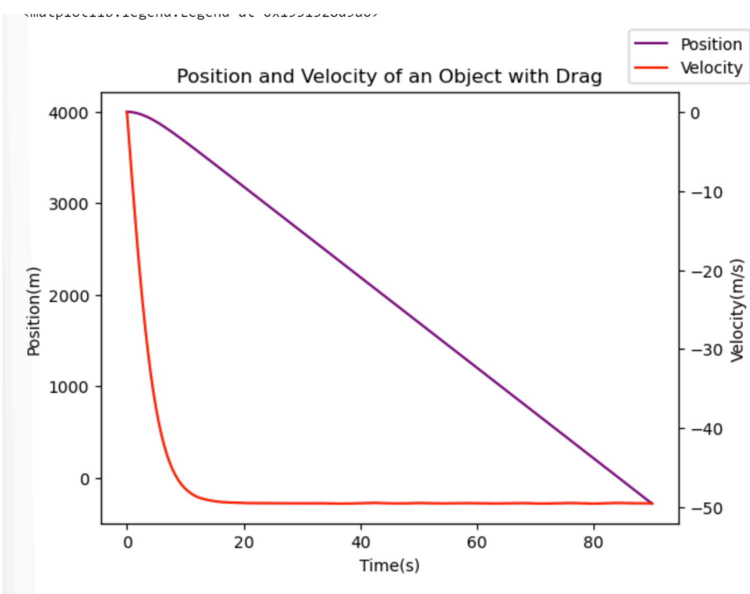
Lab Report 2

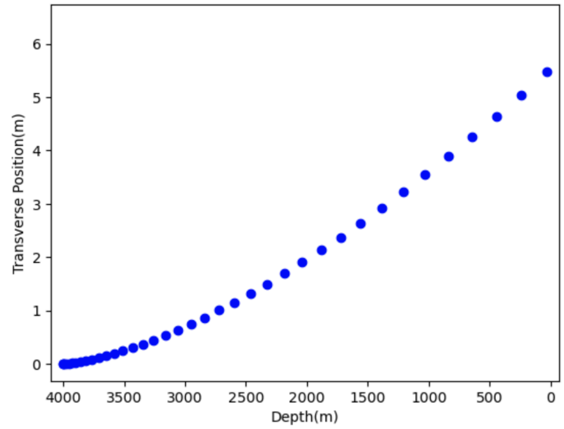
This report will illustrate how different forces and physical qualities affect how a 1 kg object falls through a mine shaft. I will measure the position and velocity of the object as well as the time it takes for the object to reach the bottom of the shaft under different assumptions starting by ignoring air resistance and assuming that the object is under a constant gravitational force. This will be compared to the fall time with a realistic gravitational force that increases as the object gets closer to the Earth's core and then we will see how air resistance affects this. I will also test what happens when the Coriolis force is applied to the object and what happens in an infinitely deep mine. Finally this will look at the effect density has on the position, velocity, and fall time of the object. The goal of this report is to determine the time it will take for this 1 kg object to fall down the deepest mine shaft on Earth and to understand which forces affect this time the most.

To determine how long it takes the mass to fall down a 4 kilometer shaft I first tested it under the assumption that a constant force of gravity is acting on the object and that there is no drag or resistance from the air that slows the object down. To do this we can use python to define a function that computes the derivatives of velocity and position and using the scipy library we can integrate these functions over a time span to determine the position and velocity of the object at different time values. From this we can extract the position and velocity data at each time measurement and plot them using object oriented plotting to see how the object acts. Object oriented plotting is done by setting up a figure with axes then you can use the command ax.plot and input your x and y variables. Then we can define an event that will stop the integration process at that event, in this case that is when the ball reaches the bottom of the shaft. In the case of a constant gravitational force and no drag this time was 28.6 seconds. Next I determined how a variable gravitational force affects this fall time as in reality the force of gravity increases as the object gets closer to the center of the earth in proportion to the formula $g(r) = g * (r/R)$ where g is the gravitational acceleration at the surface of the Earth, r is the distance from the surface of the Earth, and R is the radius of the Earth. This gave me a time value of 28.6 seconds showing that the variable gravitational force does not impact fall time significantly. Finally I wanted to see how drag affects this fall time, adding its effects to my function I got a fall time of 84.3 seconds. After plotting the position and velocity of an object experiencing a variable gravitational force as well as drag we are left with a plot that shows a steep decrease in velocity as the object falls. This shows us that drag has a much larger effect on fall time than whether or not gravity is constant.



The next thing I wanted to test was how the Coriolis force affects the mass as it's falling as this will cause the mass to move transversely because the earth is rotating as the object falls. This force will cause the object to bump into the wall, assuming it was dropped in the middle of a 5 meter shaft, at 29.6 seconds and at a depth of around 1600 meters. While the Coriolis force does cause the mass to bump into the wall it would not be strong enough to overcome the force of gravity so the object will continue to move down the shaft. I also wanted to test how drag affects this and applying drag to our function for position and velocity shows that the mass takes much longer to fall, closer to the 84.3 seconds it took the mass to fall when we tested it under the assumption of drag and no Coriolis force, which means that the object will move more in the transverse or x direction.

Figure 3: Tranverse Velocity as a Function of Depth



Next I wanted to see how density affects the position, velocity, and fall time of the object as the Earth is not uniformly dense. In the scenario of a mine shaft that runs all the way through the Earth it would take a 1 kilogram object 2532.6 seconds to reach the other side of the Earth, assuming uniform density, which is close to half of the orbital period around the Earth. We can also see from the graph of position and velocity for an infinitely deep mine that the velocity reaches a minimum when the object is at the center of the Earth and a maximum when the object is at either side of the Earth. The density of the Earth has a significant impact on the force of gravity that is applied to the object as it's falling. In a uniformly dense Earth the force of gravity is linear to the distance because density is defined as $p(r) = p_n(1 - \frac{r^2}{R^2})^n$ where p_n is the density coefficient, r is the distance, R is the radius of the Earth and n is some exponent that by varying makes the density non uniform. When n is a higher value like 9 which is an extreme case the object will take less time to fall as the crossing time decreases with the square root of density. If this object was on the moon it would take 1624.3 seconds to fall all the way through the moon. While this time is shorter it is not because the moon is less dense as the decreased density of the moon should actually increase the fall time but because the moon is much smaller in diameter this object can reach the other side of the moon quicker.

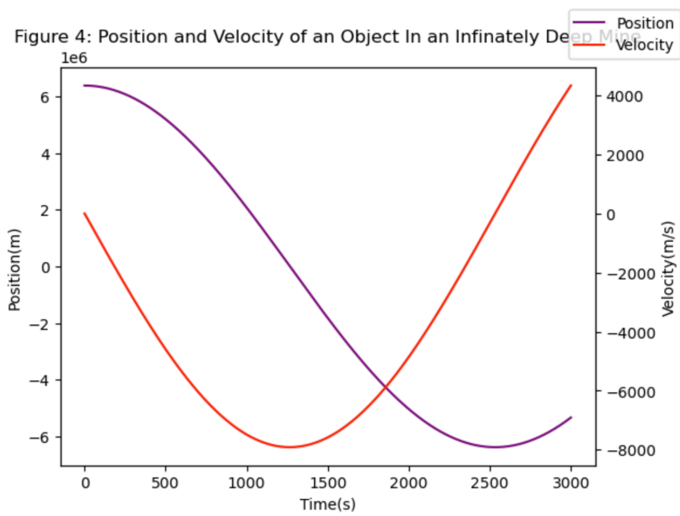


Figure 4: Position and Velocity of an Object In an Infinately Deep Mine

At different times in this lab different assumptions were made to see more directly how specific forces and physical qualities affect the object's velocity, position, and fall time. For instance when finding how drag affects the object we assumed that the terminal velocity of the object was 50 m/s and that the speed dependence of the drag, gamma, was equal to 2. Another assumption we made was that the Earth is in circular orbit to see how the fall time of the object through the diameter of the Earth compared to the orbital period of something around the Earth. We also made the assumption that the Earth is spherical throughout the entire lab which it is not perfectly so. These assumptions would all need to be corrected to reflect reality in order to determine more accurately what happens to the object.