

Speed of a Falling Object

Overview

For this team activity, you will work together to implement a fairly complicated Physics formula.

This example was chosen to give you something more interesting and involved than standard, simplistic examples like the area of shapes, to show you that you are capable of solving real-world math and science problems in the programs you are writing.

Keep in mind that even if you don't understand all of the details of the various components in the formula, you can still implement it.

Also, recognize that by extending from only one or two numbers in an expression to many more doesn't change much in your program. It's just a matter of adding more variables—everything else follows the same process.

THE PROBLEM

Determine how fast an object will fall.

THE PHYSICS

If you release an object (ball, rock, whatever) from rest (or you could throw it) and let it fall through a fluid, the change in speed of the object is affected by several things: the mass of the object, the acceleration due to gravity, the shape of the projectile, the size of the projectile, and the density of the fluid.

The function that computes the speed after "t" seconds have elapsed is given by:

$$v(t) = \sqrt{\frac{mg}{c}} \cdot \left(1 - e^{-\frac{\sqrt{mgc}}{m}t}\right)$$

This function could also be written this way:

```
v(t) = sqrt(mg/c) * (1 - exp((-sqrt(mgc)/m)t))
```

Hint from Instructor:

Please note that this formula is written the way you would see it in a Physics textbook and cannot directly be copied and pasted into Python code. For example, "mg" really means "m * g".

Also, the expression "v(t)" is how the physicist is communicating "velocity at time t", in your python code, you wouldn't want to put parentheses, but instead could just name a variable **velocity** or **velocity_at_t** or something similar.

The expression: "exp(xxxx)" means the Mathematical number "e" to the power of xxxx. In Python, you can calculate this using the library function **math.exp(xxxx)**.

The expression: "sqrt(xxxx)" means the square root of xxxx. You can calculate the square root in Python using **math.sqrt(xxxx)**

Where:

- m = mass (in kg)
- g = acceleration due to gravity (9.8 m/s² on Earth, 24 m/s² on Jupiter)
- t = time (in seconds)
- c = 1/2 ρ A C
- ρ = density of fluid (1.3 kg/m³ for air, 1000 kg/m³ for water)
- A = cross sectional area of projectile (in square meters)
- C = drag constant (0.5 for sphere, 1.1 for cylinder falling on it's side. You could look it up for other shapes.)
- exp = the number *e* (2.71828) to the given exponent. This can be computed in Python with the Math library function **math.exp(value)**.

- `sqrt` = the square root of the given expression. This can be computed in Python with the Math library function `math.sqrt(value)`.

Hint from Instructor:

When it comes to variable names, we want to make sure they are clear and descriptive. In a formula like this, because the values were expressed by the physicists as "m" or "g" or "C", even though they are one letter variable names, they would be appropriate to use in your Python code just like that, because they are not ambiguous and map directly to one specific component in the formula.

Also, be aware that when it comes to variables uppercase and lowercase matter. A variable "c" (lowercase) and "C" (uppercase) would be treated by Python as two different variables.

An example run of this program may look as follows (user input is shown with an underline):

```
Welcome to the velocity calculator. Please enter the following:

Mass (in kg): 5
Gravity (in m/s^2, 9.8 for Earth, 24 for Jupiter): 9.8
Time (in seconds): 10
Density of the fluid (in kg/m^3, 1.3 for air, 1000 for water): 1.3
Cross sectional area (in m^2): 0.01
Drag constant (0.5 for sphere, 1.1 for cylinder): 0.5

The inner value of c is: 0.003
The velocity after 10.0 seconds is: 67.512 m/s
```

Assignment

Start by completing the core requirements, then when that part is complete, if you have time, see if you can complete some of the stretch challenges as well.

CORE REQUIREMENTS

1. Prompt the user for each of the variables described above.
2. Compute the value for the inner value `c` which is computed as:

$$c = (1 / 2) * \rho * A * C$$

Display the value **c** to three decimal places.

3. Compute and display the overall velocity. Display the value to three decimal places.

STRETCH CHALLENGE

1. Try determining the velocity for a few different objects that you know. For example, you might try a bowling ball, a loaf of bread, and a skydiver.

Hints: You can find the cross sectional area of a bowling ball by using its radius and calculating the area ($\pi * r^2$). You can approximate the drag constant for a loaf of bread by thinking about it as a cylinder. Do your best to estimate the cross sectional area of a skydiver. Are they falling head first or lying flat? You can look up values for the drag constant of a skydiver.

2. Compare the difference in velocities for two different gravity values (Earth and Jupiter), assuming everything else is the same.
3. For one of the objects you picked, see if you can determine how long it takes to reach "terminal velocity" which is the fastest that the object will travel, by entering different values for "t" to see where it stops increasing.

Check your guess for the terminal velocity by using Python to compute the terminal velocity, which can be found by determining the velocity $v(t)$ as time t approaches infinity. This results in the equation for terminal velocity:

$$v_{\text{terminal}} = \sqrt{mg/c}$$

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