PHET Simulation Activity Making : Newton's Law of Universal Gravitation

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Abstract

This paper discusses details about Newton's Law of Universal Gravitation and the corresponding activities and guided questions to further understand the topic. The activity involves the use of PhET Simulations, an online platform that can be used to simulate physical systems and gather results.

1. Introduction

While an apple might not have struck Sir Isaac Newton's head as myth suggests, the falling of one did inspire Newton to one of the great discoveries in mechanics: The Law of Universal Gravitation. Pondering why the apple never drops sideways or upwards or any other direction except perpendicular to the ground, Newton realized that the Earth itself must be responsible for the apple's downward motion.

Theorizing that this force must be proportional to the masses of the two objects involved, and using previous intuition about the inverse-square relationship of the force between the earth and the moon, Newton was able to formulate a general physical law by induction.

While Newton was able to articulate his Law of Universal Gravitation and verify it experimentally, he could only calculate the relative gravitational force in comparison to another force. It wasn't until Henry Cavendish's verification of the gravitational constant that the Law of Universal Gravitation received its final algebraic form:

$$F = G\frac{Mm}{r^2}$$

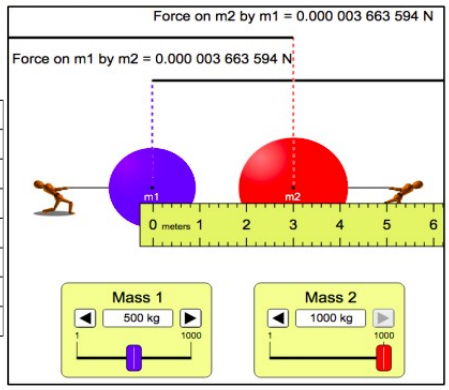
Where F represents the force in Newtons, M and m represent the two masses in kilograms, and r represents the separation in meters. G represents the gravitational constant, which has a value of $F = G\frac{Mm}{r^2}$. Because of the magnitude of G, gravitational force is very small unless large masses are involved.

2. Results and Discussion

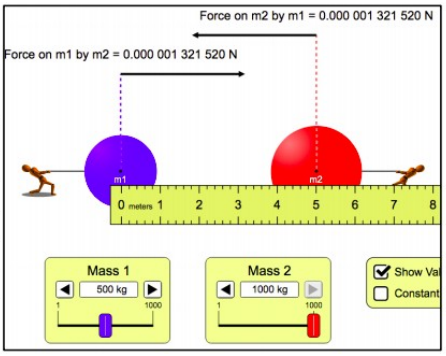
1.) Find and open the PhEt simulation entitled, "Gravity Force Lab". (https://phet.colorado.edu/en/simulation/gravity-force-lab)

2.) Complete the tables below by changing the various settings. Note: Record the values for force in scientific notation and to 2 significant figures. Move the meter stick to measure the distance between the center of mass 1 to the center of mass 2. See the pictures on the right for each table.

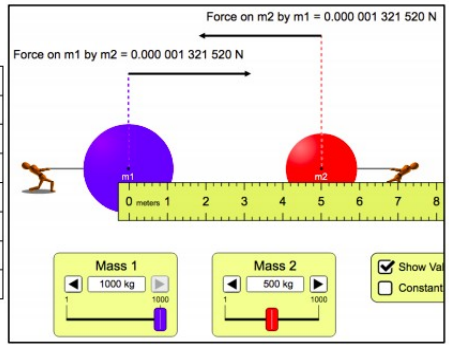
What is the relationship between F and r?			
Table 1 – Varying r, the distance between the masses			
Force = $F_1 = F_2$ / N	**m_1 / kg**	**m_2 / kg**	**r / m**
3.7×10^{-6}	500	1000	3
	500	1000	4
	500	1000	5
	500	1000	6
	500	1000	7



What is the relationship between F and m_1?			
Table 2 – Varying the mass of m_1			
Force = $F_1 = F_2$ / N	**m_1 / kg**	**m_2 / kg**	**r / m**
1.32×10^{-6}	500	1000	5
	600	1000	5
	700	1000	5
	800	1000	5
	900	1000	5



What is the relationship between F and m_2?			
Table 3 – Varying the mass of m_2			
Force = $F_1 = F_2$ / N	**m_1 / kg**	**m_2 / kg**	**r / m**
1.32×10^{-6}	1000	500	5
	1000	600	5
	1000	700	5
	1000	800	5
	1000	900	5



3.) Using your data from tables 1, 2, and 3, create graphs for the relationships of F versus r, F versus m_1 , and F versus m_2 using a graphing program such as Excel or Logger Pro. In your graphing program determine the best-fit line or curve for each of the graphs. For the F versus r graph, try the "inverse square" best-fit curve. What is the correlation for the fit? _____. Provide a sketch for each of the relationships below. Make sure to label the axis including units. Also, include the equation for the best-fit line/curve for the graph. Do not provide a numbered scale on the x and y-axis

4.) One of the graphs should appear to be an exponential decay curve. Determining the relationship between the variables is more difficult. One way is to use the equation for the best-fit line given by your graphing program. Write the equation here for the inverse square curve: _____. Given the high correlation for the curve fit, F is considered proportional to $1/r^2$.

5.) Combine the proportionalities into one equation for F. Fill in the blanks below using the variables F, m_1 , m_2 , and r. k is a constant.

$$\_\_\_\_\_ = k\frac{\_\_\_\_\_ \times \_\_\_\_\_}{\_\_\_\_\_}$$

6.) The value of the constant k can be determined from one of your proportional graphs. Use F versus m_1 . Write the value for the slope of the graph? (look at your equation)_____.

7.) Using our new relationship from (5), $F = k m_2 m_1 / r^2$ for your F versus graph. Use the value of the slope, m_2 = 1000kg, r = 5m, and calculate a value for k. Write the value for k:_____.

References

https://www.physicsclassroom.com/class/circles/Lesson-3/Newton-s-Law-of-Universal-Gravitation

https://phet.colorado.edu/en/simulation/gravity-force-lab