CSC120 2025S Lab No.3
Calculation with Math Functions

This lab aims 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 ball's movement can be determined by analyzing its vertical and horizontal movements. The ball moves vertically up and then down. Its upward speed is initially v and decreases at g. When 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 to indicate the vertical distance the ball ascends from the cliff and h_1 to indicate the vertical distance it falls. We have $h_1 = h_0 + h$. The horizontal speed remains unchanged during travel, so the distance 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 ball's speed 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 equal to

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

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. Assign meaningful names to these quantities.

The Code Structure

From the user, the program receives the angle (in degrees between 0 and 90) at which the ball is thrown, its initial speed, and the cliff's height. The program makes two sets of calculations. 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): 45
Enter speed (m/s): 10
Enter height (m): 20
........ On the Earth ........
           Height of the cliff:       20.0000 (m)
              Horizontal speed:        7.0711 (m/s)
        Initial vertical speed:        7.0711 (m/s)
                       Gravity:        9.8070 (m/s^2)
                   Upward time:        0.7210 (s)
               Upward distance:        2.5492 (s)
                 Downward time:        2.1444 (s)
             Downward distance:       22.5492 (s)
                    Total time:        2.8655 (s)
           Horizontal distance:       20.2618 (s)
........ On the Moon ........
           Height of the cliff:       20.0000 (m)
              Horizontal speed:        7.0711 (m/s)
        Initial vertical speed:        7.0711 (m/s)
                       Gravity:        1.6200 (m/s^2)
                   Upward time:        4.3649 (s)
               Upward distance:       15.4321 (s)
                 Downward time:        6.6139 (s)
```

```
24                Downward distance:       35.4321 (s)
25                       Total time:       10.9787 (s)
26              Horizontal distance:       77.6314 (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 in the output lines appear in the format String data, 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( "%30s:%14.4f (%s)%n", name, value, unit );
```

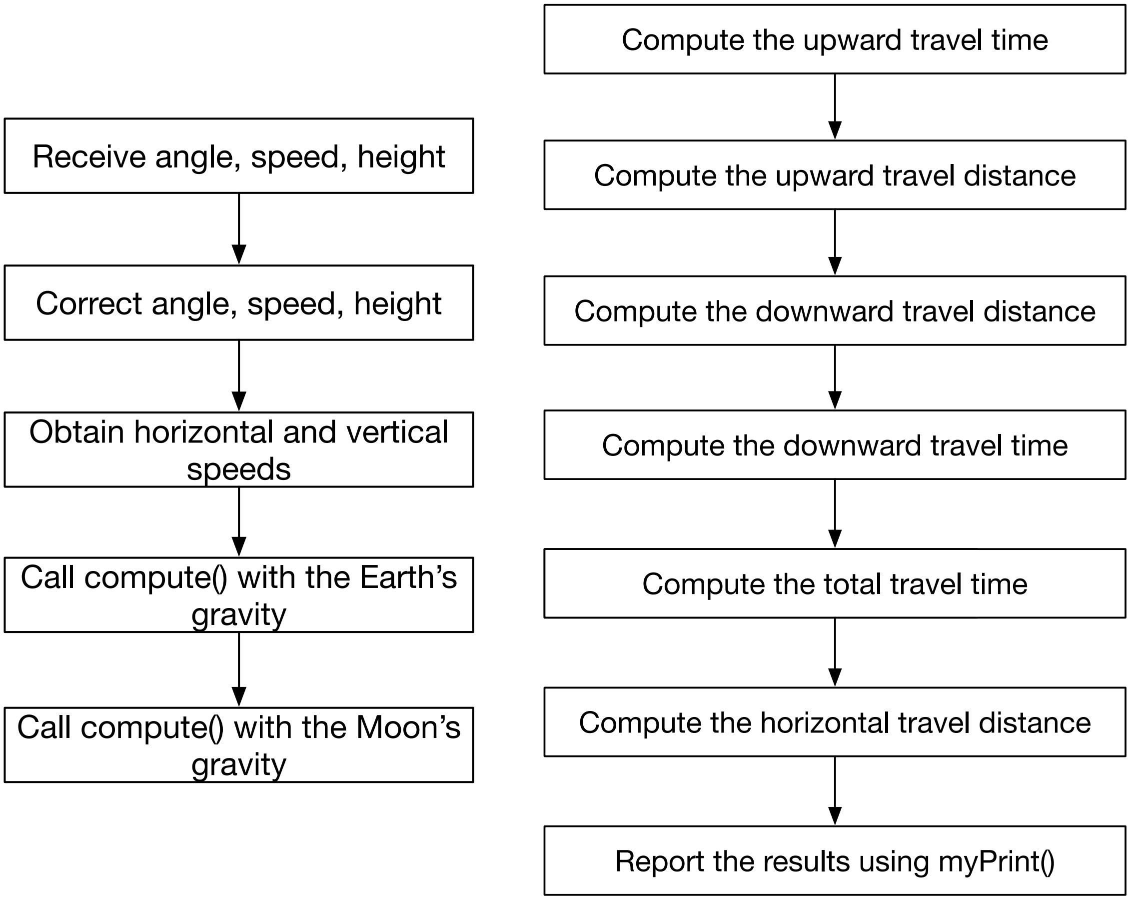
The `printf` statement means the following:

> Print the value of `name` right-flushed in 30 character spaces, print the value of `value` right-flushed in 41 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 to be between 0 and 90. You can do the correction by taking the minimum between the input value and 90 and then the maximum between 0 and the minimum you have just computed. If the angle is not corrected, the option will preserve the value. Once the correction has been made, you can compute the angle as a radian value. You obtain the vertical and horizontal speeds from the angle in radians and the speed. The former is `Math.sin` of the radian times the speed, and the latter is `Math.cos` of the radian times the speed.

Similar adjustments must be made for the speed and the height. For the speed, its adjustment is to replace it with the maximum between 0 and the input. For the height, its adjustment is to replace it with the maximum between 0 and the input. The left diagram that appears next shows the flow in the method main(), and the right one shows the flow in the method compute().


Receive angle, speed, height
Correct angle, speed, height
Obtain horizontal and vertical speeds
Call compute() with the Earth's gravity
Call compute() with the Moon's gravity
Compute the upward travel time
Compute the upward travel distance
Compute the downward travel distance
Compute the downward travel time
Compute the total travel time
Compute the horizontal travel distance
Report the results using myPrint()