Experiments in Physics
**Inquiry Lab – Newton's Universal Law of Gravitation – PhET simulation**
Name_____Score_____

Introduction: An interesting aspect of our universe is that anything that has mass has a gravitational pull. In other words, masses "attract" other masses by pulling on each other. Isaac Newton realized that the pull created by masses, known as gravity, applied to all masses including small objects, like apples, and large celestial objects, like the Moon and the Earth. In 1687 Newton discovered the mathematical relationship that exits between masses. The relationship that Newton's discovered is one of the most important relationships in Physics and has helped humans put satellites into orbit and understand the motion of the planets in the solar system. The purpose of this lab is to discover the relationship that exists between masses known as Newton's Universal Law of Gravitation.

Instructions:
  (1) Find and open the PhET simulation entitled, "Gravity Force Lab". (https://phet.colorado.edu/)
  (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
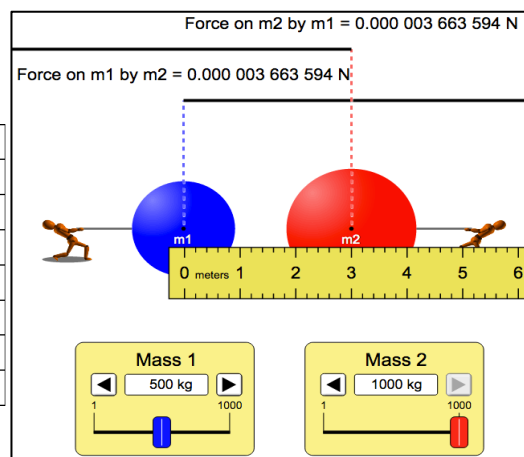
What is the relationship between F and m_1?			
Table 2 – Varying the mass of m_1			
Force = $F_1 = F_2$ / N	m_1 / kg	m_2 / kg	r / m
1.32×10^{-6}	500	1000	5
	600	1000	5
	700	1000	5
	800	1000	5
	900	1000	5
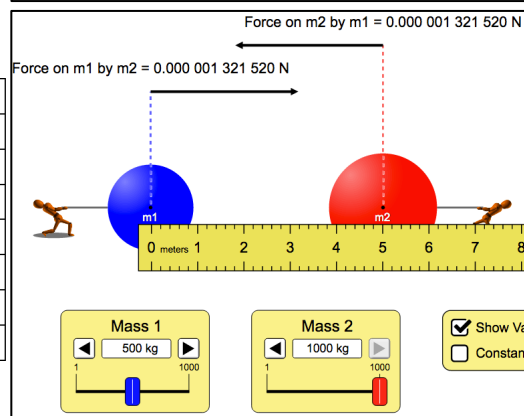
What is the relationship between F and m_2?			
Table 3 – Varying the mass of m_2			
Force = $F_1 = F_2$ / N	m_1 / kg	m_2 / kg	r / m
1.32×10^{-6}	1000	500	5
	1000	600	5
	1000	700	5
	1000	800	5
	1000	900	5
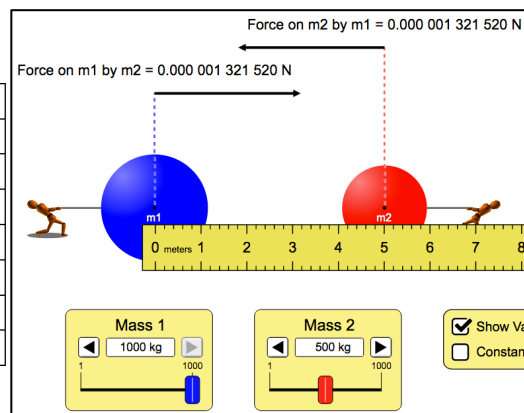
(3) Using your data from tables 1, 2, and 3, create graphs for the relationships of F versus r, F versus m_1, and F versus m_2 using a graphing program such as Excel or Logger Pro. In your graphing program determine the best-fit line or curve for each of the graphs. For the F versus r graph, try the "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.
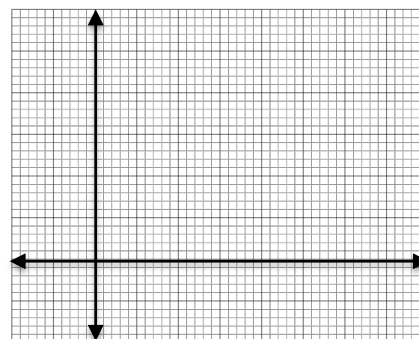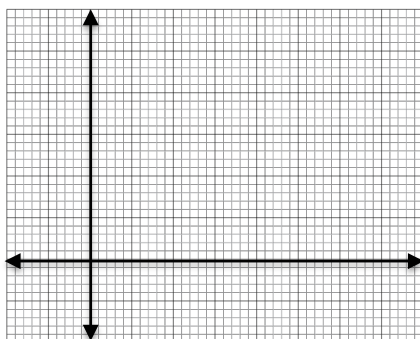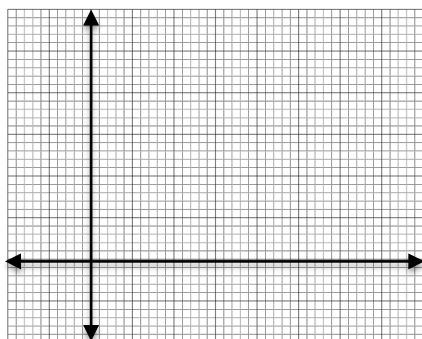
(4) When a graph is linear and passes through the origin, the relationship between the variables is said to be proportional. When two quantities are proportional, the quantities differ by the multiplication of a constant. For example, if F is proportional to m_1 then F = (constant)*m_1.

(5) Write the two equations that represent the proportional relationships in your sketches from the best-fit lines in your graphing program. Do not include the y-intercept in the equation. Within experimental uncertainties, we will assume the intercept is zero.

(1) _____ (2)_____

(6) 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 $1/r^2$.

(7) 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.

$$\underline{\quad\quad} = k\,\frac{\underline{\quad\quad}\times\underline{\quad\quad}}{\underline{\quad\quad}}$$

(8) 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) _____

(9) Using our new relationship from (7), $F = \dfrac{km_2}{r^2} \cdot m_1$ for your F versus m_1 graph. Use the value of the slope, m_2 = 1000kg, r = 5m, and calculate a value for k. Write the value for k: _____.

(10) The actual value for k is known as the Universal Gravitational Constant, G. $G = 6.67 \times 10^{-11}\, Nm^2 kg^{-2}$.

(11) Write the complete formula for Newton's Universal Law of Gravitation in the box below. Using the internet check if your formula is correct.

(12) Using the equation for Newton's Universal Law of Gravitation (a) determine the force of attraction between the Earth, $m_{Earth} = 5.98 \times 10^{24}\, kg$, and the Moon, $m_{Moon} = 7.36 \times 10^{22}\, kg$, if the average mean distance between the Earth and the Moon is $3.84 \times 10^8\, m$. (b) If a single Saturn V rocket has a thrust of $3.5 \times 10^7\, N$, how many Saturn V rockets is the force in (a) equivalent to?