New York City College of Technology
The City University of New York

Measuring the acceleration due to gravity

Laboratory activity description
Physics Department
Physics PHYS 1441, Summer session, 2020.

Introduction

Newton's law of universal gravitation gives the force F of attraction (gravity) between two objects of mass m_1 and m_2, as shown in **Fig. 1**.

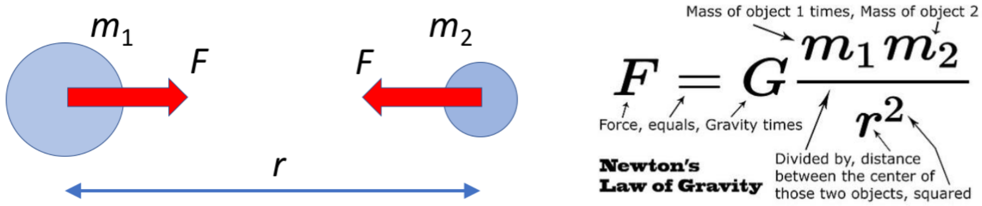

Figure 1 Newton's law of universal gravitation

Now let us consider two objects – our Earth of mass M and a ball of mass m. (That is, m_1=M and m_2=m in the formula in Fig. 1) At the Earth's surface, the weight of a ball m (which is mg where g is the acceleration due to gravity) is equal to the gravitational force of attraction between the ball and Earth:

$$mg = G\frac{Mm}{r^2} \qquad (1)$$

where $G = 6.67 \times 10^{-11}$ Nm^2/kg^2 is the universal gravitational constant, and r is the radius of Earth. We cancel m in both sides of equation (1) and receive the acceleration due to gravity:

$$g = G\frac{M}{r^2} \qquad (2)$$

This equation (2) can be used to determine acceleration due to gravity on any planet of mass M and radius r.

Procedure

This lab uses The Physics Aviary Acceleration on a Planet Simulation. Open the link:
https://www.thephysicsaviary.com/Physics/Programs/Labs/AccelerationOnPlanetLab/

Part I – Acceleration due to gravity on Earth

A) Measurements

1. Click on the link above to open the simulation in your browser.
2. Click 'Begin' to start the lab.
3. Click on 'Ball' at the top of the screen to set the ball properties. Choose "Plastic" as material and radius of 1.2 cm.
4. Click on 'Planet' at the top of the screen. Set the mass and radius of the planet to those for Earth. Approximate the Earth radius as r=6.5*10^6 m and the Earth mass as M=6*10^{24}kg.
5. Click 'Zoom in', then click on 'Ruler' and set the initial height of the ball to the minimum. Write down the initial height in Table 1.
6. Drop the ball to the ground by clicking "Drop" button.
7. Click on the grid on bottom right of the screen. Record data for the impact velocity at the ground, v, and the free fall time, t, in Table 1.
8. Click 'Reset', increase the initial height of the ball, drop the ball and record the impact velocity at the ground, v, and the free fall time, t, for this new height in Table 1.
9. Repeat measurements of the impact velocity at the ground, v, and the free fall time, t, each time increasing the initial height of the ball until the initial height reaches the maximum possible one on this ruler. For each measurement, record your data in Table 1. Add new lines in Table 1 if needed

Initial height h, m	Impact velocity V (m/s)	Free fall time, t (s)

Table 1. Data for the free fall on Earth.

B) Data analyses.

1. Plot a graph of V versus t for your data in Table 1.
   Determine the slope of the graph.
   What does the slope of this graph tell you?

2. How to determine the acceleration due to gravity on Earth from the data of your measurements in Table 1 of from the graph you just plotted?
   You can use the textbook or lecture notes to find out the answer on this question.
   Answer this question in writing in your report.

3. Following your reasoning in paragraph 2 above and a graph you made in paragraph 1, find the free fall acceleration *g* on Earth.
   Is the value of *g* you have found equal to 9.8 m/s^2? If not, why? What might be the reason for the difference of your results and 9.8 m/s^2?

   How far the result of your measured free fall acceleration is from the value usually given in textbooks, g=9.8 m/s^2? Use %Difference to characterize the relative difference of the free fall acceleration you found and 9.8 m/s^2.

4. Plot a graph V^2 vs h for the data in Table 1. Find the slope of the graph. What is the meaning of the slope?

   How to determine the acceleration due to gravity, *g*, from the graph you plot in this paragraph 4?
   You can use the textbook or formulas in lecture notes to find out the answer on this question. Answer this question in writing in your report.

5. Find the acceleration due to gravity from the graph and your reasoning in paragraph 4 above.

6. Compare the value you found with that you obtained earlier in paragraph 3 above.
   Are the two values the same?
   Why? Explain in writing.

<u>Part II – Acceleration due to gravity on Venus</u>

Venus is the second planet (counting from the Sun) in our solar system. Venus' mass and the radius can be approximated as M=5*10^{24} kg and r=6*10^6 m.

1. Following the same steps as in Part I, determine the free fall acceleration on Venus.

For that, click on "Planet" on the screen and set the mass and radius of the planet to those for Venus. Then, collect your data, record it in Table 2, plot the graphs *V* vs *t* and V^2 vs *h*, and find the value for the acceleration due to gravity from both graphs.

Initial height h, m	Impact velocity V (m/s)	Free fall time, t (s)

Table 2. Data for the free fall on Venus.

2. Is the acceleration due to gravity on Venus larger or smaller than the acceleration due to gravity on Earth? Why? If different, in how many times? Describe in writing.

In *Conclusion* of your lab report, summarize your findings and methods you use to determine the acceleration due to gravity.

To get full point, in your report answer questions 1 and 2 below and show your solution of the questions.

Questions:

1. You determined the free fall acceleration on Venus in the lab activity above. If it takes 2 seconds for an object to fall from a certain height on Earth, how much time it takes for an object to fall from the same height on Venus?

2. In a 2014 film “Interstellar”, astronauts landed to planet Miller orbiting the star called Gargantua, to determine if the humanity can escape there from Earth. According to Interstellar Wiki (https://interstellarfilm.fandom.com/wiki/Miller_(planet)) the acceleration due to gravity is “punishing” 130% of that on Earth. Assuming the density of Miller is the same as the density of Earth, find the mass of Miller.

   Is the mass of Miller bigger or smaller than that of Earth? In how many times?

   Note: Approximate the Earth density as 5,500 kg/m^3, and assume that Miller has an ideal spherical shape. The Earth mass and radius are given above in this lab manual.

The online lab handout is designed by Dr. G. Kolmakov. The handout partially uses the text from the Physics Department of the City College of New York, CUNY. Special thanks to Profs. Vinod Menon and Claude Telesford.