Introduction to Computers and Engineering Problem Solving
Spring 2011
Problem Set 2: Throwing a ball into a basket
Due: 12 noon, February 24, 2012

Problem statement

You learn in physics that projectiles follow a parabolic path through the air, due to the acceleration of gravity. In this problem set, you will calculate the release angles and speeds for throwing a ball into a basket.

The kinematic equations lead to an equation describing the relationship between release angle, θ, initial speed, v_0, and distance, d:

$$d = \frac{v_0^2 \sin 2\theta}{g}$$

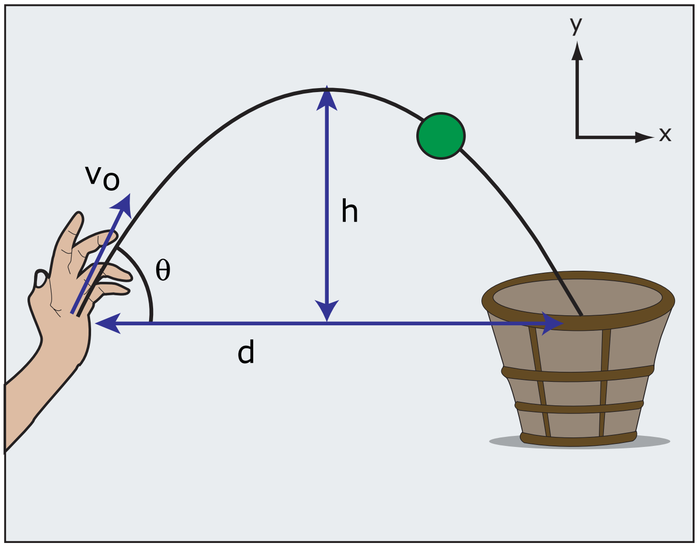

Image by MIT OpenCourseWare.

where $g = 9.8$ m/s^2 is the acceleration due to gravity. Let's assume you always throw the ball with the same initial speed, v_0, each time. There will then be a small range of angles at which the ball can be released and still land within the diameter of the basket.

In order to ensure the ball doesn't hit the ceiling, we will also look at its maximum height, h, at the top of the trajectory, given by:

$$h = \frac{v_0^2 \sin^2 \theta}{2g}$$

Program

Design a Java class with a set of static methods to compute the optimal release angle, and the range of acceptable angles, in order to toss a ball into a basket from a given distance. Your class will have a `main()` method that will prompt the user for inputs, call the static methods to perform the calculations, and print the results. None of the calculations should be performed directly by the `main()` method.

Your program should prompt the user for the following inputs:

- distance, d, from thrower's hand to the center of the basket (in meters)
- diameter of the basket (in meters)
- initial ball speed v_0 (in meters/second)
- height of the ceiling from the basket (in meters)

Assume that the ball is thrown exactly along the x axis. The size of the ball is much smaller than the size of the basket, so you may ignore it.

When all the parameters have been entered correctly, your `main()` method should call a separate static method to perform each of the following:

1) Compute the optimal angle (in degrees) for releasing the ball, such that it lands in the center of the basket. Note that the trajectory angle equation is in radians.
2) Compute the smallest angle (in degrees) that will still land the ball in the basket. Assume the ball will go into the basket if the center of the ball hits the edge. You should not rewrite the contents of any methods you have already written.
3) Compute the largest angle (in degrees) that will still land the ball in the basket. You should not rewrite the contents of any methods you have already written.
4) Determine whether or not the ball will hit the ceiling when thrown at the optimal angle.
5) If the ball will hit the ceiling, you will need to throw the ball faster. Write a method that continuously increments the initial v_0 by 0.1 and re-computes the angle and max height, until the height constraint is met. You should not rewrite the contents of any methods you have already written. This method only needs to print to the console all the different values of v_0 and θ that are tried, and what max heights they corresponded to.

Print each of these results from the `main()` method. You may find built-in methods in the `Math` class useful for computing trigonometric values (for example, `Math.cos(double a)` computes the cosine of an angle in radians). A list of available methods is found here: http://docs.oracle.com/javase/6/docs/api/java/lang/Math.html

Example Calculations and Outputs:

Consider a 10cm diameter basket located 2m from the thrower, an initial speed of 5 m/s and a ceiling height of 2m. Your program should print approximately the following. Do not worry about numerical formatting.

```
Optimal angle   25.814 degrees.
Range of acceptable angles is from 24.927 degrees to 26.738 degrees.
The maximum height of the ball is 0.242 meters.
Will the ball hit the ceiling? false
```

If we now move the basket to 15m from the thrower and throw the ball at an initial speed of 13 m/s, the program should print approximately the following. Again, do not worry about numerical formatting.

```
Optimal angle   30.219 degrees.
Range of acceptable angles is from 30.052 degrees to 30.388 degrees.
The maximum height of the ball is 2.184m.
Will the ball hit the ceiling? true
Trying v0   13.1 m/s, theta   29.468 degrees. Max height   2.119 meters
Trying v0   13.2 m/s, theta   28.765 degrees. Max height   2.059 meters
Trying v0   13.3 m/s, theta   28.102 degrees. Max height   2.002 meters
Trying v0   13.4 m/s, theta   27.476 degrees. Max height   1.950 meters
```

Turn In

1. Place a comment with your full name, section, TA name and assignment number at the beginning of the .java file for your solution.
2. Place all of the files in your solution in a single zip file.
   a. Do not turn in copies of compiled byte code or backup (.class or .java~ files)
   b. Do not turn in printed copies of your solution.
3. Submit the single zip file on the 1.00 Web site under the appropriate section. For directions see *How To: Submit Homework* on the 1.00 Web site.
4. Your uploaded files should have a timestamp of no later than noon on the due date.
5. After you submit your solution, please recheck that you submitted your .java file. If you submitted your .class file, you will receive **zero credit**.

Penalties

- 30 points off if you turn in your problem set after Friday noon but before noon on the following Monday. You have one no-penalty late submission per term for a turn-in after Friday noon and before Monday noon.
- No credit if you turn in your problem set after noon on the following Monday.

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