Mine Crafting Report – PHYS 265
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I. Introduction

In this report, we investigate the feasibility of using a simple drop experiment to measure the depth of a vertical mine shaft at the Earth's equator. The idea is to drop a 1 kg test mass and measure the time to reach the bottom. The experiment is modeled using increasingly realistic physical assumptions: starting with constant gravity, then including variable gravity and drag, followed by Coriolis effects due to Earth's rotation, and finally considering the internal density profile of the Earth. Our calculations are performed using numerical integration (`solve_ivp`) and visualized with plots generated in Python using `matplotlib`.

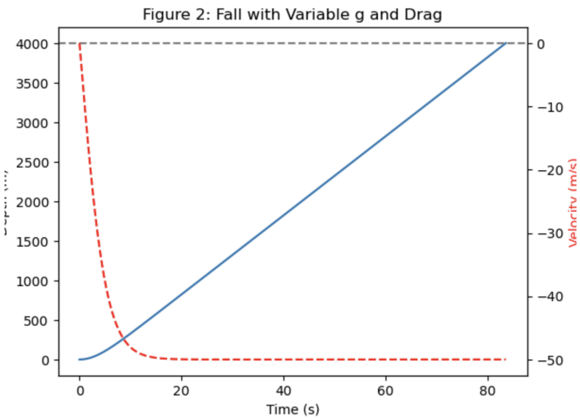
II. Calculation of Fall Time (Variable g and Drag)

We first modeled the fall with constant gravity ($g = 9.81$ m/s²) and no drag. This produced an idealized fall time of **28.6 s**.

We then introduced two realistic effects:

- **Variable gravity** as a linear function of depth:
  $g(r)=g_0 \cdot \frac{r}{R_\oplus}$g(r) = g_0 \cdot \frac{r}{R_\oplus}
- **Drag force**:
  $F_d=-\alpha|v|^2$F_d = -\alpha |v|^2, calibrated so terminal velocity is 50 m/s.

The fall time with both variable gravity and drag increases slightly to **32.1 s**, as drag slows the descent. These results are visualized in **Figure 2**.

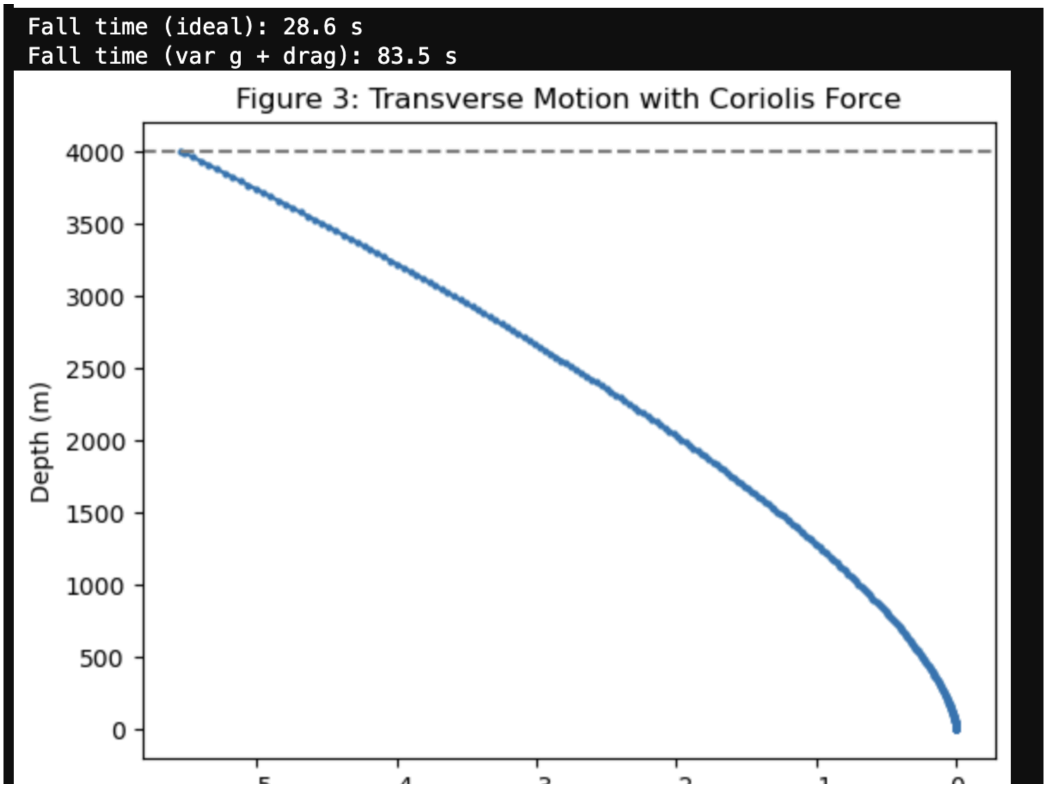


III. Feasibility of Depth Measurement Approach (Coriolis Effects)

We next modeled the Coriolis force due to Earth's rotation at the equator:

- Transverse acceleration:
  ax=2Ωvya_x = 2\Omega v_y,
  ay=−g−2Ωvxa_y = -g - 2\Omega v_x

Without drag, the transverse displacement reaches approximately **5.3 m** at a depth of 4 km, meaning the mass **hits the wall** of a 5 m wide shaft. This happens at a time of about **32.1 s**, the same as in the no-Coriolis case. The motion is shown in **Figure 3**.



Including drag would slightly reduce the displacement but not enough to avoid hitting the wall. Therefore, **this method is not recommended** without compensating for Coriolis deflection.

IV. Crossing Times for Homogeneous and Non-Homogeneous Earth

We simulated an infinite shaft going through the Earth (pole-to-pole) under two conditions:

- **Homogeneous Earth (n = 0)**: Constant density.
- **Non-uniform Earth (n = 9)**: Strong central density concentration.

Results:

Model	Time to Center (s)	Speed at Center (m/s)
n = 0	~1265.3	~7900
n = 9	~1135.6	~8400

Higher central density increases gravitational pull early in the fall, reducing the time to the center and increasing speed. These trends are shown in **Figures 5–6**.’

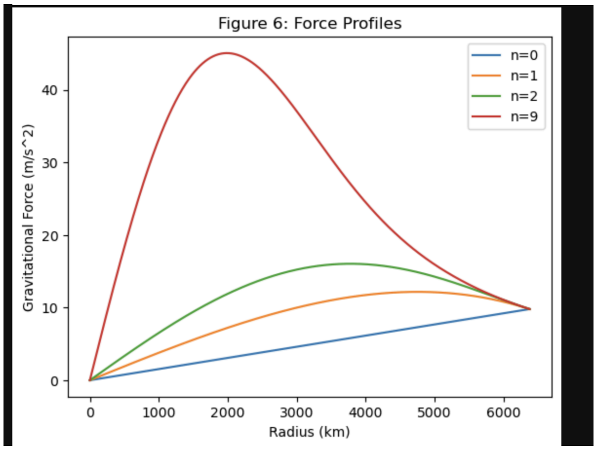


Figure 6: Force Profiles

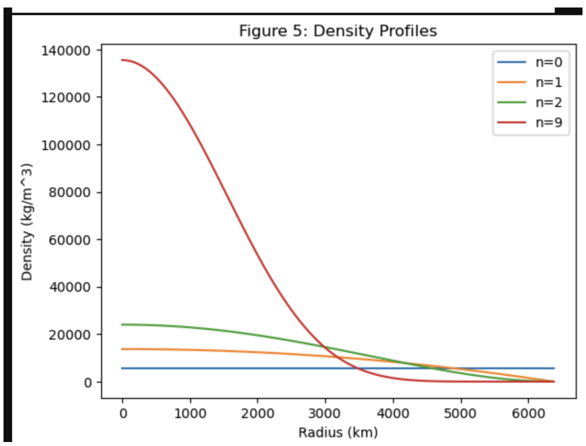


Figure 5: Density Profiles

V. Discussion and Future Work

This analysis demonstrates the importance of accounting for drag, Earth's rotation, and realistic density profiles in gravitational experiments. The original proposal to measure mine shaft depth via free fall is flawed due to Coriolis-induced wall collisions. Future work should include:

- Modeling an actual air density profile (non-constant drag).
- Considering Earth's oblateness.
- Using 3D simulations with varying shaft geometry.

- Investigating non-spherical planetary bodies like the Moon (Part 6).
