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PHYS 265

Lab 2 Report: Mine Crafting

Introduction

The purpose of this lab is to explore where we can verify the depth of 4 kilometers mine shaft by dropping a 1 kg test object and to measure how long it takes to hit the bottom of the mine shaft. We incorporate basic physics such as fulling gravity and then we improve the model and calculation by adding realistic effects such as air resistance, changes in gravity concerning depth, and the Earth's rotation. Our strategy was to use Python stimulation to model how objects would move under these conditions. Next, we differentiate how the fall time changes depending on the assumptions we make.

To perform the simulations and generate models in this research, we used the following Python libraries: NumPy, Matplotlib, and Solve_ivp. NumPy is essential for efficient numerical computations. It deals with arrays, vectorized math operations, and constants. These things are critical for implementing the physics equations governing motion. Matplotlib is useful for generating high-quality plots of simulation results, such as position and velocity over time. It allowed us to clearly visualize different physical effects such as drag and Coriolis forces and how they influence the motion. Solve_ivp (from SciPy) numerically solves differential equations. In this case, this function is solving the equations of motion we derived for the falling test mass. It allowed us to simulate realistic scenarios where forces change with time, speed, or position, and to track when the mass hits the bottom using event detection.

Calculation of Fall Time

The first calculation on how long it would take for the test object to fall 4 kilometers. We used one of the standard physics formulae: t = sqrt(2y/g). Utilizing NumPy and solve_ivp, we were able to get the result of 28.6 seconds. See Figure 1. This matches exactly with our computer simulation when we only include gravity and ignore air resistance. Next, we considered that gravity weakens slightly as you fall deeper into the Earth. As a result, the fall time increased a little to 28.8 seconds. Then we added air resistance. To do so, we used a common approach from physics, where the force of air pushing back on a falling object depends on how fast it's moving.

We set the drag so the object would stop accelerating once it reached 50 meters per second which is a typical "terminal speed". With this, the fall time increased more significantly to 33.4 seconds.

Feasibility of Depth Measurement

We wanted to test if our strategy would work in real life. The first problem is that Earth rotates and that rotation pushes falling objects sideways, and this is called the Coriolis effect. Even if we drop the object straight down, it will curve sideways as it falls. We simulated this and found that the object drifted sideways and hit the side of the shaft just before reaching the bottom around 3995 meters deep and 1266 seconds into the fall. Even after we added air resistance, which slowed the object down and reduced sideways motion, the object still did not reach the bottom. It either took too long or drifted too far sideways. In conclusion, without some kind of guiding system, this method won't work, and the test mass won't fall straight down. See Figure 2a & 2b.

Crossing Times for Homogenous and Non-Homogenous Earth

We studied what would happen if the mine shaft went all the way through the Earth from one pole to the other. We considered that Earth isn't made of uniform material for it is denser near the core. We tested different models where the density is more or less concentrated toward the center. See Figure 3a and 3b .These are the results:

Density Profile(n)	Time to Center(S)	Speed at Center(m/s)
Uniform(n=0)	1265.8	7905.0
Slight Denser(n=1)	1095.2	10457.4
Realistic(n=2)	1033.8	12182.5
Concentrated(n=9)	942.6	18370.1

As Earth becomes more concentrated toward the center, the fall becomes faster, and the object reaches higher speeds at the center.

Discussion and Future Work

This lab depended on a plethora of simplifications to make the physics of falling motion more manageable to analyze and simulate. While these models yielded valuable insights, they do not fully capture the complexity of real-world conditions. The key approximations made are listed: The Earth was modeled as a perfect sphere. Simplified density models were used instead of empirically derived density distributions. The atmosphere was assumed to be uniform, with no variation in air density or pressure with altitude. Major constraints were ignored such as frictions. Finally, the mine shaft was assumed to be either perfectly vertical or aligned through the poles

My recommendation for future work is to enhance the realism and applicability of the results. Future simulations should incorporate realistic Earth density profiles based on seismic and geological data. We should also account for object orientation, shape, and aerodynamics, including rotational motion and turbulence.

Figures

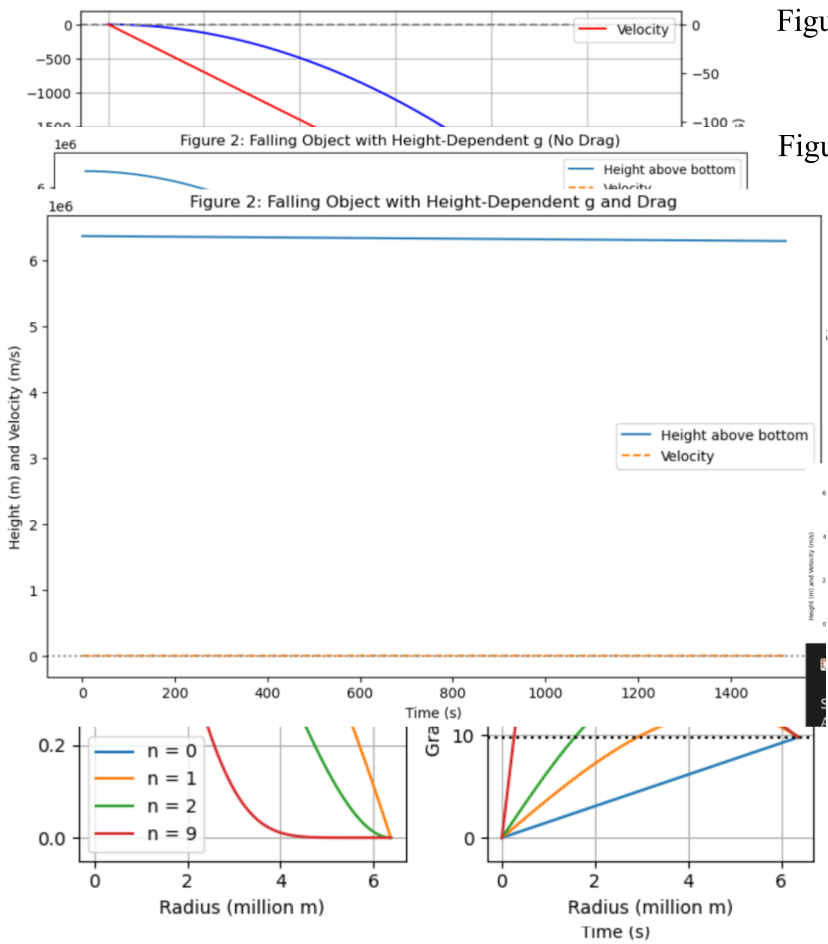

Figure 1

Figure 2a

Figure 2b

Figure 3a

Figure 3b