January 20, 2018

## Galileo Experiment Re-created in Space

## Activity Guide for Students: Free Fallin'

Purpose: To serve as an introduction to gravitational acceleration and the equivalence principle. To determine if an object's composition or the height at which an object is dropped affects its gravitational acceleration.

Procedural overview: Measure the masses and sizes of different balls to determine their densities. Drop each ball from a certain height and record the time required for each ball to fall. Using this data, calculate each ball's gravitational acceleration. Additionally, a ball may be dropped from different heights to determine if the ball's distance from the ground affects its gravitational acceleration.

## Procedure:

1. Using a balance or scale, measure the mass M of a ball. Record the result in your data table, making sure to include units of measurement.
2. Using a ruler, measure the diameter $D$ [in centimeters] of the ball. Record the result in your data table, making sure to include units of measurement.
3. Calculate the volume $V=(\pi / 6) D^{3}$ of the ball. Record the result in your data table, making sure to include units of measurement.
4. Calculate the density $\rho=M / V$ of the ball. Record the result in your data table, making sure to include units of measurement.
5. Decide how far you will let the ball fall, and use a tape measure to measure the distance $d$ [in meters]. Record the result in your data table. It is recommended that you choose distances that give fall times between 1.0 second (approximately 5 meters) and 1.5 seconds (approximately 11.25 meters).
6. Drop the ball and use a stopwatch or cell phone timer to measure the time $t$ [in seconds] for it to travel that distance. It is important to release the ball and not throw it, and to measure the time as accurately as possible. Record the result in your data table.
7. Calculate the average velocity during the fall, Vavg $=d / t$. Record the result in your data table, making sure to include units of measurement.
8. Assuming the ball accelerates at a uniform rate, the average velocity should be half of the final velocity. Calculate the final velocity $v_{\text {final }}=2 v_{\text {avg }}=2 \mathrm{~d} / \mathrm{t}$. Record the result in your data table, making sure to include units of measurement.
9. Calculate the acceleration during the fall, $\mathrm{a}=$ Vfinal $/ \mathrm{t}=2 \mathrm{~d} / \mathrm{t}^{2}$. Record the result in your data table, making sure to include units of measurement.
10. Repeat steps No. 6-9 to make a total of five measurements for the same ball and same distance. Record the results in your data table, making sure to include units of measurement.
11. Find the average of your five acceleration measurements for that ball, $a_{\text {avg }}=\left(a_{1}+a_{2}+a_{3}+a_{4}+a_{5}\right) / 5$. Record the result in your data table, making sure to include units of measurement.
12. Repeat steps No. 1-11 for other balls of different densities. Record the results in your data table, making sure to include units of measurement.
13. Plot your data points for acceleration versus ball density on the accompanying graph. How does density affect the acceleration of a ball, and why?
14. How does aerodynamic drag affect the time it takes for an object to fall. Based on your data, which balls appear to be affected the most by aerodynamic drag? Explain how aerodynamic drag would affect the calculated acceleration for an object.
15. Repeat steps No. 1-11 using the same ball, but dropping it over four different distances. Measure the time and acceleration five times for each distance, and take the average of those five measurements. Record the results in your data table, making sure to include units of measurement.
16. Plot your data points for acceleration versus distance on the accompanying graph. How does distance affect the acceleration of a ball, and why?
17. How would you expect your experimental results to change if you conducted the experiment in a vacuum?
18. How would you expect your experimental results to change if you conducted this experiment on the moon or on another planet?
