

Intro Screen

Play with one or two pendulums and discover which variables (such as length, mass, gravity, or angle) affect the period.

SEE the initial angle

DISCOVER the period with Period Trace

COMPARE two pendulums

ADJUST the length and mass

INVESTIGATE the effects of friction

Energy Screen

Explore the energy in the system in real-time and discover the conservation of mechanical energy.

SELECT the pendulum

OBSERVE the energy in the system in real-time

VIEW the legend

ZOOM to adjust the scale

PAUSE the sim to set up an experiment; **JUMP** forward by 0.01 seconds

Lab Screen

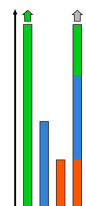
Measure the period precisely and view the velocity and acceleration throughout the pendulum's swing.

The screenshot shows the PhET Pendulum Lab simulation interface. It features a central pendulum with a blue bob and a yellow string, swinging on a blue arc. The interface includes several control panels and a data display:

- Top Left:** A panel with checkboxes for "Velocity" (green arrow), "Acceleration" (yellow arrow), and "Energy Graph" (green plus).
- Top Right:** A panel with sliders for "Length 1" (0.1 to 1 m, set at 0.70 m), "Mass 1" (0.1 to 1.5 kg, set at 1.00 kg), "Gravity" (0 to 25 m/s², set at 9.81 m/s²), and a dropdown menu for "Planet X" (set to "Earth"). A "Friction" slider is also present.
- Bottom Left:** A "Period" display showing "1.7306 s" with a play button.
- Bottom Center:** A control bar with a red stop button, a play button, and a "Normal" vs "Slow" toggle.
- Bottom Right:** A "STOP the motion of the pendulum" callout box.
- Callout Boxes:** Three grey boxes with white text: "OBSERVE the vectors" (pointing to velocity/acceleration vectors), "MEASURE the time period precisely" (pointing to the period display), and "CONTROL gravity; DETERMINE the gravity on a mystery planet" (pointing to the gravity controls).

Complex Controls

- The remove heat button in the Energy Graph will instantaneously remove the thermal energy from the system. If friction is on, the thermal energy will still continue to accumulate.
- When the energy is off-scale, an arrow will appear above the bar in the Energy Graph. To re-scale the graph, zoom out until the arrows are no longer visible



Insights into Student Use

- Students may try to use the formula for the period of a pendulum, $T = 2\pi\sqrt{l/g}$, which is only valid in the small-angle regime. Students can experiment using Jupiter or the Moon to discover what “small” means or they might be able to conduct a literature search. Note that there is no absolutely clear answer to this question — it depends on the level of precision maintained.
- When experimenting, it may be helpful to first pause the sim and then set up the experiment.
- The purpose of the ruler is to set the scale. Students generally use the ruler to verify that the length is measured to the pendulum's center of mass.

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 Pendulum Lab, if you only want to include the 1st and 2nd screens (`screens=1,2`), with the 2nd screen open by default (`initialScreen=2`) use:

https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_all.html?screens=1,2&initialScreen=2

To run this in Spanish (`locale=es`), the URL would become:

https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_all.html?locale=es&screens=1,2&initialScreen=2

Query Parameter and Description	Example Links
<code>screens</code> - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center .	<code>screens=1</code> <code>screens=2,1</code>
<code>initialScreen</code> - opens the sim directly to the specified screen, bypassing the home screen.	<code>initialScreen=1</code> <code>initialScreen=3</code>
<code>locale</code> - 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”.	<code>locale=es</code> (Spanish) <code>locale=fr</code> (French)
<code>allowLinks</code> - when <code>false</code> , disables links that take students to an external URL. Default is <code>true</code> .	<code>allowLinks=false</code>

Model Simplifications

- As you move the pendulum, the angles are constrained to be an exact integer number of degrees.
- The potential energy is relative to the resting point of the mass, so pendulums with different lengths will have different zero-points.
- The Period Timer operates as a triggered mechanism (photogate), which starts when the pendulum crosses the vertical dotted line. The period will be displayed after one cycle.
- If a parameter (e.g. gravity, mass) is changed mid-swing, the instantaneous length, mass, angle, and tangential velocity will be used as the new initial conditions for the equation of motion. As a result, the amplitude of the swing may be affected, and will no longer correspond to the tick mark on the protractor.
- Friction is modeled as quadratic drag ($F_{\text{drag}} \propto v^2$) which is valid in the high Reynold's number limit appropriate for macroscopic objects. Increasing the friction will increase the value of the drag coefficient in the model.
- For more information about the drag force or the equation of motion, see [Pendulum Lab Model](#).

Suggestions for Use

Sample Challenge Prompts

- Explain what the period of a pendulum represents.
- Determine a method to measure the period without using the Period Timer tool.
- Design a controlled experiment to (qualitatively or quantitatively) determine how a variable — such as length, mass, gravity, or angle — affects the period.
- Estimate the speed of the pendulum from the Energy Graph (e.g. maximum, medium, or zero).
- Predict the position of the pendulum from the Energy Graph.
- Compare the period on Planet X to Earth. Which planet has a larger gravitational acceleration

- Calculate the value of g on Planet X.
- Predict the direction and magnitude of the velocity vector at various points along the swing.
- Determine what constitutes a “small” angle. (Note that the answer depends on the desired level of precision.)

See all published activities for Pendulum Lab [here](#).

For more tips on using PhET sims with your students, see [Tips for Using PhET](#).

SIMPLE PENDULUM

PROBLEMS

1. When is the motion of a simple pendulum simple harmonic?
2. What is the effect of the following physical quantities on the period of oscillation of a simple pendulum: mass of the pendulum bob, length, acceleration due to gravity, and angular displacement.

MATERIALS

Pendulum Lab (PhET simulation)

ONLINE RESOURCES

Pendulum Lab PhET simulation: https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html

PROCEDURE

Frequency and Spring Constant

1. Open the Pendulum Lab PhET simulation. Select LAB.
2. Set the following parameters:

Length	1 m
Friction	none
Environment	Earth
Simulation speed	slow
Velocity indicator	enabled
Acceleration vector	enabled
Simulation	PAUSED
Angular displacement	10 degrees

3. Run the simulation by clicking on the pause/play button. Observe the motion of the pendulum and the length of the velocity vector at different positions of the pendulum bob.

QUESTION:

- What happens to the speed of the pendulum bob as it (a) swings away from the equilibrium position and (b) toward the equilibrium position?

- At what position(s) is the speed of the pendulum bob at its maximum value? At what position(s) is the pendulum bob instantaneously at rest?

- What is the direction of the acceleration when the pendulum bob is (a) at the right side of the equilibrium position and (b) at the left side of the equilibrium position?

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- At what position(s) is the acceleration of the pendulum bob at its maximum value? minimum value?
- Based on these observations, is the motion of a simple pendulum simple harmonic? Explain.

Period and Mass

1. Set the following parameters:

Length	1 m
MASS	0.3 kg
Friction	none
Environment	Earth
Simulation speed	normal
Velocity indicator	disabled
Acceleration vector	disabled
Simulation	PAUSED
Angular displacement	15 degrees
Period Timer	enabled

2. Run the simulation by clicking on the pause/play button. While the pendulum bob is oscillating, activate the Period Timer and note the period of oscillation.
3. Using the same parameters in (1), make several trials, each time, increasing the mass by 0.3 kg until $m = 1.5$ kg. Record your data in the table below.

Mass m , of the Pendulum bob (kg)	Period, T , of Oscillation (s)
0.3	
0.6	
0.9	
1.2	
1.5	

4. Using a spreadsheet, plot the graph of the period of oscillation (T) against the mass of the pendulum bob (m). Describe the graph formed.

QUESTION:

What does the T vs. m graph suggest about the relationship between the period of oscillation of a simple pendulum and its mass?

Period and the length
of the Pendulum

1. Set the following parameters:

LENGTH	0.2 m
Mass	0.5 kg
Friction	none
Environment	Earth
Simulation speed	normal
Velocity indicator	disabled
Acceleration vector	disabled
Simulation	PAUSED
Angular displacement	15 degrees
Period Timer	enabled

2. Run the simulation by clicking on the pause/play button. While the pendulum bob is oscillating, activate the PERIOD TIMER and note the period of oscillation.
3. Using the parameters in (1), make several trials, each time, increasing the length by 0.2 m until the length equals $L = 1\text{ m}$. Record your data in the table below.

Length, L of the pendulum (m)	Period, T, of Oscillation (s)	Period Squared (T^2) (s^2)
0.2		
0.4		
0.6		
0.8		
1.0		

4. Using a spreadsheet, plot the graph of the period (T) against the length (L) of the pendulum. Describe the graph formed.
5. Plot the graph of T^2 against L. What kind of graph was formed?

QUESTIONS:

- What does the graph of T^2 vs. L suggest about the relationship between T and L?

Period and
Acceleration due to
Gravity

1. Set the following parameters:

Length	1 m
Mass	1 kg

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GRAVITY	5 m/s²
Friction	none
Environment	Earth
Simulation speed	normal
Velocity indicator	disabled
Acceleration vector	disabled
Simulation	PAUSED
Angular displacement	15 degrees
Period Timer	enabled

- Run the simulation by clicking on the pause/play button. While the pendulum bob is oscillating, activate the PERIOD TIMER and note the period of oscillation.
- Using the parameters in (1), make several trials, each time, increasing the acceleration due to gravity by 5 m/s² until g = 5 m/s². Record your data in the table below.

Acceleration due to gravity, g, (m/s ²)	Period, T, of Oscillation (s)	(T ²) (s ²)	1/g (s ² /m)
5			
10			
15			
20			
25			

- Plot the graph of T² against 1/g. Describe the graph formed.

QUESTIONS:

- What does the graph of T² vs. 1/g suggest about the relationship between the period of oscillation of the pendulum and the acceleration due to gravity?

Period and Angular Displacement

- Set the following parameters:

Length	1 m
Mass	1 kg
Environment	Earth
Friction	none
Environment	Earth
Simulation speed	normal
Velocity indicator	disabled
Acceleration vector	disabled
Simulation	PAUSED
ANGULAR DISPLACEMENT	3 degrees
Period Timer	enabled

- Determine the period of oscillation using the photogate timer.

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3. Repeat procedure (1) for different values of the angular displacement (Refer to the table below)
4. Record your data.
- 5.

Angular Displacement (degrees)	Period (s)	Angular Displacement (degrees)	Period (s)
3		25	
6		40	
9		55	
12		70	
15		85	
18		90	

QUESTIONS:

- For $\theta < 15^\circ$, does the period of oscillation depends on the angular displacement?
- For $\theta > 15^\circ$ does the period of the pendulum depend on the angular displacement? What happens to the period of the pendulum as the angular displacement increases?
- When do you say that the motion of a simple pendulum is simple harmonic?

CONCLUSION(S)

GOING FURTHER

In the simulation, the acceleration due to gravity on Planet X is not known. Develop a method to determine the acceleration due to gravity on Planet X.