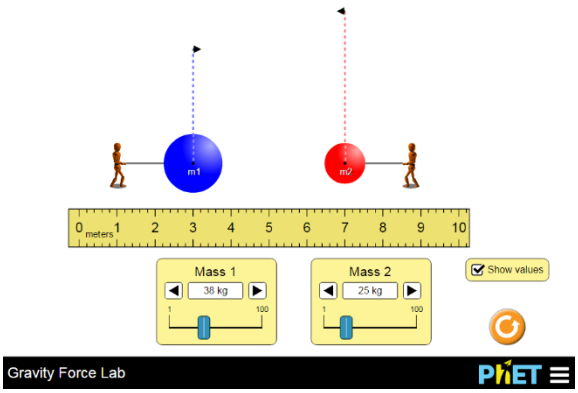
Determination of the Force of Gravity

Go to **http://tinyurl.com/ma8rw9x**



Learning Goal: Students will investigate the variables that affect the force of gravity on objects.

Background information:

Variable-A variable is any factor that can be changed or controlled

Independent Variable (IV) – something that is changed by the scientist

- What is tested
- What is manipulated

Dependent Variable (DV) – something that might be affected by the change in the independent variable

- What is observed
- What is measured
- The data collected during the investigation

INSTRUCTIONS: Open up the Gravity simulation on the PhET website.

1. Get familiar with the simulation by moving the figures back and forth as well as changing the mass of the spheres.

2. Circle the different variables that can be found in this simulation.

Distance between figures	**Mass of the spheres**
Force	**Size of the figures**
Strength of the figures	**Size of the meter stick**

What do you think the size of the arrows on top of each sphere represent?
They are vector arrows that communicate visually the magnitude (size) and the direction of the force.

True or False

1. **Gravity is a force that can be changed. T/F**
2. **The more mass an object is, the smaller the force of gravity. T/F**
3. **As one object gets closer to another object, the force of gravity will increase. T/F**
4. **The Sun has a greater gravitational force than Jupiter. T/F**

Circle the Correct Answer

An object with more mass has **more/less** gravitational force than an object with a smaller mass.

Objects that are closer together have **more**/**less** of a gravitational force between them than objects that are further apart.

Qualitative Observations

1. How does the changing the separation of the objects affect the force between them? (increases, decreases, not affected)

   The more separation two objects have, the more the force between them **decreases**.

2. What happens to the force between the objects when mass 1 increases? (increases, decreases, not affected)

   When mass 1 increases the force between the objects **increases**.

3. What happens to the force between the objects if Mass 2 decreases? (increases, decreases, not affected)

   If Mass 2 decreases, the force between the objects **decreases.**

4. What is the ratio of the force on the blue object to the force on the red object? What if the mass of the blue one is twice as big as the red object? Explain.

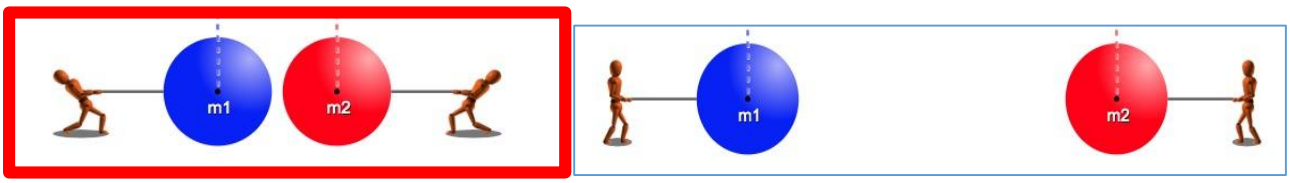
   $F_{Blue} : F_{Red} = 1 : 1$. If the Mass of the blue object is twice as big

5. What direction are the gravitational forces acting on the objects?

   Always toward each other (Attractive)

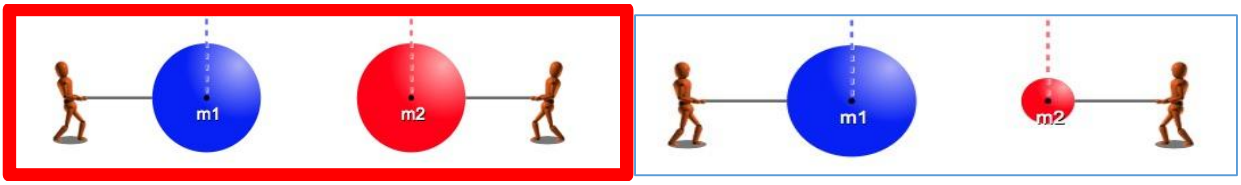
Circle the Correct Answer

Circle the pair with the greater gravitational force.

1. 

Explain why you chose the diagram you did.

The masses look to be the same but the distance between the objects seems to be a lot less, and with increased distance, there is an increase in the mutual Force between the objects

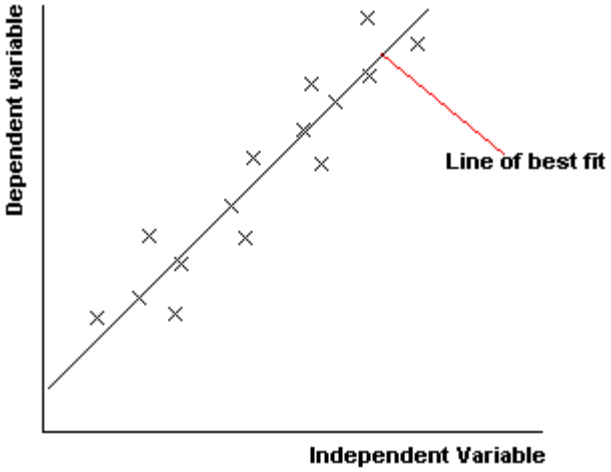
2. 

Explain why you chose the diagram you did.

The mass of m1 for each option looks to be the same, but the mass of m2 looks to be less. Assuming that, the left option seems to be the better option because the combined mass seems larger.

Analysis Question: Why do you think Saturn and Jupiter have more moons than the other planets in our solar system?

Graph showing a positive correlation between figures



Quantitative

It is now time to build a model.

1. What THREE things can we change/vary?
   Mass 1, Mass 2, distance (separation)

2. Select an independent (IV) and dependent variable (DV) and constant C

   a. DV Force (N) on m2 by m1

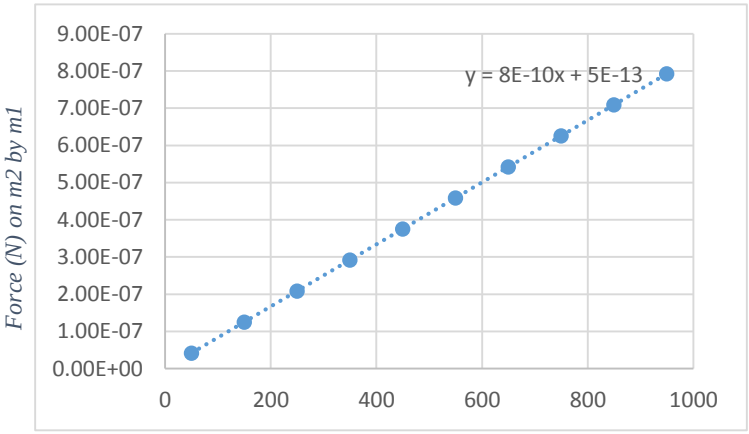
   b. IV Mass of 1 (kg)

   c. C Mass of 2 (kg) = 200;

      and Distance (m) = 4;

3. Collect 10 data points and graph. Summarize what you changed and what happened below the table

Manipulated (Independent) Variable	Dependent Variable
Mass of 1 (kg)	Force (N) on m2 by m1
50	4.17E-08
150	1.25E-07
250	2.09E-07
350	2.92E-07
450	3.75E-07
550	4.59E-07
650	5.42E-07
750	6.26E-07
850	7.09E-07
950	7.93E-07



4. Select a new independent and dependent variable and constant

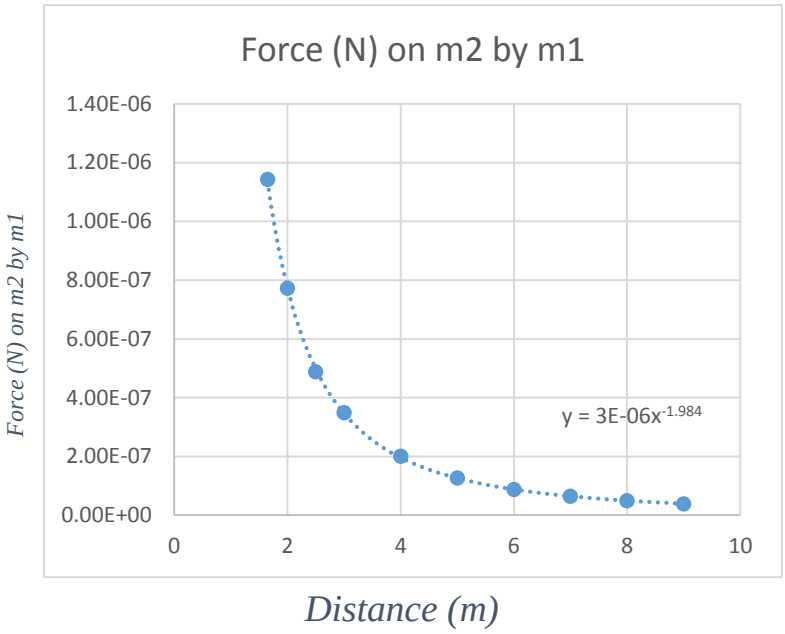
   a. DV Force (N) on m2 by m1

   b. IV Distance (m) between m2 and m1

   c. C Mass (kg) of m2 and mass m1

5. Collect 10 data points and graph. Summarize what you changed and what happened below the table

Manipulated (Independent) Variable	Dependent Variable
Distance (m)	Force (N) on m2 by m1
1.65	1.14E-06
2	7.73E-07
2.5	4.88E-07
3	3.49E-07
4	2.01E-07
5	1.27E-07
6	8.74E-08
7	6.45E-08
8	4.96E-08
9	3.90E-08



6. Repeat the varying mass vs. force experiment, changing the second mass.

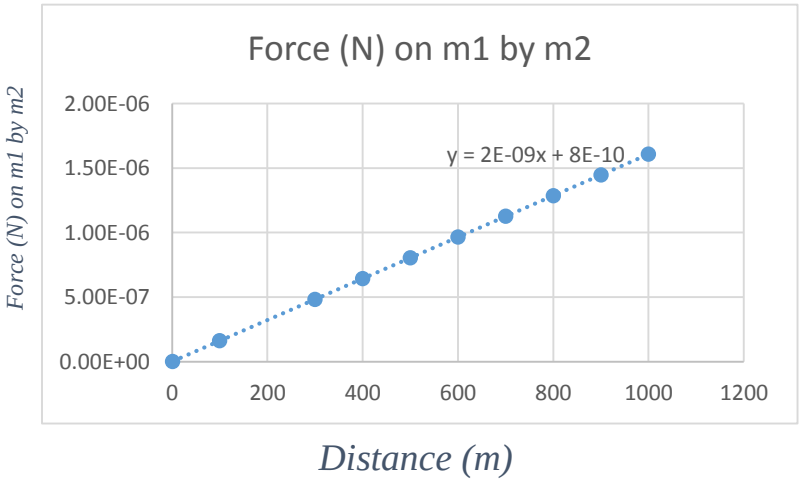
   a. DV Force (N) on m1 by m2

   b. IV Mass of 2 (kg)

   c. C Mass of 1 (kg) = 400;

      and Distance (m) = 4;

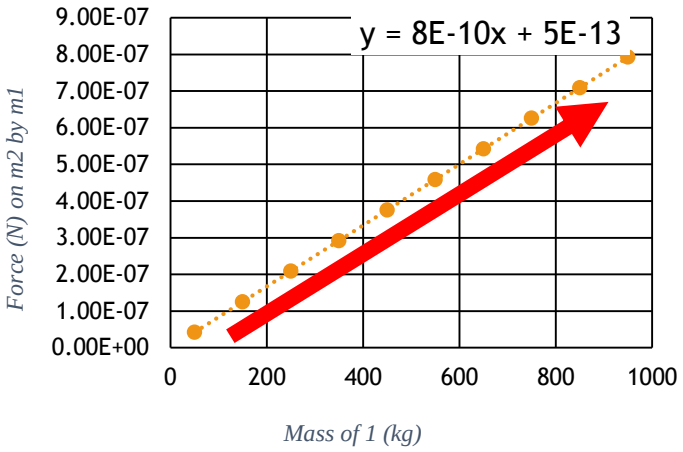
Manipulated (Independent) Variable	Dependent Variable
Mass of 2 (kg)	Force (N) on m2 by m1
1	1.61E-09
100	1.62E-07
300	4.83E-07
400	6.45E-07
500	8.05E-07
600	9.66E-07
700	1.13E-06
800	1.29E-06
900	1.45E-06
1000	1.61E-06



Questions

1. Explain why varying the second mass had the same effect on the force as varying the first mass.

   The Force is proportional to the masses of the objects. When either mass is changed, the force changes proportionally.



2. What is the relationship (proportionality) between Mass and force? What happens to the force if you double the mass of the blue object? What happens to the force if you then triple the red object's masses?

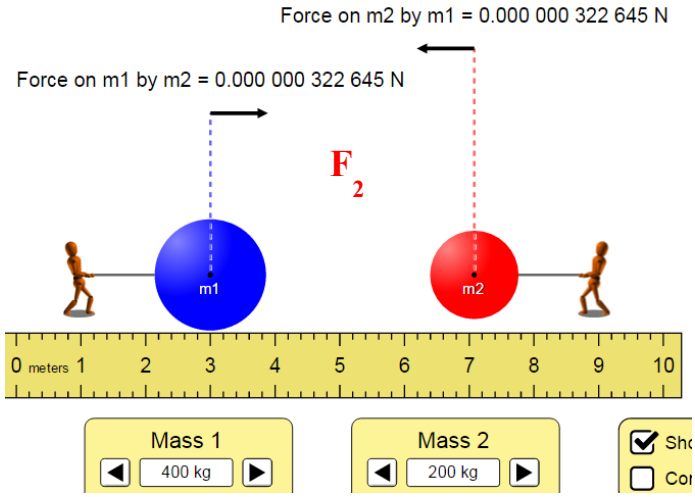
   Force proportional to the mass of the object

   $F \propto M_1$

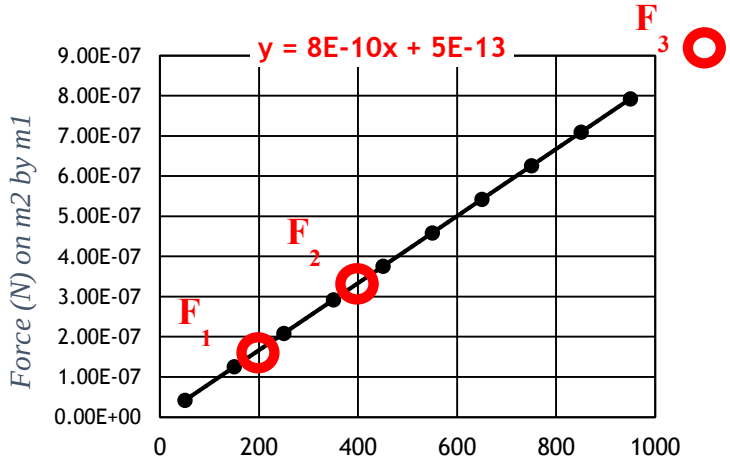
   Distance = 4 m:
   Mass 1 = 200 kg » Mass 2 = 200 kg
   F_1 = 1.60001E-07
   M1 x2 = 400 kg » Mass 2 = 200 kg
   F_2 = 3.20001E-07
   $F_2 / F_1 \cong 2$

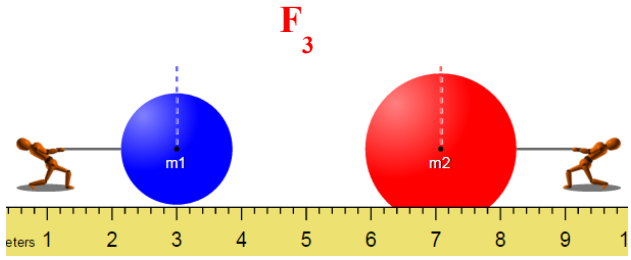
   Double mass → doubles force

   Mass 1 = 400 kg » Mass 2 = 1200 [M1x3]
   F_3 = 2.4008E-06 [F_2 = 4.008E-07 (Q 6)]
   $F_3/F_2 \cong 6$



   THEN triple red → triples force, so net change is 6 times greater





Quantitative Question 6 above; repeat experiment

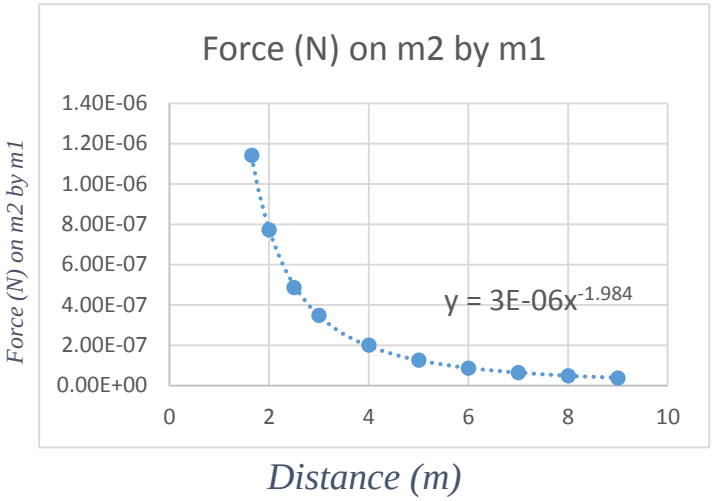
3. What is the relationship between distance and the force of gravity? What happens if you triple the distance between the objects? Half the distance between them?

Force is inversely related to the square of the distance

$$F \propto \frac{1}{d^2}$$

Triple distance → Force decreases by 9

$$\text{Distance} = 2\text{ m} \gg F_1 = 7.73\text{E-}07\text{ N}$$
$$\text{x3} \quad = 6\text{ m} \gg F_2 = 8.74\text{E-}08\text{ N}$$
$$\frac{F_1}{F_2} \cong 9\,;\frac{F_2}{F_1} = \frac{1}{9} = \frac{1}{3^2}$$



Half distance → 4 time greater force

4. Combine your proportions between Mass 1 (**m_1**), Mass 2 (**m_2**) distance (**r**) into a single proportion to the Force of gravity (**F_g**).

$$F \propto M_1 \times M_2 \times \frac{1}{d^2}$$
$$F \propto \frac{M_1\, M_2}{d^2}$$

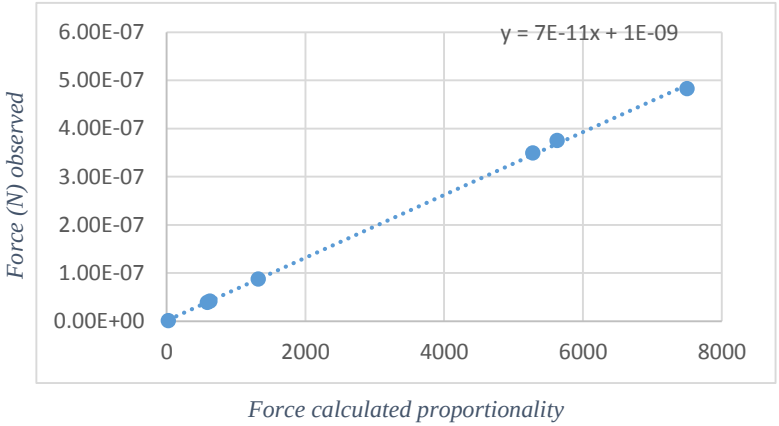
Show your instructor your proportionality before you continue.

5. Does your lab data for **m_1**, **m_2**, and **r** does equal **F_g**? Also work out your units, do they equal a unit of force?

The values do not match. Neither do the units.

6. Make a graph of Force vs. your proportionality

	Fg = (m1 x m2)/d^(2)	Observed (Fg)
Experiment 1	625	4.17E-08
Experiment 1	5625	3.75E-07
Experiment 1	11875	7.93E-07
Experiment 2	586	3.90E-08
Experiment 2	1319	8.74E-08
Experiment 2	5278	3.49E-07
Experiment 3	25	1.61E-09
Experiment 3	25000	1.61E-06
Experiment 3	7500	4.83E-07
Slope formula	(y2 - y1)/ (x2 - x1)	6.67384E-11



7. Determine the gravitational constant (**G**) that will satisfy your units

G= 6.67384×10^{-11}

8. Write your full formula and check with your instructor.

$$F_{gravity} = \frac{GMm}{d^2}$$

$$G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$$

In the equation:

F is the force of gravity (measured in Newtons, N)
G is the gravitational constant of the universe and is always the same number
M is the mass of one object (measured in kilograms, kg)
m is the mass of the other object (measured in kilograms, kg)
r is the distance those objects are apart (measured in meters, m)
So if you know how massive two objects are and how far they are apart, you can figure out the force between them.

In summary, we calculated the gravitational constant using given force data and deriving or figuring out proportionality relationships between Mass and gravitational force as well as distance and gravitational force.

We found that: The Gravitational Force proportional to the mass of the object. Also that gravitational Force is inversely related to the square of the distance.
We put formulas describing these relationships together and came up with the formula:

$$F \propto \frac{M_1 M_2}{d^2}$$

However when we plotted data using this formula against actual force data we got different results. Plotting our calculated results against the actual gravitational force data, we found there to be a difference that grew in magnitude by a factor of 6.67×10^{-11} we inserted this into our original equation and this turned out to be the Gravitational force constant that is part of Newton's law of universal gravitation (see above)