CSC120 Lab Week 3: Calculation with Math Functions

Instructor: Mitsu Ogihara

The goal of this lab is to write a class `BallReach` for finding how far a ball will reach when you throw it off a cliff at an upward angle. We can solve the problem using elementary physics using the following quantities (in parentheses are their units):

- the gravity constant g (in m/s^2),
- the horizontal speed u (in m/s),
- the initial vertical speed v (in m/s), and
- the height of the cliff h (in m).

The movement of the ball can be determined by first analyzing its vertical movement and then horizontal movement. The ball vertically moves up and then down. The upward speed is initially v and decreases at the rate of g. At the point the speed reduces to 0, the ball starts falling. The ball keeps falling until it reaches the ground. Let us use t_0 for the duration of the upward movement and t_1 for the downward movement. The total duration $t_2 = t_0 + t_1$. Also, let us use h_0 for the vertical distance the ball goes up from the cliff and h_1 for the vertical distance the ball falls. We have $h_1 = h_0 + h$. During the travel, the horizontal speed remains unchanged, and so how far the ball reaches, r, is $u(t_0 + t_1)$.

Now let us see how we will determine these quantities.

- For t_0, we have the equation $v - gt_0 = 0$ (at time t_0, the ball's vertical speed becomes 0), and so we have
$$t_0 = v/g.$$
- For h_0, the speed at time $t, 0 \leq t \leq t_0$, is $v - gt$, so we have
$$h_0 = vt_0 - \frac{1}{2}gt_0^2 = g\left(\frac{v}{g}\right)^2 - \frac{1}{2}gt_0^2.$$
This is equal to $\frac{1}{2}gt_0^2$ as well as too $\frac{1}{2g}v^2$.
- We have
$$h_1 = h_0 + h = \frac{1}{2g}v^2 + h.$$
- For t_1, the speed of ball at t from the moment it starts falling ($0 \leq t \leq t_1$) is gt, and so the distance it has fallen at t is $\frac{1}{2}gt^2$. This quantity is equal to h_1. By solving it for t, we have
$$t_1 = \sqrt{2h_1/g} = \sqrt{\frac{v^2}{2g^2} + \frac{h}{g}}.$$

- The total travel time $t_2 = t_0 + t_1$, so

$$t_2 = \frac{v}{g} + \sqrt{\frac{v^2}{2g^2} + \frac{h}{g}}.$$

- The horizontal travel distance r is $u(t_0 + t_1)$, which is

$$u\left(\frac{v}{g} + \sqrt{\frac{v^2}{2g^2} + \frac{h}{g}}\right).$$

Using the last formula gives you the answer to the question, but in this assignment, you will write a code that computes t_0, h_0, h_1, t_1, t_2, and r in this order.

The Code Structure

The program receives, from the user, the angle (in degrees between 0 and 90) at which the ball is thrown, its initial speed, and the height of the cliff. The program makes two sets of calculation. The first set is based on the Earth's gravity constant 9.807. The second set is based on the Moon's gravity constant 1.620. Below is a sample execution of the program, where the characters in blue represent the user input.

```
........ Distance Calculation ........
Enter angle (degree): 30
Enter speed (m/s): 150
Enter height (m): 150
........ On the Earth ........
           Height of the cliff:      150.0000 m
              Horizontal speed:      129.9038 m/h
        Initial vertical speed:       75.0000 m/h
                       Gravity:        9.8070 m/s^2
            Upward travel time:        7.6476 s
        Upward travel distance:      286.7849 s
          Downward travel time:        9.4380 s
      Downward travel distance:      436.7849 s
             Total travel time:       17.0856 s
    Horizontal travel distance:    2,219.4865 s
........ On the Moon ........
           Height of the cliff:      150.0000 m
              Horizontal speed:      129.9038 m/h
        Initial vertical speed:       75.0000 m/h
                       Gravity:        1.6200 m/s^2
            Upward travel time:       46.2963 s
        Upward travel distance:    1,736.1111 s
          Downward travel time:       48.2549 s
```

```
24        Downward travel distance:    1,886.1111 s
25              Total travel time:       94.5512 s
26      Horizontal travel distance:   12,282.5565 s
```

Lines 1, 5, and 16 are to be produced using a method `message`, which takes a `String m` as its parameter and prints `m` using

```
System.out.printf( "........ %s ........\n", m );
```

The periods appearing in the output lines appear in the format String and so the message part is the rest of the output. Lines 2, 3, and 4 are for receiving input from the user. The parts appearing after `: ` are the input.

The other lines are to be produce using a method `myprint`, which takes three parameters, `String name`, `double value`, and `String unit` and executes one line of code

```
System.out.printf( "%25s:%11.4f (%s)\n", name, value, unit );
```

The `printf` statement means the following:

> Print the value of `name` right-flushed in 25 character spaces, print the value of `value` right-flushed in 11 character spaces with the last four spaces representing the four digits of the value after the decimal point, append the value of `unit` within a pair of matching parentheses (i.e., `()`), and then go to the next line.

For the gravity constants, define them using `public static final double`, which is to be inside the class but outside the methods.

The method `compute` does the calculation for one combination of height, horizontal speed, vertical speed, and gravity. Before calling `compute`, you need to correct the angle so that the angle is between 0 and 90. This can be possible to take the minimum between the input value and 90, and then the maximum between 0 and the minimum that just has been computed. From the angle, you can compute the radian of the angle. The speed has to be adjusted to the maximum between 0 and the input. Similarly, the height has to be adjusted to the maximum between 0 and the input. From the angle in radian and the speed, you obtain the vertical and horizontal speeds. The former is `Math.sin` of the radian times the speed, and the latter is `Math.cos` of the radian times the speed. Before executing the calculations, you must adjust the value of `angle` so that it falls between 0 and 90.0.