SI Physics - Full Discipline Demo

Simple Harmonic Motion

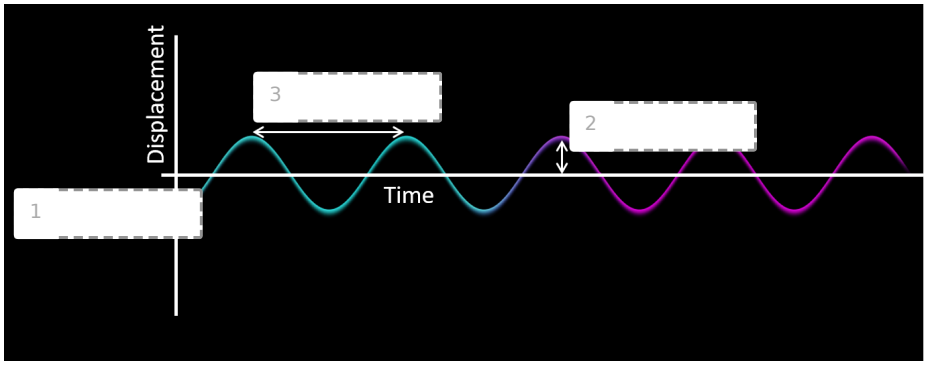
Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Label the pendulum oscillation diagram.

Amplitude | Equilibrium | Period



Correct answers:

1 Equilibrium 2 Amplitude 3 Period

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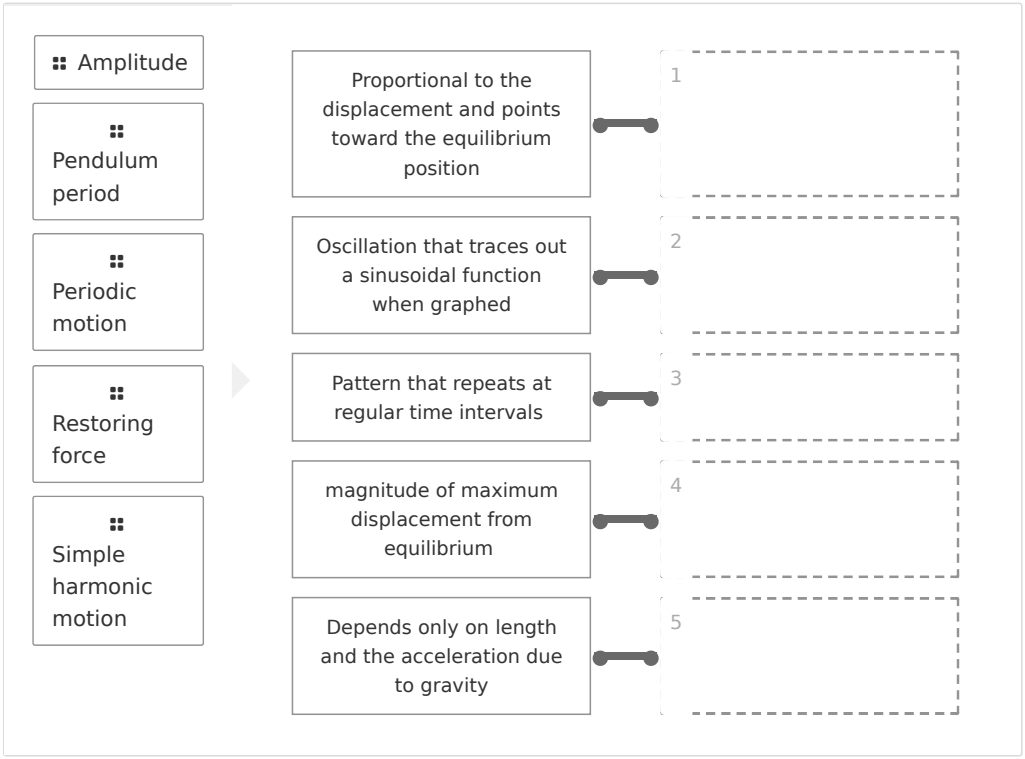
Match the term to the best description of a pendulum system.



Correct answers:

1 Restoring force 2 Simple harmonic motion 3 Periodic motion

4 Amplitude 5 Pendulum period

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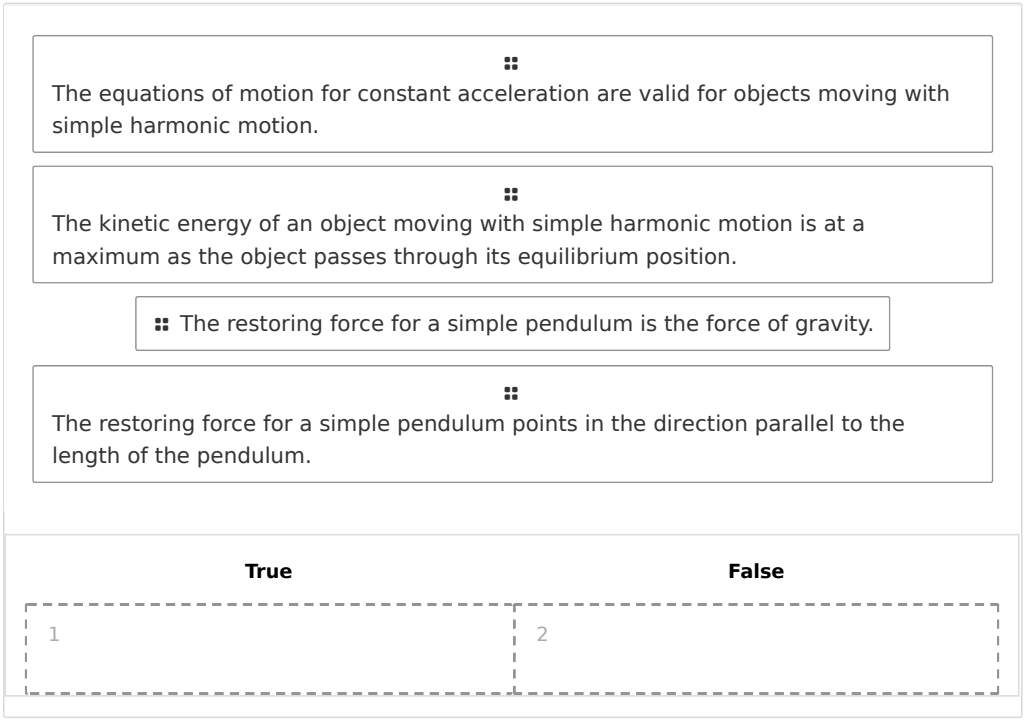
Identify each statement as True or False.



Correct answers:

1 The restoring force for a simple pendulum is the force of gravity.

The kinetic energy of an object moving with simple harmonic motion is at a maximum as the object passes through its equilibrium position.

2

The equations of motion for constant acceleration are valid for objects moving with simple harmonic motion.

The restoring force for a simple pendulum points in the direction parallel to the length of the pendulum.

Exploration

Simple harmonic motion is any motion that repeats at regular intervals.

- True
- False ✔

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The position where the oscillating object experiences no force is the _____.

- displacement
- equilibrium ✔
- amplitude
- All of the above

The restoring force always points toward the equilibrium position.

- True ✔
- False

The mass of a simple pendulum is _____ of the pendulum.

- concentrated at the end ✔
- distributed evenly along the length
- concentrated at several locations along the length
- All of the above

The restoring force for a simple pendulum is caused by _____.

- the force of gravity
- the component of the force of gravity pointing along the length of the pendulum
- the component of the force of gravity pointing perpendicular to the length of the pendulum ✔
- None of the above

At the top of the arc of a pendulum the value of the _____ is zero.

- kinetic energy ✔
- potential energy
- acceleration
- All of the above

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The period of a simple pendulum depends on the _____ of the pendulum and the acceleration due to gravity.

- [x] length
- [ ] mass
- [ ] amplitude
- [ ] All of the above

Exercise 1

Determine the position in the oscillation where an object in simple harmonic motion:

a. has the greatest speed.

b. has the greatest acceleration.

c. experiences the greatest restoring force.

d. experiences zero restoring force.

a. The greatest speed occurs at the equilibrium position, or the bottom of the arc.

b. The greatest acceleration occurs at the maximum displacement, or the top of the arc.

c. The greatest restoring force is experienced at the maximum displacement, or the top of the arc.

d. Zero restoring force occurs at the equilibrium position, or the bottom of the arc.

Describe simple harmonic motion, including its cause and appearance.

Simple harmonic motion occurs whenever the motion is repeated at regular time intervals and the path of the motion traces out a sine or cosine curve when graphed over time. Simple harmonic motion is caused by a restoring force where F = -kx so that the force varies linearly with the displacement, and points in the direction opposite the displacement from the equilibrium position.

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Use the information listed in Data Tables 1 to 3 to describe how the change in a. amplitude (angle), b. length, and c. mass affect the period of the pendulum.

The change in amplitude or angle and the change in mass had no effect at all on the period of the pendulum as shown in the periods of 2.5 s for each amplitude and 2.0 s for each mass. The pendulum must move faster for the larger amplitude swings, but only moves fast enough so that the period is unaffected. The longer the length of the pendulum, the larger the period of oscillation for the pendulum as shown in the periods of 2.5, 2.0 and 1.4 s for the lengths of 1.50, 1.00 and 0.50 m, respectively.

Compare your calculations of g using individual measurements and using the graph in Graph 1, listed in Data Table 4. Do your measurements including uncertainty fall within the accepted value? Which method is more accurate? List possible sources of error in your data and calculations.

All measurements, when uncertainty is included, fall within the accepted value of 9.81 m/s^2. The calculation for the 1.5 m length gave the closest value to the accepted value, with an effective uncertainty of 0.0%. However, on average, the uncertainty for the graphed value of g has the lowest uncertainty and takes into account more data. The graphical method is probably most accurate because it encompasses the most data and because it smooths over any random error. Error and uncertainty appear in the measurement of time, in that the exact moment when the pendulum reaches the top of the arc is difficult to discern and there is some reaction time for the timer to be stopped. Error and uncertainty also appear in the measurement of length, as it is difficult to determine the exact center of the pendulum bob. The pendulum is not exactly a simple pendulum because the string does have a small amount of mass as well. The number of periods measured could be miscounted, leading to a substantial random error. The exact angle the pendulum is released at each trial is also uncertain, especially for the longer pendulums because it is difficult to see the angle and hold the pendulum bob at the same time. Finally, the pendulum could interact with the wall behind it, altering the period, and small amounts of air resistance and friction will slow the swing of the pendulum over long periods of time.

Was energy conserved during the motion of your pendulum? If not, list some possible ways energy could have been lost from the pendulum system.

Energy was mostly conserved. There is a loss of 1.3% between the calculated maximum kinetic energy and the calculated maximum potential energy. Some energy could be lost to friction (air

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resistance) which manifests as heat-energy. Energy could also be lost to sound if the pendulum bob collided with the wall during the experiment.

Why did you measure 10 periods of the pendulum instead of just 1? Would your measurements be improved by measuring 100 periods instead of 10? Why or why not? How many periods do you think is the optimal number to measure?

Measuring 10 periods and solving for the average period spreads out the small timing errors caused by human reaction time over the 10 periods so that the uncertainty in a single period is greatly reduced. Measuring 100 periods would probably not improve the accuracy of the period measurement significantly because it would introduce other uncertainties and errors such as counting errors and friction or the possible obstruction of the swing. Measuring 20 periods might be even better than 10, reducing the timing errors without unduly burdening the experimenter or significantly increasing other sources of error.

Data Table 1: Amplitude and Period for L = 1.50 m, m = 50 g
(SAMPLE ANSWER BELOW)

Angle (°)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)	Period (s)	Observations
5	24.7	24.8	24.5	24.7	2.5	Slow speed
10	24.4	24.7	24.6	24.6	2.5	Slow speed
20	24.9	25.0	24.6	24.8	2.5	Slow speed

Data Table 2: Length and Period for θ = 10°, m = 50 g
(SAMPLE ANSWER BELOW)

Length (m)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)	Period (s)	Observations
1.50	24.4	24.7	24.6	24.6	2.5	Slow speed
1.00	20.0	19.8	20.0	19.9	2.0	Medium speed
0.50	14.1	14.1	14.1	14.1	1.4	Fast speed

Data Table 3: Mass and Period for θ = 10°, L = 1.0 m
(SAMPLE ANSWER BELOW)

Mass (g)	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)	Period (s)	Observations
50	20.0	19.8	20.0	19.9	2.0	Medium speed
100	20.2	20.3	20.2	20.2	2.0	Medium speed
150	19.8	20.0	19.8	19.9	2.0	Medium speed

Data Table 4: Acceleration Due to Gravity for θ = 10°, m = 50 g
(SAMPLE ANSWER BELOW)

Length (m)	Period squared (m/s^2)	g (calculated) (m/s^2)	Δg (calculated) (m/s^2)	% Error (calculated)	g (graph) (m/s^2)	% Error (graph)

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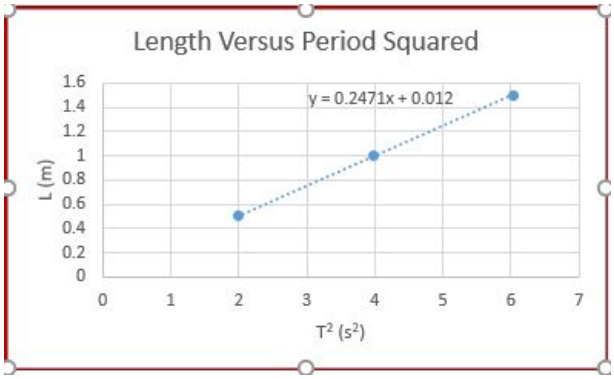
1.50	6.0	9.8	0.2	0.0	9.8	0.6
1.00	4.0	9.9	0.3	1.3		
0.50	2.0	9.9	0.5	1.2		

Graph 1: L versus T2

(SAMPLE ANSWER BELOW)



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Data Table 5: Energy for θ = 10°, m = 50 g, L = 1.00 m
(SAMPLE ANSWER BELOW)

Amplitude (m)	U_{max} (J)	K_{max} (J)	% Difference
0.17	0.0075	0.0076	1.3

Competency Review

A(n) _____ is an example of Simple Harmonic Motion.

- ticking wrist-watch
- oscillating mass on a spring ✔
- beating heart
- All of the above

_____ is a measure of the maximum displacement for oscillatory motion.

- Amplitude ✔
- Frequency
- Equilibrium
- All of the above

The restoring force is calculated using the equation _____.

- F = kx
- F = -kx ✔
- $F = kx^2$
- None of the above

The restoring force for a pendulum is proportional to the mass and inversely proportional to the length of the pendulum.

- True ✔
- False

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The maximum displacement of a pendulum swing is the _____.

- amplitude
- maximum angular displacement
- top of the arc
- All of the above ✔

The location of a pendulum bob in its swing where the kinetic energy is maximum is the same as the location where the potential energy is maximum.

- True
- False ✔

The period of a pendulum is independent of the _____.

- acceleration due to gravity
- length
- mass ✔
- All of the above

When constructing a simple pendulum, the length of the pendulum is measured from the attachment point to the bottom of the pendulum bob.

- True
- False ✔

A graph of pendulum length versus period squared produces a _____ line.

- straight horizontal
- straight diagonal ✔
- upwardly concave
- None of the above

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The minimum kinetic energy for a pendulum is _____.

- zero
- at the maximum displacement
- at the position where acceleration is maximum
- All of the above ✔

Extension Questions

How would the motion of a pendulum change at high altitude like a high mountain top? How would the motion change under weightless conditions? (SAMPLE ANSWER BELOW)

At high altitude, the acceleration due to gravity is slightly smaller than at sea-level. Since the period of the pendulum is inversely proportional to the square root of the acceleration due to gravity, the pendulum on top of a high mountain would have a slightly longer period than it would at sea-level. Under weightless conditions, the pendulum would not swing, because there would be no restoring force from gravity acting on the pendulum bob.

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