TechLab: The Laws of Attraction

details on the gravitational attraction between two bodies

PERIOD	1.		
	2.		
GROUP	3.		
	4.		

• Purpose •

In this activity you will investigate the quantitative nature of gravitational attraction.

• Apparatus •

___ computer (or tablet)

___ PhET simulation: "Gravity Force Lab" (available at http://phet.colorado.edu)

Note: The HTML5 version of the sim was used to develop this activity; some procedures won't work in the "classic" Java applet version.

• Setup •

1. Turn the computer on and allow it to complete its start-up sequence.

2. Open the simulation "Gravity Force Lab." If you're not sure how to run the simulation, ask your instructor.

3. Examine the initial setup displayed in the sim. Label m1, m2, Ruler, Reset, Show Values, Mass 1 selector, Mass 2 selector.
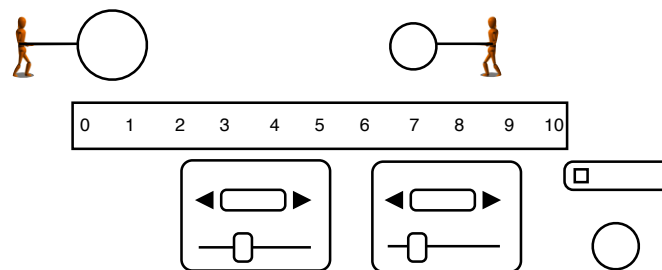
• Procedure •

1. THE BASICS

a. What **two distinct changes** can you make to the blue mass to **increase** the attraction? Be specific (i.e., don't use the word "change" in your response; instead, describe the changes using words such as "increase," "decrease," "bigger," "smaller," "toward," "away," etc.).

i.

ii.

b. Reset the sim using the onscreen Reset button. What **two distinct changes** can you make to the red mass to **decrease** the attraction? Again, be specific.

i.

ii.

                             db

c. Make sure the onscreen Show Values checkbox is checked.

i. What's the largest gravitational force you can produce between the two masses? (Note: it's convenient to express the forces in this sim in terms of piconewtons—pN. One piconewton is 0.000 000 000 001 N.)

F = _____

ii. What masses did you use and what was the distance between them?

iii. What's the smallest gravitational force you can produce between the two masses?

F = _____

iv. What masses did you use and what was the distance between them?

2. STATIC FORCE MATCH GAME I: GOING THE DISTANCE
There is clearly a relationship between force, mass, and distance. The rest of the lab will help find it.

a. Arrange the simulated apparatus.
i. Reset the sim.
ii. Move the blue mass (m1) back to the zero-meter mark on the ruler. (The location of a mass is indicated by the black dot at the mass's center. Notice that the ruler's zero is not at the end of the stick.)
iii. Move the ruler up so that the top edge of the ruler is slightly below the "Force on m1 by m2" arrow.
iv. Set m1 to 1 kg.
v. Move the red mass (m2) to 1.00 m on the ruler. If possible on your device, zoom in to check your accuracy.
vi. Set m2 to 1 kg.

b. What is the force of attraction in this—the baseline—arrangement? F = _____.

c. Move the red mass (m2) to 2.00 m on the ruler. If possible, zoom in to check your accuracy.

d. Increase the red mass (m2) until the baseline force (recorded in 2.b. above) is achieved (most nearly—a perfect match may not be possible given the limitations of the sim). Record the new mass in the Data Table below.

e. Repeat this process to find force-matching red masses at 3.00 m, 4.00 m, 5.00 m, etc., if it is possible in the sim. Record each value—if found—on the Data Table.

Distance d (m)	1.00	2.00	3.00	4.00	5.00
Mass m2 (kg)	1				

Distance d (m)	6.00	7.00	8.00	9.00	10.00
Mass m2 (kg)					

db

f. Could the same effect be achieved in each case if the moved red mass (m2) were set to 1 kg and the blue mass (m1) had been changed? (Try it to find out.)

g. Describe the relationship between the changing mass (the mass that isn't kept at 1 kg) and the corresponding distance.
i. First choose one of these:

___m ∝ √(d)   ___m ∝ d   ___m ∝ d²   ___m ∝ 1/√(d)   ___m ∝ 1/d   ___m ∝ 1/d²

ii. Express the proportionality in words.

3. STATIC FORCE MATCH GAME II: TOTAL MASS RETAIN
a. Arrange the simulated apparatus.
i. Reset the sim.
ii. Move the blue mass (m1) back to the zero-meter mark on the ruler. (The location of a mass is indicated by the black dot at the mass's center.)
iii. Move the ruler up so that the top edge of the ruler is slightly below the "Force on m1 by m2" arrow.
iv. Set m1 to 1 kg.
v. Move the red mass (m2) to 1.00 m on the ruler. If possible on your device, zoom in to check your accuracy.
vi. Set m2 to 1 kg.

b. What is the force of attraction in this—the baseline—arrangement? F = _____.

c. Change the red mass (m2) to 2 kg.

d. Move the red mass (m2) until the baseline force (recorded in 3.b. above) is achieved (most nearly—a perfect match may not be possible given the limitations of the sim). Record the new distance in the Data Table below. (Note: the value can be recorded to the nearest centimeter—1/100th of a meter.)

e. Repeat this process to find force-matching distances for red masses of 3 kg, 4 kg, 5 kg, etc. Record each value on the Data Table.

Mass m2 (kg)	1	2	3	4	5
Distance d (m)	1.00				

Mass m2 (kg)	6	7	8	9	10
Distance d (m)					

db

f. Could the same effect be achieved in each case if the moved red mass (m2) were set to 1 kg and the blue mass (m1) had been changed? (Try it to find out.)

g. Describe the relationship between the distance and the corresponding mass .
i. First choose one of these:

___d ∝ √(m)　　　___d ∝ m　　　___d ∝ m²　　　___d ∝ 1/√(m)　　　___d ∝ 1/m　　　___d ∝ 1/m²

ii. Express the proportionality in words.

4. DYNAMIC FORCE I: VARY THE MASS
a. Arrange the simulated apparatus.
i. Reset the sim.
ii. Move the blue mass (m1) back to the zero-meter mark on the ruler. (The location of a mass is indicated by the black dot at the mass's center.)
iii. Move the ruler up so that the top edge of the ruler is slightly below the "Force on m1 by m2" arrow.
iv. Set m1 to 12 kg.
v. Move the red mass (m2) to 4.00 m on the ruler. If possible on your device, zoom in to check your accuracy. **Once set, do not move either mass during this procedure.**
vi. Set m2 to 12 kg.

b. i. What is the force of attraction in this—the baseline—arrangement? F_0 = _____.

ii. The ratio of this force to the baseline force (F/F_0) must be 1.00 since this force is the baseline force.

c. Double the red mass (m2 = 24 kg) and determine the new (F/F_0) ratio. (Hint: the answer is 2.00.) Record this value in the Data Table below (beneath the m1 | 2m2 heading).

d. Arrange the masses according to the subsequent headings. Determine the (F/F_0) ratio for each arrangement and record the results.

e. Create your own mass arrangements for the last two trials. Record the masses and the (F/F_0) ratios. Remember: do not change the distance between the charges.

Masses: m1, m2	m1 | m2	m1 | 2·m2	2·m1 | 2·m2	m1 | m2/2	m1/2 | m2/2
Force (F/F_0)	1.00				

Masses: m1, m2	2·m1 | m2/2	m1 | 3·m2	m1/3 | 6·m2		
Force (F/F_0)					

　　　db

f. Describe the relationship between the force and the corresponding masses.
i. First choose one of these:

___$F \propto m1 + m2$ ___$F \propto m1 \cdot m2$ ___$F \propto m1 / m2$

ii. Express the proportionality in words.

5. DYNAMIC FORCE II: VARY THE DISTANCE
a. Arrange the simulated apparatus.
i. Reset the sim.
ii. Move the blue mass (m1) back to the zero-meter mark on the ruler. (The location of a mass is indicated by the black dot at the mass's center.)
iii. Move the ruler up so that the top edge of the ruler is slightly below the "Force on m1 by m2" arrow.
iv. Set m1 to 12 kg. **Do not change the mass for the remainder of this procedure.**
v. Move the red mass (m2) to 4.00 m on the ruler. If possible on your device, zoom in to check your accuracy.
vi. Set m2 to 12 kg. **Do not change the mass for the remainder of this procedure.**

b. i. What is the force of attraction in this—the baseline—arrangement? F_0 = _____.

ii. The ratio of this force to the baseline force (F/F_0) must be 1.00 since this force is the baseline force.

c. Double the distance (move the red mass to 8.00 m) and determine the new (F/F_0) ratio. (Hint: the answer is 0.25.) Record this value in the Data Table below (beneath the 2d heading).

d. Arrange the distance according to the subsequent headings. Determine the (F/F_0) ratio for each distance and record the results.

e. Create your own mass arrangements for the last two trials. Record the masses and the (F/F_0) ratios. Remember: do not change the distance between the charges.

Distance d	d	2d	d/2	d/4	d/$\sqrt{2}$
Force (F/F_0)	1.00				

f. Describe the relationship between the force and the corresponding distance.
i. First choose one of these:

___$F \propto \sqrt{d}$ ___$F \propto d$ ___$F \propto d^2$ ___$F \propto 1/\sqrt{d}$ ___$F \propto 1/d$ ___$F \propto 1/d^2$

ii. Express the proportionality in words.

db

6. GETTING IT TOGETHER
a. How does gravitational attraction force relate to the masses and distance involved? Put together the proportionalities found in procedures 3 and 4. Express in symbols and words.

SYMBOLS   WORDS

• Post-Lab •

1. Each of the four diagrams below show configurations in which the gravitational attraction is the same. Record the correct value of m2 in each case for which it is not given.

m1 = 1 kg   m2 = 1 kg

m1 = 1 kg   m2 = 36 kg

m1 = 2 kg   m2 = _____

m1 = 3 kg   m2 = _____

2. Give two more correct and distinct mass combinations that would work. Mass values must be expressed in whole numbers. (m1 = 36 kg | m2 = 1 kg is correct but is not distinct; m1 = 5 kg | m2 = 8 kg is distinct but not correct)

a. _____   b. _____

3. The gravitational attraction between two 25-kg masses 2 meters apart is 10 nN. What is the attraction between them if they are

a. 4 meters apart? _____.   b. 1 meter apart? _____.