppose `getElementAt` returns (the name on the tab of) a `GObject gob`. If `gob == paddle`, you know the paddle has collided with the single-point ball at (x, y) . If `gob` is an instance of `Brick`, then `gob` must be a brick. So, we have just explained how to test whether a single-point ball has collided with the paddle or a brick.

But the ball is not a single point. It occupies physical area, so it may collide with something on the screen even though its center does not. The easiest thing to do—which is typical of the simplifying assumptions made in real computer games—is to check a few carefully chosen points on the outside of the ball and see whether any of those points has collided with anything. As soon as you find something at one of those points (other than the ball of course) you can declare that the ball has collided with that object.

You should check the four corner points on the square in which the ball is inscribed. A `G oval` is defined in terms of its bounding rectangle, so that if the upper left corner of the ball is at the point (x, y) , the other corners are at the locations shown in the diagram to the right (r is the radius of the ball). These points have the advantage of being outside the ball, so that `getElementAt` can't return the ball itself. But they are close enough to make it appear that a collision has occurred.



Write a function

```
GObject getCollidingObject()
```

that checks the four corners, one at a time; if one of them collides with the paddle or a brick, stop the checking immediately and return the object involved in the collision. Return `null` if no collision occurred.

Now, in the main-loop repetend, after moving the ball, call `getCollidingObject` to check for a collision. If the ball going up collides with the paddle, don't do anything. If the ball going down collides with the paddle, negate the vertical direction of the ball. If the ball (going in either vertical direction) collides with a brick, remove the brick from the board and negate the vertical direction.

Inherited function `remove(gob)` can be used to remove object `gob`. You can check whether the object is a brick by asking whether it is an instance of class `Brick`.

Try to get this done by 30 November.

6. Finishing up

The basic parts are now done. A few more details have to be taken care of, and these may cause you to reorganize procedure `run`. Think carefully about the following tasks and how you want to design the final program before proceeding.

1. *Take care of the case that the ball hits the bottom wall.* Right now, the ball just bounces off this wall like all the others, but hitting the bottom means that the ball is gone. In a game, the player should get three balls before losing. If the player can have another ball, put a message on the board somewhere (use a `GLabel` object), telling the player that another ball is coming in 3 seconds, pause for 3 seconds, remove the message, and continue with a new ball.
2. *Check for hitting the last brick, in which case the player wins.* An easy way to do this is to keep track of how many bricks are left on the board; when there are none, the game ends and the player has won.
3. *When a game ends,* place a message somewhere on the window (use a `GLabel` object).
4. Experiment with the settings that control the speed of your program. How long should you pause in the loop that updates the ball? Do you need to change the velocity values to get better play action?
5. Test your program to see that it works. Play for a while and make sure that as many parts of it as you can check are working. If you think everything is working, try this: Just before the ball is going to pass the paddle level, move the paddle quickly so that the paddle collides with the ball rather than vice-versa. Does everything still work, or does your ball seem to get “glued” to the paddle? If you get this error, try to understand why it occurs and how you might fix it.

7. (Completely optional) Make a jar file You might want people to be able to play your game without having to have DrJava installed. Create a jar file `Breakout.jar`, checking that you can run it as a stand-alone application (e.g. by double-clicking on its icon). You can use the procedure outlined in the lecture notes (covered in appendix I.4 in the text), or use DrJava's project facilities (instructions here: <http://drjava.org/index.php?page=docs/user/ch04.html>). You don't have to turn anything in for this step; just send your jar file to your friends and let them amuse themselves for a couple of hours destroying innocent bricks that never did them any harm, while you study for the final.

Strategy and tactics

Here are some hints for this assignment:

1. *Start as soon as possible.* If you wait until the day before this assignment is due, you will have a hard time completing it. If you do one part of it every 2–3 days, you will enjoy it and get it done on time. The hard part may be “finishing up” —designing the final reorganization in order to incorporate three balls in a game.
2. *Implement the program in stages,* as described in this handout. Don’t try to get everything working all at once. Make sure that each stage is working before moving on to the next stage.
3. *Set up a schedule.* We have suggested some milestones, but make up your own schedule. Leave time for learning things and asking questions. You may have to learn some points about package `acm.graphics` by yourself.
4. Check the assignments page on the course website for FAQs concerning this assignment.
5. *Don’t try to extend the program until you get the basic functionality working* (see the next section). If you add extensions too early, debugging may get very difficult.

Possible extensions

There are many ways —and fun ways— to extend this assignment. Add more and we will be a bit more lenient with grading than if you implement the bare minimum. But note that a submission that does not have a good class invariant and good specifications for the methods will not be looked at kindly under any circumstances.

Here are some ways to extend the game. Number 1 is one of the best.

1. *Improve user control over bounces.* The program gets rather boring if the only thing the player has to do is hit the ball. Let the player control the ball by hitting it with different parts of the paddle. For example, suppose the ball is coming down toward the right (or left). If it hits the left (or right) 1/4 the paddle, the ball goes back the way it came (both `vx` and `vy` are negated).
2. *Let the player play as many games as they want.* The player could click the mouse button to start a new game. A call on inherited procedure `waitForClick()` will wait (or pause) until the mouse is clicked.
3. *Play appropriate sounds for game events.* This is an easy extension. The course webpage contains some audio files that might make nice game noises; you can easily find lots more. You can load an audio file (e.g. `bounce.au`) by writing

```
AudioClip bounceClip= MediaTools.loadAudioClip("bounce.au");
```

and play it (when the ball hits something, for instance) by calling `bounceClip.play()`. The sound might get monotonous after a while, so make the sounds vary, and figure out a way to let the user turn sound off (and on).

4. *Add in the kicker.* The arcade version of `Breakout` lures you in by starting off slowly. But as soon as you think you were getting the hang of things, the ball speeds up, making life more exciting. Implement this in some fashion, perhaps by doubling the horizontal velocity of the ball on the seventh time it hits the paddle.
5. *Keep score.* Display the score (number of bricks destroyed, say) underneath the paddle, but remember, a `GLa-bel` is an object, and the ball hitting it should have no effect. Perhaps you can make the bricks in the higher rows more valuable.
6. *Use your imagination.* What else have you always wanted a game like this to do?

Submitting your assignment

Before the due date,

- (1) Put a comment at the top of class `Breakout` that contains the time you spent on this project, and gives a brief overview of any extensions you added to it.
- (2) Add a comment that gives your opinion of this assignment —whether it was educational, interesting, exciting, loads of fun, too easy, too long, horribly described, how we could improve it, etc.

Most students should submit file `Breakout.java` on the CMS.

However, if you have extra files to submit, put all your files in a zip file `everything.zip` and submit it instead. Do not give us `.class` files and other stuff, just zip up `Breakout.java` and other files that your program needs.