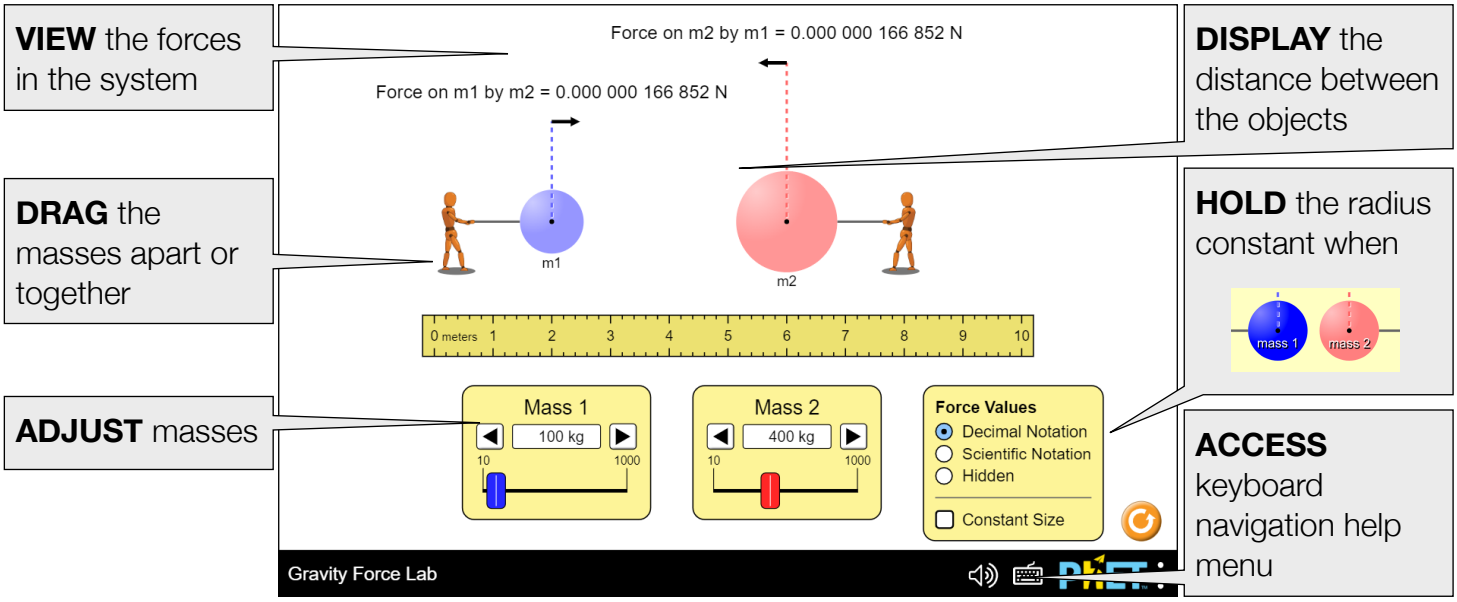
PhET Tips for Teachers

Gravity Force Lab

In ***Gravity Force Lab*** students observe the gravitational force that two objects exert on each other, and adjust the properties of the masses to see the effect on gravitational attraction.

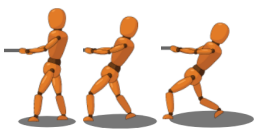


Insights into Student Use

- Students should measure distances from the center of mass, but we want them to discover this on their own. If they use something else, like distance between outer edges, they should find that their data doesn't make sense.
- We encourage students to construct their own ideas through exploration, and have found that referring directly to the "Universal Law of Gravity" may encourage some students to simply look up the relevant equation.

Model Simplifications

- The scale of the masses and distances allow students to explore the gravitational force between everyday objects. To experiment with forces on the order of 10-1-103 N, see Gravity Force Lab: Basics.
- By default, the masses will maintain a constant density. If the mass is increased, the radius will increase proportionally to maintain the density. If the simulation is in Constant Size mode, the radii of the masses will instead remain constant. The color saturation of the mass maps to its density (i.e. larger masses will have a more saturated color).
- The figures attached to the masses are displayed to help students understand why the objects stay apart, despite their attraction. The figure will lean further back to indicate that the force exerted on the mass it is holding has increased. However, the figure is massless and does not contribute to the forces in the system.



Inclusive Features

Sound and Sonification

- A tone plays that changes with the magnitude of the force as mass OR distance change to emphasize the change on the gravitational force by either variable.
- Extra emphasis on the magnitude of the mass as being different than the force sound is possible by enabling Enhanced Sounds in the PhET menu. A change in mass also plays a percussive tone that changes pitch with the magnitude of the mass.
- See the Sound Features Video for more useful tips on how concepts and sound are integrated in this sim. See the published Sound Design Documentation for more details on all sounds in this simulation.

Interactive Description

- This simulation features interactive description to support non-visual access, delivered only while using screen reader software. See the Introduction to Interactive Description video for more info on how to use this feature.
- Teachers can access the A11y View here to decide if this sim's interactive description meets their instructional needs. *Reminder: A11y View is not intended for student use and will not provide a good experience for learners using screen reader software.*

See the simulation page for all supported inclusive features.

Customization Options

Query parameters allow for customization of the simulation, and can be added by appending a '`?`' to the sim URL, and separating each query parameter with a '`&`'. The general URL pattern is:
`…html?queryParameter1&queryParameter2&queryParameter3`

For example, in Gravity Force Lab, if you want to mute the audio (`sound=muted`), and disable external links (`allowLinks=false`) use:
https://phet.colorado.edu/sims/html/gravity-force-lab/latest/gravity-force-lab_all.html?sound=muted&allowLinks=false

To run this in Spanish (`locale=es`), the URL would become:
https://phet.colorado.edu/sims/html/gravity-force-lab/latest/gravity-force-lab_all.html?locale=es&sound=muted&allowLinks=false

Query Parameter and Description	Example Links
`locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
`sound` - if muted, audio is muted by default. If disabled, all audio is permanently turned off.	`sound=muted` `audio=disabled`
`allowLinks` - when `false`, disables links that take students to an external URL. Default is `true`.	`allowLinks=false`

Suggestions for Use

Sample Challenge Prompts

- Identify two ways you can change the amount of gravitational force that the objects experience. How could you increase the gravitational force using each factor? How could you decrease the gravitational force using each factor?
- If gravity is a force of attraction between objects, why aren't objects like your pencil being pulled towards you? Explain your reasoning.
- Select two different values for mass 1 and mass 2. How does the force that the smaller mass exerts on the larger mass compare to the force that the larger mass exerts on the smaller mass?
- Predict what happens to the gravitational force as the distance between the masses is doubled.
- Pick an independent variable to manipulate and design an experiment to determine what happens to the gravitational force as this variable is changed. What do you observe?
- Design an experiment to determine the equation that describes the relationship between the gravitational force and the masses of the objects and the distance between the objects. Plot your data and choose an appropriate trend line.

Explore Inverse Square Laws

Use Coulomb's Law to investigate the electrostatic force.

- Determine the similarities and differences between the gravitational and electrostatic forces.
- Compare the magnitudes of the gravitational and electrostatic forces in the Hydrogen atom.

See all published activities for Gravity Force Lab here.
For more tips on using PhET sims with your students, see Tips for Using PhET.

Name: _____ Period: _____

Gravity Force Simulation

Directions: Use the "Gravity Force Simulation" to explore gravity. Record some **observations** below:

Identify **two** ways you can change the amount of force (gravity) the objects experience. How could you **increase** gravitational force using each factor? How could you **decrease** gravitational force using each factor?

One factor is...
A second factor is...

Complete the chart for each scenario below.

Mass of 1	Location of 1	Mass of 2	Location of 2	Force (1 on 2)	Force (2 on 1)
25 kg	3 m	25 kg	7 m		
25 kg	1 m	25 kg	9 m		
100 kg	1 m	100 kg	9 m		
100 kg	1 m	1 kg	9 m		

Summarize: Determine whether each statement about gravity is true or false.

____ The force of gravity increases as objects move closer together.

____ The force of gravity increases as an object's mass increases.

____ If two objects have different masses, the more massive object pulls with a greater force.

Apply:
The earth's gravity is pulling on you. Are you pulling on the earth? Explain your reasoning.

Gravity is a force of attraction between objects based on their mass and their distance apart. Why aren't other objects, like your pencil, being pulled towards you? Explain your reasoning.

Experiment 5

Determination of Value of Universal Gravitational Constant

Time for activity 40-60 minutes

Resources

The Virtual Lab https://phet.colorado.edu/sims/html/gravity-force-lab/latest/gravity-force-lab_en.html

Paper. Pencil, Calculator

Software Requirements

The new HTML5 sims can run on iPads and Chromebooks, as well as PC, Mac, and Linux systems.

iPad:
iOS 11+ Safari
iPad compatible sims

Android:
Not officially supported. If you are using the HTML5 sims on Android, we recommend using the latest version of Google Chrome.

Chromebook:
Latest version of Google Chrome
The HTML5 and Flash PhET sims are supported on all Chromebooks.
Chromebook compatible sims

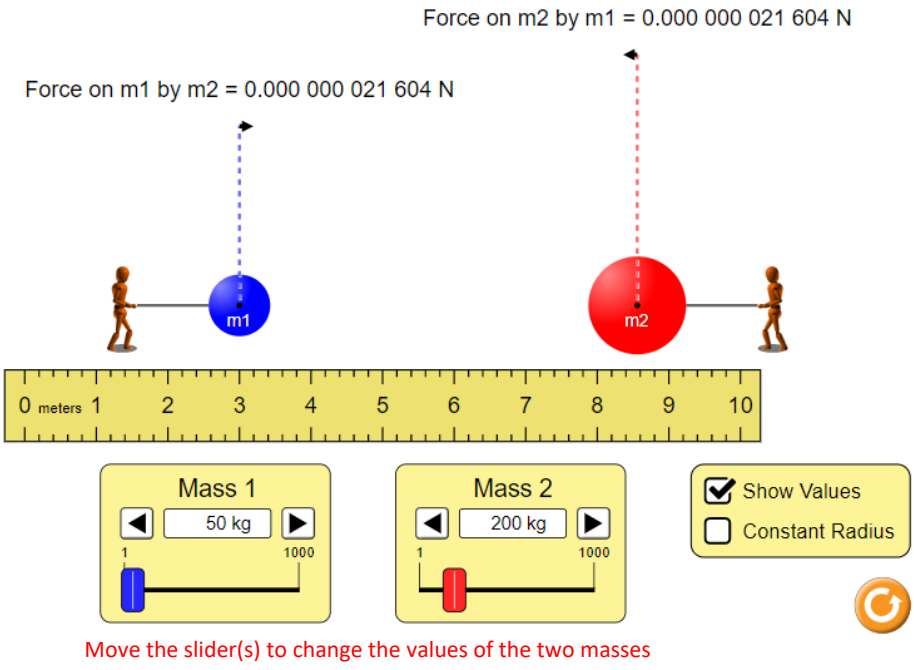
Windows Systems:
Microsoft Edge and Internet Explorer 11, latest version of Firefox, latest version of Google Chrome.

Macintosh Systems:
macOS 10.9.5+, Safari 9+, latest version of Chrome.

Linux Systems:
Not officially supported. Please contact phethelp@colorado.edu with troubleshooting issues.

The Lab Environment

Spend a few minutes to understand/ explore the functionalities of the different tabs/components.



Instructions

1. Hold and drag the two masses to adjust the distance between the two masses. Let it is r
2. Drag the sliders to adjust the two masses. Let these masses are m_1 and m_2.
3. Note down the values of the forces exerted by the two masses on one another. Since these forces will be equal in magnitude and opposite in direction, select any one and let it is F_{12}, that is force on mass 2 because of the mass 1. It can be noted that the force exerted by the mass 2 on mass 1 will be F_{21} and is of the same magnitude.

Gravitational force depends on the masses and the distance.
Newton developed the following equation to describe quantitatively the magnitude of the gravitational force if distance r separates masses m_1 and m_2:

Newton's Law of Universal Gravitation

$$F_g = G\frac{m_1 m_2}{r^2}$$

$$\text{gravitational force} = \text{constant} \times \frac{\text{mass 1} \times \text{mass 2}}{(\text{distance between masses})^2}$$

G is called the *constant of universal gravitation*. The value of G was unknown in Newton's day, but experiments have since determined the value to be as follows:

$$G = 6.673 \times 10^{-11}\,\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}$$

4. We can make the G as subject of formula, that is

$$F_{12} = G\frac{m_1 m_2}{r^2} \qquad \Rightarrow \qquad \boxed{G = \frac{F\ r^2}{m_1\ m_2}}$$

5. Using the above relation, find the value of the constant. Write your answer in scientific notation.

6. Compare the calculated value of G with $G = 6.673 \times 10^{-11}\ \frac{N.m^2}{kg^2}$ and calculate the %age error.

Experiment 1

Determination of Value of Universal Gravitational Constant

Student's Name_____ **Grade** ___

Observations and calculations

No. of Obs	Mass M_1	Mass m_2	r	F_{12}	$G = \frac{F\ r^2}{m_1\ m_2}$	
1						
2						
3						
4						

Average $G =$ _____

%age Error

Calculated Value of $G =$ _____

Actual Value of $G =$ _____

%age Error $= \frac{\left| Actual\ value\ of\ G - Calculated\ value\ of\ G \right|}{Actual\ value\ of\ G} \times 100 =$ _____ %