Calculate Gravitational Acceleration

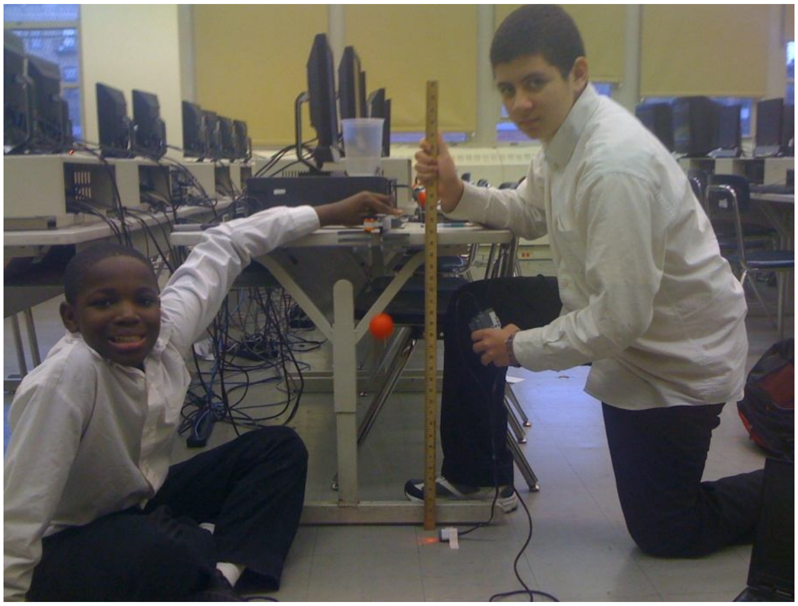
Subject Areas	Algebra, measurement, physics, science and technology
Associated Unit	None
Associated Lesson	None
Activity Title	Calculate Gravitational Acceleration
Header	Insert image 1 here, right justified to wrap

Image 1

ADA Description: Students performing gravitational acceleration LEGO experiment

Caption: Calculate g with LEGO Mindstorms

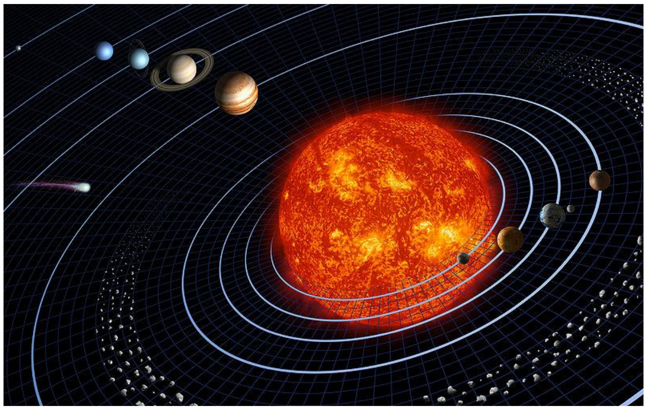
Image file name: CalculateGravitationalAccelerationImage1.jpg



Grade Level	7 (6-8)
Time Required	50 minutes
Group Size	4

Insert Image 2 here, centered

Image 2
ADA Description: Gravitation keeps the planets in orbit around the sun
Caption: The Solar System
Image file name: CalculateGravitationalAccelerationImage2.jpg
Source/Rights: Public Domain
http://en.wikipedia.org/wiki/File:Solar_sys.jpg



Summary

Students explore the natural phenomenon of gravity through the use of the LEGO Mindstorms kit and the included Data Logging software. First, students learn about the role of gravity in various phenomena such as gravity keeping a planet in orbit around the sun and free-falling objects. Students become familiar with Newton's universal law of gravitation and calculate the theoretical value for gravitational acceleration, g. Next, the students construct a simple robot design as the one illustrated in the LEGO Mindstorms manual. The students add on the robot arm attachment illustrated in the included attachment. Students actively participate in a free-fall activity using the LEGO Mindstorms software, LEGO light sensor, and Data Logging software. Students calculate an experimental value for the gravitational acceleration experienced by all objects on Earth to a reasonable approximation.

Engineering Connection

Newton's law of universal gravitation accounts for most of the detailed information we have regarding our solar system. Even though we have not traveled to any other planets or the Sun, we are able to determine the masses of celestial bodies such as the various planets and the Sun by relating the laws of gravity to their respective orbits. A planet maintains its orbit because of the gravitational pull that it experiences from the Sun. Knowing this information allows for the successful deployment of satellites to study our solar system and for communication purposes such as GPS.

Engineering Category Relates physics concept to engineering

Keywords gravitational acceleration, gravitational constant, robotics, sensor, universal law of gravitation

Educational Standards

- New York State science: 1.1, 1.2, 2.1.12, 2.1.13
- New York State math: 1.2.31, 1.2.32, 1.2.33, 1.3.61, 3.2.15

Pre-Requisite Knowledge Basic algebra, LEGO Mindstorms software programming, variables and equations

Learning Objectives

After this activity, students should be able to:

- Explain and use Newton's law of universal gravitation
- Describe various phenomena where gravity plays a role
- Identify the value of g, using both theoretical and experimental means

Materials List

Each group needs:

- LEGO NXT kit
- Mindstorms software 2.0 with Data Logging
- Long serial cable included in the kit
- Calculator
- Copy of attached worksheet

To share with the entire class:

- Meter stick
- Scotch tape
- Chart where the students can record the values of g obtained experimentally and theoretically for comparison.

Introduction / Motivation

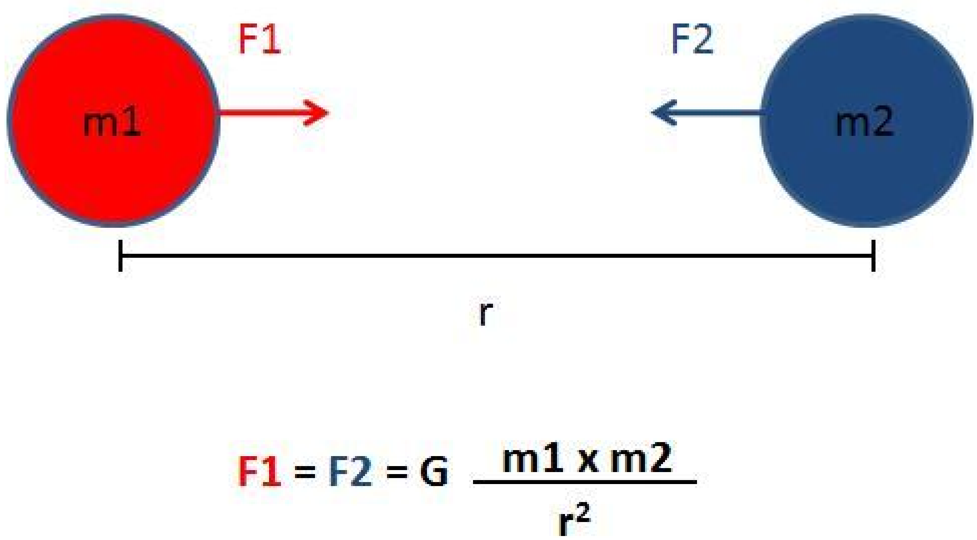
Can anyone tell me what is responsible for objects falling to the ground when we release them? Why don't these objects remain where they are when we release them, or perhaps "fall" in the opposite direction, upwards towards the sky? (Give the students some time to respond here.) Gravity is the correct answer, but does anyone know the true nature of gravity? Why does it exist? What causes gravity? What is the law of universal gravitation and to whom do we credit this remarkable discovery?

Every planetary body, including Earth, has its own gravitational field which exerts an attractive force on all objects. This attractive force originates from the object's mass and is directed toward its center. Because of this attraction towards the center of the Earth, all objects fall toward this center, which from our perspective is the ground. In addition, not only planetary bodies but every object with mass exerts a gravitational force. The force of gravitational attraction of two bodies is proportional to the product of their mass and inversely proportional to the square of their distance. Newton expressed this statement in a mathematical equation:

$$F=Gm_1m_2/r^2$$

Insert Image 3 here, centered

Image 3 **ADA Description:** Force of attraction between two point masses **Caption:** Newton's Law of Universal Gravitation **Image file name:** CalculateGravitationalAccelerationImage3.jpg **Source/Rights:** Copyright 2010 Michael Hernandez



Vocabulary / Definitions

Word	Definition
gravity	The net attractive force exerted by the Earth on all objects within the vicinity of its gravitational field.
gravitation	A natural phenomenon by which bodies with masses attract one another.
sensor	Any device that receives a signal or stimulus and responds to it in a distinctive manner.
orbit	The path followed by a celestial body or (man-made) satellite as it revolves around another body.

Procedure

Before the Activity

- Construct and program a robot claw similar to that illustrated in the attached worksheet.

With the Students

1. Divide the class into groups of four.
    a. Make sure each group has a calculator, Scotch tape, and a printout of the attached worksheet.
2. Introduce the students to the free-fall equation which they will use to calculate the value of g:

$\Delta y = y_0 + v_0 t - 1/2gt^2$

a. Make sure to explain each variable in the equation and what they mean:
    i. Δy: The change in the height of the ball from time 0 to the time it hits ground (Describe why this value is negative).
    ii. $y_{0:}$ Initial height of ball (This is our starting point = 0)
    iii. $v_{0:}$ Initial velocity of ball (in our case 0 ft/sec)
    iv. t: time in seconds
    v. g: gravitational acceleration (This is what we are solving for)

3. Go over how the teams will conduct their experiments, explained in detail in the attached worksheet.

4. Give a demonstration how the light sensor together with the Data Logging software work.

5. Have the teams designate a measurement taker, data recorder, robot holder, light sensor placement holder and program starter.
    a. Designate what each role is responsible for:
        i. Measurement taker: records initial height of the ball (measured from the bottom of the ball) and align the path of the falling ball with the light path.
        ii. Data recorder: Fills out the worksheet.
        iii. Robot holder: In charge of holding the robot claw steady at the desired height.
        iv. Light sensor placement holder and programmer: Holds the light sensor steady at the ground and starts the Calculate g robot program.

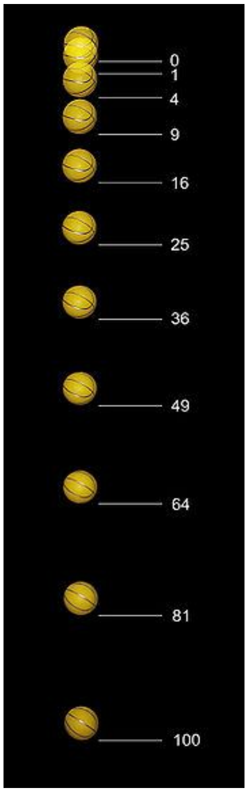
6. Instruct students to follow the directions on their worksheet making sure that each student carries out their role responsibly as real scientists would.

7. Once the students get a value for g at each designated height, instruct them to write it on the large chart so that the whole class can check and compare values.

8. Once all groups complete the worksheet, bring the class together for a group discussion regarding the values obtained. Is there a general agreement between values of g? Can anyone explain why there are differences? Have groups calculate their % error after giving them the formula. Let them know that in science, it is acceptable to have some error within a reasonable range.

Insert Image 4 here, centered

Image 4 **ADA Description:** Ball falling freely under influence of gravity **Caption:** Falling Ball **Image file name:** CalculateGraviationalAccelerationImage4.jpg **Source/Rights:** Public Domain http://en.wikipedia.org/wiki/File:Falling_ball.jpg



Attachments

Calculate Gravitational Acceleration Worksheet (CalculateGravitationalAccelerationWorksheet.docx)

Calculate Gravitational Acceleration Robot Program (CalculateGravitationalAcceleration.rbt)

Troubleshooting Tips

Test the robot design and program to get comfortable with the experiment prior to using this activity with the class.

Investigating Questions

None

Assessment

Pre-Activity Assessment

Guessing g: Ask the students to guess at what they think the value of g actually is and record a number of these guesses on the large chart in front of class.

Activity Embedded Assessment

Does Height Really Matter: Ask the students to predict whether the different starting heights would have an effect on the value of g? What about the velocity?

Post-Activity Assessment

Now that's g: Now that the students know the value of g, ask them what they can tell us about the position of a free-falling ball at time t=0, t=1, t=2, etc.

Activity Extensions

None

Activity Scaling

- For lower grades, use one robot designed and programmed prior to class and have the groups come up one at a time to record measurements.
- For upper grades, have the members design and program the robots themselves. Also, pose questions as to what properties of the items being dropped would affect the value of g. Would these properties matter in a vacuum?

Redirect URL http://gk12.poly.edu/amps-cbri/

Owner Michael Hernandez

Contributors Michael Hernandez, Carole Chen

Copyright The development of this activity was supported by Project AMPS under a GK-12 Fellows grant 0741714 from the National Science Foundation.

Version: February 2010