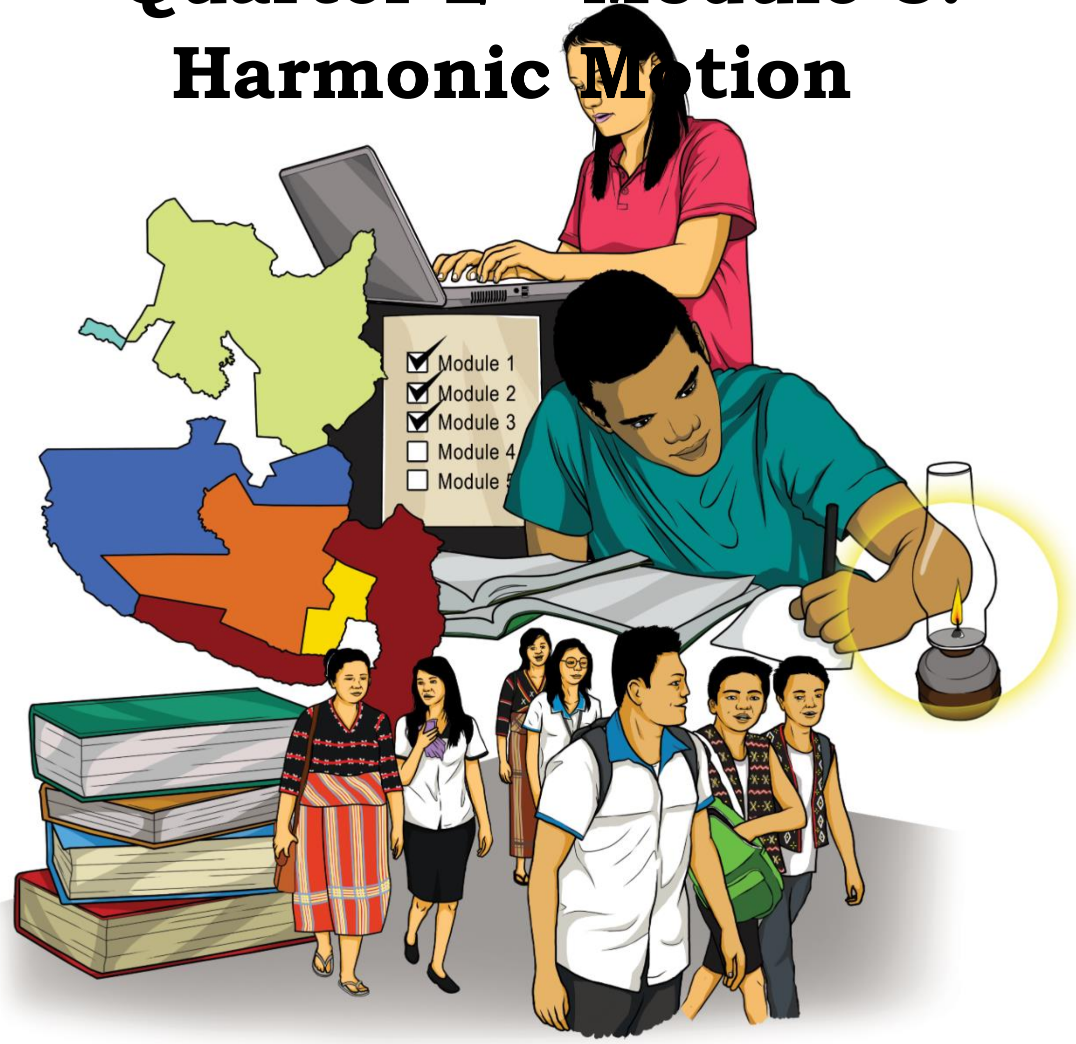
12

DepED
DEPARTMENT OF EDUCATION

General Physics 1

Quarter 2 – Module 3: Harmonic Motion



SELF-LEARNING MODULE

SLM

DEPARTMENT OF EDUCATION - SOCCSKSARGEN

Subject Area – 12
Self-Learning Module (SLM)
Quarter 2 – Module 3: Harmonic Motion
First Edition, 2020

Development Team of the Module

Writers: Jan Jeffrey R. Camina John Whood D. Sanico
Nelson B. Malificiado

Editors: Christine G. Sua Nestor A. Raguindin, Emma T. Surita

Reviewers: Blessy Mae M. Cabayao, Murdy F. Bautista, Jay Sheen A. Molina

Illustrator: Merbin M. Sulit

Layout Artist: Welmer M. Leysa

Cover Art Designer: Ian Caesar E. Frondoza
Management Team: Dr. Allan G. Farnazo, CESO IV – Regional Director
Fiel Y. Almendra, CESO V – Asst. Regional Director
Ruth L. Estacio PhD, CESO IV- OIC-SDS
Jasmin P.Isla- Assistant Schools Division Superintendent
Gilbert B. Barrera – Chief, CLMD
Arturo D. Tingson, Jr. – REPS, LRMS
Peter Van C. Ang-ug – REPS, ADM
Lalaine SJ. Manuntag PhD – CID Chief
Nelida A. Castillo – EPS, LRMS
Marichu Jean R. Dela Cruz – EPS Science, ADM

Printed in the Philippines by Department of Education – SOCCSKSARGEN Region

Office Address: Regional Center, Brgy. Carpenter Hill, City of Koronadal
Telefax: (083) 2288825/ (083) 2281893
E-mail Address: region12@deped.gov.ph

12

General Physics 1

Quarter 2 – Module 3:
Harmonic Motion

SELF-LEARNING MODULE

DEPARTMENT OF EDUCATION - SOCCSKSARGEN

Introductory Message

For the facilitator:

Welcome to the General Physics 1 - 12 Self-Learning Module (SLM) on Harmonic Motion.

This module was collaboratively designed, developed and reviewed by educators both from public and private institutions to assist you, the teacher or facilitator in helping the learners meet the standards set by the K to 12 Curriculum while overcoming their personal, social, and economic constraints in schooling.

This learning resource hopes to engage the learners into guided and independent learning activities at their own pace and time. Furthermore, this also aims to help learners acquire the needed 21st century skills while taking into consideration their needs and circumstances.

In addition to the material in the main text, you will also see this box in the body of the module:

Notes to the Teacher

This contains helpful tips or strategies that will help you in guiding the learners.

As a facilitator you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress while allowing them to manage their own learning. Furthermore, you are expected to encourage and assist the learners as they do the tasks included in the module.

For the learner:

Welcome to the Physics 11/12 Self-Learning Module (SLM) on Harmonic Motion.

The hand is one of the most symbolized part of the human body. It is often used to depict skill, action and purpose. Through our hands we may learn, create and accomplish. Hence, the hand in this learning resource signifies that you as a learner is capable and empowered to successfully achieve the relevant competencies and skills at your own pace and time. Your academic success lies in your own hands!

This module was designed to provide you with fun and meaningful opportunities for guided and independent learning at your own pace and time. You will be enabled to process the contents of the learning resource while being an active learner.

This module has the following parts and corresponding icons:

What I Need to Know	This will give you an idea of the skills or competencies you are expected to learn in the module.
What I Know	This part includes an activity that aims to check what you already know about the lesson to take. If you get all the answers correct (100%), you may decide to skip this module.
What's In	This is a brief drill or review to help you link the current lesson with the previous one.
What's New	In this portion, the new lesson will be introduced to you in various ways such as a story, a song, a poem, a problem opener, an activity or a situation.
What is It	This section provides a brief discussion of the lesson. This aims to help you discover and understand new concepts and skills.
What's More	This comprises activities for independent practice to solidify your understanding and skills of the topic. You may check the answers to the exercises using the Answer Key at the end of the module.
What I Have Learned	This includes questions or blank sentence/paragraph to be filled in to process what you learned from the lesson.

What I Can Do	This section provides an activity which will help you transfer your new knowledge or skill into real life situations or concerns.
Assessment	This is a task which aims to evaluate your level of mastery in achieving the learning competency.
Additional Activities	In this portion, another activity will be given to you to enrich your knowledge or skill of the lesson learned. This also tends retention of learned concepts.
Answer Key	This contains answers to all activities in the module.

At the end of this module you will also find:

References	This is a list of all sources used in developing this module.

The following are some reminders in using this module:

1. Use the module with care. Do not put unnecessary mark/s on any part of the module. Use a separate sheet of paper in answering the exercises.
2. Don't forget to answer *What I Know* before moving on to the other activities included in the module.
3. Read the instruction carefully before doing each task.
4. Observe honesty and integrity in doing the tasks and checking your answers.
5. Finish the task at hand before proceeding to the next.
6. Return this module to your teacher/facilitator once you are through with it.

If you encounter any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator. Always bear in mind that you are not alone.

We hope that through this material, you will experience meaningful learning and gain deep understanding of the relevant competencies. You can do it!

What I Need to Know

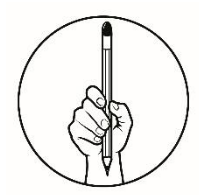
This module was designed and written with you in mind. It is here to help you master the principles of Simple Harmonic Motion. The scope of this module permits it to be used in many different learning situations. The language used recognizes the diverse vocabulary level of students. The lessons are arranged to follow the standard sequence of the course. But the order in which you read them can be changed to correspond with the textbook you are now using.

The module is divided into three lessons, namely:

Lesson 1 – Amplitude, frequency, angular frequency, period, displacement, velocity and acceleration and acceleration of oscillating systems.
Lesson 2 – Simple Harmonic Motion
Lesson 3 – Application of Simple Harmonic Motion

After going through this module, you are expected to:

1. Understand the relationship of Amplitude, frequency, angular frequency, period, displacement, velocity and acceleration and acceleration of oscillating systems.
2. Calculate and solve the Amplitude, frequency, angular frequency, period, displacement, velocity and acceleration and acceleration of oscillating systems.
3. Identify necessary conditions for an object to undergo Simple Harmonic Motion
4. Apply the concept of Simple Harmonic Motion
5. Analyze and solve problems involving Simple Harmonic Motion.



What I Know

PRE-TEST. Choose the letter of the correct answer. Encircle the letter of you chosen answer on the answer sheet provided.

1. Which of the following is a mass on a spring undergoes Simple Harmonic Motion and the maximum displacement from the equilibrium?

   A. Period B. Frequency C. Amplitude D. Wavelength

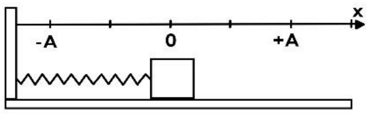
2. Which of the following in a periodic process, the number of cycles per unit of time?

   A. Period B. Frequency C. Amplitude D. Wavelength

3. Which of the following in a periodic process, the time required to complete one cycle is called?

   A. Period B. Frequency C. Amplitude D. Wavelength

For numbers 4-7, refer to the diagram below:



4. What is the instantaneous velocity, when the mass reaches point x = +A?

   A. Maximum and positive
   B. Zero
   C. Maximum and Negative
   D. Less than maximum and positive

5. What is the instantaneous velocity, when the mass reaches point x = 0?

   A. Maximum and can be positive or negative
   B. Constant and doesn't depend on the location
   C. Zero
   D. Slightly less than maximum and positive

6. What is the instantaneous acceleration, when the mass reaches point x = 0?

   A. Maximum and can be positive or negative
   B. Constant and doesn't depend on the location
   C. Zero
   D. Slightly less than maximum and positive

7. What is the instantaneous acceleration, when the mass reaches point x = +A?

   A. Maximum and can be positive or negative
   B. Constant and doesn't depend on the location
   C. Zero
   D. Slightly less than maximum and positive

8. An object with a mass M is suspended from an elastic spring with a spring constant k. The object oscillates with maximum amplitude A. If the amplitude of oscillations is doubled, how will it change the period of oscillations?

   A. The period is increased by factor two
   B. The period is increased by factor four
   C. The period is decreased by factor two
   D. The period is decreased by factor four
   E. The period remains the same

9. An object with a mass M is suspended from an elastic spring with a spring constant k. If the mass of oscillations is quadrupled, how will it change the period of oscillations?

   A. The period is increased by factor two
   B. The period is increased by factor four
   C. The period is decreased by factor two
   D. The period is decreased by factor four
   E. The period remains the same

10. An object with a mass M is suspended from an elastic spring with a spring constant k. The object oscillates with period T on the surface of Earth. If the oscillating system is moved to the surface of Moon, how it will change the period of oscillations? Acceleration due to gravity on moon= 1.6 m/s^2

   A. The period is increased by factor $\sqrt{6}$
   B. The period is increased by factor four
   C. The period is decreased by factor $\sqrt{6}$
   D. The period is decreased by factor four

11. The length of a simple pendulum oscillating with a period T is quadrupled, what is the new period of oscillations in terms of T?

   A. 2T B. 4T C. ½ T D. ¼ T

12. The length of a simple pendulum oscillating with a period T is quartered, what is the new period of oscillations in terms of T?

   A. 2T B. 4T C. ½ T D. ¼ T

13. A simple pendulum has a period of 1 s. What is the length of the string?

   A. 1 m B. 2 m C. 4 m D. ½ m E. ¼ m

14. A simple pendulum has a period of 2 s. What is the length of the string?

   A. 1 m B. 2 m C. 4 m D. ½ m E. ¼ m

15. A simple pendulum has a period of 4 s. What is the length of the string?

   A. 1 m B. 2 m C. 4 m D. ½ m E. ¼ m

Lesson 1

Amplitude, Frequency, Angular Frequency, Period, Displacement, Velocity and Acceleration of Oscillating Systems

Learning Objective:

1. Understand the relationship of Amplitude, frequency, angular frequency, period, displacement, velocity and acceleration and acceleration of oscillating systems.
2. Calculate and solve the Amplitude, frequency, angular frequency, period, displacement, velocity and acceleration and acceleration of oscillating systems.

What' s In

In the previous lesson we learned all about Kepler's Laws of planetary motion and circulation motion. Now let's try to relate the concepts of circulation motion and try to think what velocity and acceleration does the revolving body experience.

Activity 1.1 Complete Me!

1st Law: The planets move about the sun in ELLIPTICAL orbits, with the sun at one focus of the ellipse.

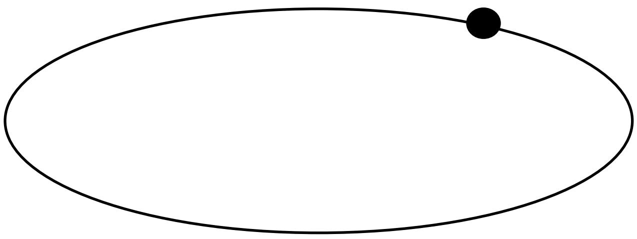
2nd Law: The straight line joining the sun and given planet sweeps_______________ _____________

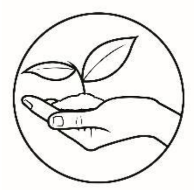
➔ Can be remembered as _________________.

3rd Law: The square of the period of revolution of a planet ABOUT THE SUN is proportional of the cube of its mean distance from the sun.

➔ Stated in equation from as _______________.

A planet is in the orbit as shown below. Where are the two possible locations for a Sun?





What's New

Activity 1.2 Drop and See!

Perform the Activity.

Material:
Rubber Ball

1. **Ball Drop at your knee level**	**2.** **Ball Drop at your waist level**	**3.** **Ball Drop at your chest level**
Hold the Ball at the level of your knee and drop it into a flat surface, and let the ball bounce on its on until it will stop.	Hold the Ball at the level of your waist and drop it into a flat surface, and let the ball bounce on its on until it will stop.	Hold the Ball at the level of your chest and drop it into a flat surface and let the ball bounce on its on until it will stop.

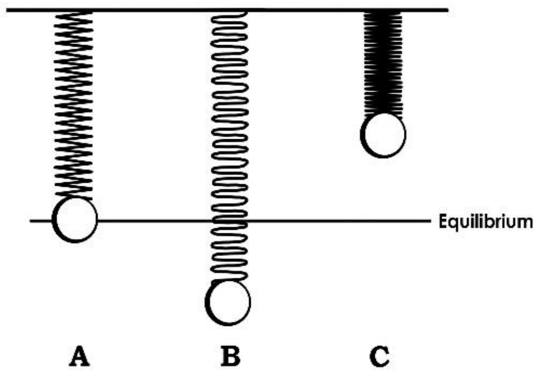
Questions:

1. After the First Bounce, did you notice that the ball return to its initial height?
2. Which of the following levels allows the ball to bounce the longest?
3. What word or term can you relate to the activity you performed?

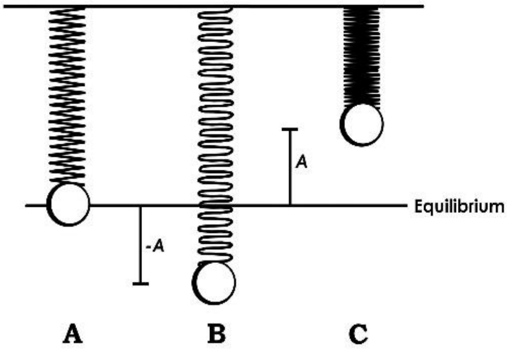
What is It

Periodic Motion

Imagine attaching a spring to a ball while hanging them vertically and you pull the ball at a certain displacement from the equilibrium point. It can be observed that the ball at high speed seems to vibrate or oscillate, this motion is called a **Periodic Motion**. Specifically, Periodic motion is a motion that repeats itself in a definite cycle, It occurs whenever a body has a stable equilibrium position and a restoring force acts when it is displayed from equilibrium.

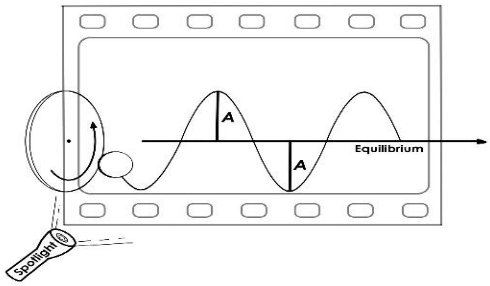


It can be said at point A that the ball is at equilibrium, and no force is acting on it. This point, where the spring isn't stretched or compressed, is called the equilibrium point. At point B, the ball pushes against the spring, and the spring retaliates with force F opposing that pushing. At point C, the spring releases, and the ball springs to an equal distance on the other side of the equilibrium point. At this point, the ball isn't moving, but a force acts on it, which is force F, so it starts going back the other direction. If friction and air resistance is neglected it can be said that the periodic motion is directly proportional to the displacement (y), this motion is called **Simple Harmonic Motion**.



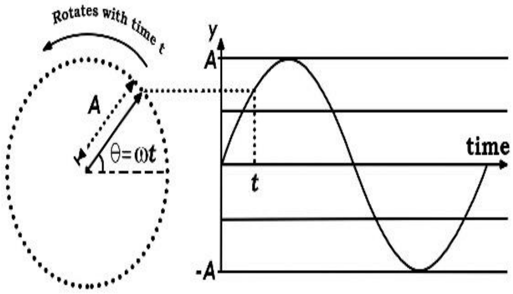
Amplitude (A)

When the example moves in a Simple Harmonic Motion, the distance made by the object from its equilibrium point is called the **Amplitude**. Specifically, amplitude is simply the maximum extent of the oscillation or the size of the oscillation.



Period (T)

Imagine shining a light in front of the ball as it cast its shadow. Film the movement of the shadow as shown in the image. Add a reference circle and try to trace the wave formed from the film and relate it to the circle. Each time an object moves around a full circle, it completes a cycle. The time the object takes to complete the cycle is called the **Period**.



When an object moves in a full circle, completing a cycle, the object goes 2π radians. It travels that many radians in T seconds, so its angular speed, ω is:

$$\omega = \frac{2\pi}{T} \longrightarrow T = \frac{2\pi}{\omega}$$ (Relationship of period to angular speed)

unit in seconds (s)

Frequency (f) & Angular Frequency (ω)

The **frequency** is the number of cycles that are completed per second. For example, if the disk rotates 1,000 full turns per second the frequency (f) would be 1,000 cycles per second. Cycles per second can also be called hertz (Hz). It is defined as:

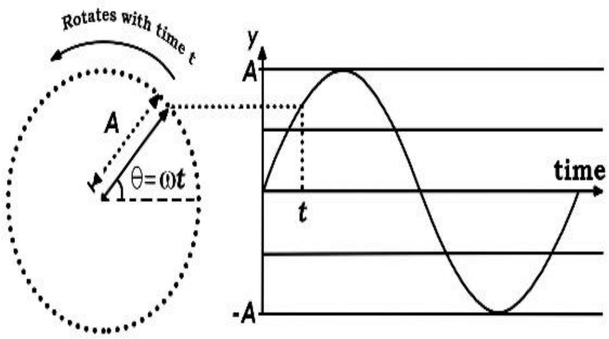
$$f = \frac{1}{T}$$ (Frequency) unit in hertz (Hz)

(Angular Frequency) unit in radians per seconds (rad/s)

$$\omega = \left(\frac{2\pi}{T}\right)Tf = 2\pi f$$

Displacement, Velocity & Acceleration

By observing the reference circle, we can relate time with the movement of the ball along the y-axis. Let amplitude(A) be the hypotenuses, distance y be the opposite and the angle be θ which is equal to ωt.



From the said given we can get the relationship of the amplitude to frequency(f):

sin(θ) = sin(ωt) = y/A;

$\boxed{y = A*\sin(\omega t)}$

Convert angular frequency (ω) to frequency (f):

$\boxed{y = A*\sin(2\pi f t);\ \text{where } \omega = 2\pi f}$

(*Note: since the motion of the ball is a vertical motion, going up or down, displacement y is the one computed.*)

By using the equation above, and differentiating it with respect to time(t) we can get the relationship of **velocity(v)** to frequency(f):

y = A*sin(ωt)

$\boxed{v = \frac{dy}{dt} = A * \omega\cos(\omega t)}$

$v = \frac{dy}{dt} = A * \omega\cos(\omega t)$

Convert angular frequency (ω) to frequency (f):

$\boxed{v = A*(2\pi f)\cos(2\pi f t)}$

By using the equation above, and differentiating it with respect to time(t) we can get the relationship of **acceleration(a)** to frequency(f):

$\frac{d^2y}{dt^2} = -A * \omega^2 \sin(\omega t) a =$

$\boxed{a = -\omega^2 y}$

Since $\omega = \frac{2\pi}{T}$

$a = -(\frac{2\pi}{T})^2 y$

$\boxed{a = -(\frac{4\pi^2}{T^2})y}$

Convert angular frequency (ω) to frequency (f):

$\boxed{a = -(2\pi f)^2 y}$

Equate to Period (T):

$T^2 = -(\frac{4\pi^2}{a})y$

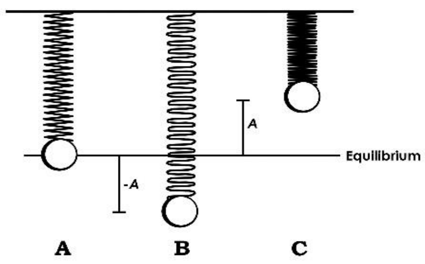
$\boxed{T = 2\pi\sqrt{(\frac{-y}{a})}}$

Relationship of Period (T) to acceleration (a) and displacement (y)

**Note: y is used since the example is in a vertical motion*

Example:

When amplitude (A) is 16 cm and the ball bounces back and forth in a span of 4 seconds. Find (a) frequency and angular frequency, (b) acceleration and velocity at x = 16 cm, and (c) acceleration and velocity at x = 10 cm.



(a) Frequency (f) — Angular Frequency (ω)

f = 1/T = ¼s = **0.25 Hz** — ω = 2πf = 2π(0.25) = **0.5π rad/s**

(b) Acceleration (a)

a = $-\omega^2 x$ = -(0.5π rad/s)^2(16 cm)

a = **-4π^2 cm/s^2**

Velocity (v)

v = A ωcos(ωt) ; *ωt = sin^{-1}(y/A) = sin^{-1}(16/16) = 90 deg*

v = (16)(0.5π)cos(90 deg)

v = **0.0 cm/s**

(c) Acceleration (a)

a = $-\omega^2 x$ = -(0.5π rad/s)^2(10 cm)

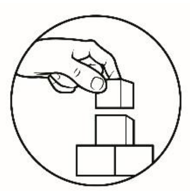
a = **-4π^2 cm/s^2**

Velocity (v)

v = A ωcos(ωt) ; *ωt = sin^{-1}(y/A) = sin^{-1}(10/16) = 38.68 deg*

v = (16 cm)(0.5π rad/s)cos(38.68 deg)

v = **19.62 cm/s**



What's More

Activity 1.3 STRETCH IT UP!

Instruction: Provide the following materials and follow the given procedures. Based on your experiment complete the table given and answer the following questions below.

Materials:

1 Paper Clip
6 Rubber Bonds
2 Push Pins
1 Flat Wood
1 Ruler

Procedures:

1. Place the push pin in 1 foot apart.
2. Connect the 3 rubbers bonds. To create 2 sets.
3. Connect the 2 sets of rubber bonds together with a paper clip
4. Place the both ends of the rubber to the push pin.
5. Stretch the paper clip 10 cm to the right.
6. Record the time when the paper clip reaches 10 cm to the left.

Complete the Table

	Amplitude (m)	Frequency (Hz)	Angular Frequency (rad/s)	Period (s)	Displacement (m)	Velocity (m/s)
Paper Clip						
Paper Clip with Coin						

Question:

1. What causes the paper clip to move back and forth?
2. Given the mass of the paper clip ____ g and the coefficient of the elasticity of the rubber bond k=________. Solve for the Acceleration of the motion?
3. Given the mass of the paper clip and the coin ____ g and the coefficient of the elasticity of the rubber bond k=________. Solve for the Acceleration of the motion?
4. What changes you observe between the two scenarios?

What I Have Learned

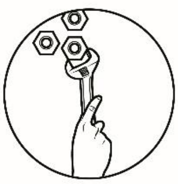
Instruction: Fill in the blanks with the correct answer.

1. It is a motion that repeats itself in a definite cycle is called _________________.

2. It is the maximum extent of the oscillation or the size of the oscillation is called __.

3. It is the time the object takes to complete the cycle is called __________________.

4. It is the number of cycles that are completed per second is called _______________.



What I Can Do

Activity 1.4 Let's Solve It!

Instruction: Solve and illustrate the problem given. And show your solution and diagram legibly.

A 100-g body is attached at the end of a hanging spring with a spring constant of 2,000 dynes/cm. It is displaced 10 cm from its equilibrium position and then released.

(a) Calculate the period T.
(b) Find the maximum acceleration of the body.
(c) Find the acceleration of the body when it is 5.0 cm from the equilibrium position.

Lesson 2 Simple Harmonic Motion

Learning Objective

1. Identify necessary conditions for an object to undergo Simple Harmonic Motion
2. Analyze and solve problems involving Simple Harmonic Motion.

What's In

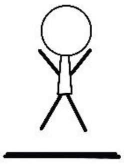
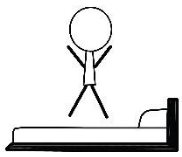
In the previous lesson, we learned the relationship of amplitude, frequency, angular frequency, period, displacement, velocity and acceleration to simple harmonic motion. Now let's try to relate harmonic motion with the reactive force present in elastic objects such as springs.

Activity 2.1 Match Me!
Instruction: Match the column A with correct answer on column B, write only the letter of answer on the blank provided.

Column A	Column B
_______**1. Frequency**	**a.** The number of cycles that are completed per second
_______**2. Period**	**b.** The time the object takes to complete the cycle.
_______**3. Amplitude**	**c.** the distance made by the object from its equilibrium point.
_______**4. Periodic motion**	**d.** It is a motion that repeats itself in a definite cycle
_______**5. Harmonic motion**	**e.** It is repetitive movement back and forth through an equilibrium.

What's New

Activity 2.2: "Let's Follow"

	
Jump in a flat surface Start jump in place one time	Jump in your foam bed Using any Chair jump to your foam bed

Questions:
1. What factor allows your body to go back to its initial position?
2. What word or term can you relate to the following?

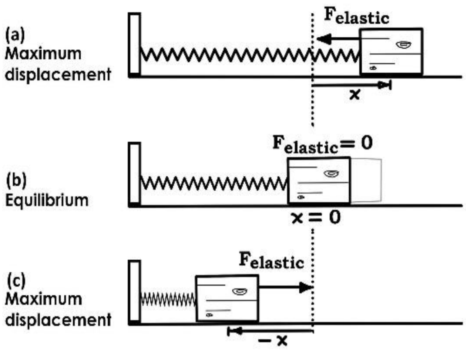
What is It

Simple Harmonic Motion (SHM)

Imagine a block of wood attached vertically with a spring attached to a wall. (a) When the spring is stretched to the right, the spring force pulls the mass to the left. (b) When the spring is unstretched, the spring force is zero. (c) When the spring is compressed to the left, the spring force is directed to the right.

To calculate the force exerted by the spring to the body at each of point, we need to use the Hooke's Law for ideal springs. The equation is:

$F_x = -kx$ (restoring force exerted by an ideal spring)
Where k = force constant
x = displacement from equilibrium



The force exerted by the spring to the block acts as a restoring force that tries to maintain the position of the block at the equilibrium point. In Newton's 2nd Law of Motion clearly defines that force is equal to mass multiplied by acceleration (F = ma). We will relate the force from Newton's law to the force obtained from Hooke's law to define Simple Harmonic Motion (SHM).

(first equate force from Hooke's Law to force from Newton's 2nd Law)

$F_x = F$

$-kx = ma$

$-kx = m(-\omega^2 x)$

(substitute acceleration [a] with the acceleration obtained from the previous lesson, but instead of using the amplitude y we use amplitude x since the motion is on the horizontal axis. [a $= -\omega^2 x$])

$-kx = m(-\omega^2 x)$

$-k = m(-\omega^2)$

$\frac{-k}{m} = \frac{m(-\omega^2)}{m}$

(cancel out the common terms from both sides)

$\frac{k}{m} = \omega^2$

(equate the equation by angular frequency [ω])

$$\boxed{\omega = \sqrt{\frac{k}{m}}}$$

Or when ω is converted to T

$\omega = 2\pi f = \frac{2\pi}{T}$

$T = \frac{2\pi}{\omega}$, $\omega = 2\pi f$

$$\boxed{T = 2\pi\sqrt{\frac{m}{k}}}$$

(Period [T] of SHM)

From the previous derivations it can be seen that **Simple Harmonic Motion (SHM)** is the combination periodic motion and a restoring force whose magnitude depends on the displacement from the equilibrium position.

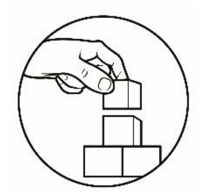
Example:

A 100-g body is attached is attached at the end of a hanging spring with a spring constant of 2,000 dynes/cm. It is displaced 10 cm from its equilibrium position and then released, Calculate the period T.

Given: m = 100 g   k = 2000 dynes/cm

A = 10 cm   x = 5.0 cm

T = $2\pi\sqrt{m/k}$ = $2\pi\sqrt{100g/(2{,}000\frac{dynes}{cm})}$ = **1.404 s**.



What's More

Activity 2.3: "Let's Work Together"

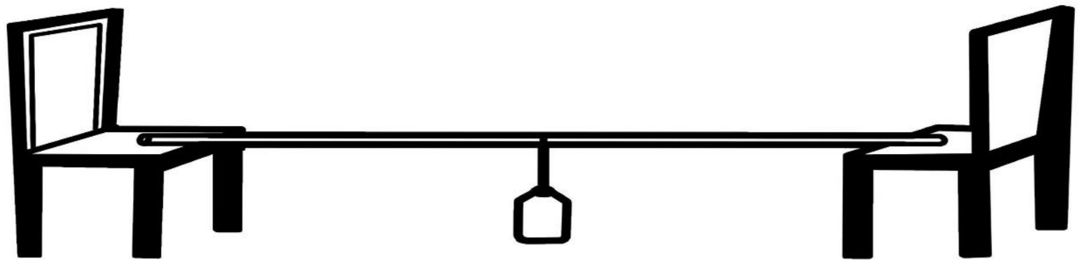
Instruction: Provide the following materials and perform the procedures. Observe properly and answer the following questions given below.

Materials:

2 feet yarn
2 feet connected rubber bands
1pc. 330 ml mineral bottle filled with water
1 meter wooden or bamboo stick
2 chair
1 tape

Procedures:

1. Using the 1-foot rubber bonds, tie the mineral bottle that is filled with water.
2. Put the wooden or bamboo stick between a distant chair. Using the tape assure the stick will not move.
3. Tie the material prepared in procedure No. 1 at the middle of the wooden or bamboo stick suspending it at a length of about an elbow's length.
4. Place the bottled water on the to top of the stick where you tie it.
5. Release and top the bottle.
6. Observe its movement.
7. Repeat the procedure using the yarn.



Questions:

1. What do you observe when the bottled released?
   Using the yarn? Rubber band?
2. What do you observe with the movement of the bottle with two materials?
3. Will the frequency matters with the materials used? How about its velocity?
4. In the activity, Is there a restoring force that allows the object to restores its initial position?

What I Have Learned

Instruction: Fill the blanks with the correct answer. Choose your answer on the given set of words in the box.

stiffer	stretch	greater	decrease	less

The greater the spring constant (k), the 1)______the spring; hence a greater force is required to 2)________or compress the spring. When force is greater, acceleration is 3) __________, and the amount of time required for a single cycle should 4)________________(assuming that the amplitude remains constant). Thus, for a given amplitude, a stiffer spring will take 5)_________ time to complete one cycle of motion than one that is less stiff.

What I Can Do

Activity 2.3 Let's Solve It!

Instruction: Solve and analyze the problem carefully. Show your solution.

The body of a 1275 kg car is supported on a frame by four springs. Two people riding in the car have a combined mass of 153 kg. When driven over a pothole in the road, the frame vibrates with a period of 0.840 s. For the first few seconds, the vibration approximates simple harmonic motion. Find the spring constant of a single spring.

Lesson 3	Application of Simple Harmonic Motion

Learning Objective:

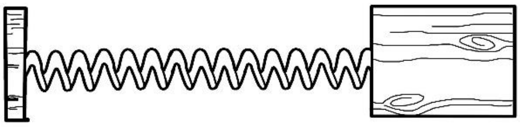
1. Apply the concept of Simple Harmonic Motion
2. Analyze and solve problems involving Simple and Physical Pendulum.

What' s In

In the previous activity we have derived the equation for a mass-spring system in harmonic motion now let's try to expound the concept by applying the previous derivation to some real-life situation where harmonic motion is seen.

Activity 3.1 Know Me!

Instruction: Using the three objects below. Illustrate the following.



a. At maximum stretch

b. At equilibrium

c. At maximum compress

What's New

Activity 1.1 Rubber Bounce!

Instruction: Perform the activity and observe it properly.
Materials:
3 Different weights of rubber balls

Procedures:
1. Hold the Ball at the level of your chest and drop it into a flat surface, and let the ball bounce on its on until it will stop.
2. Observe the movement of every ball.

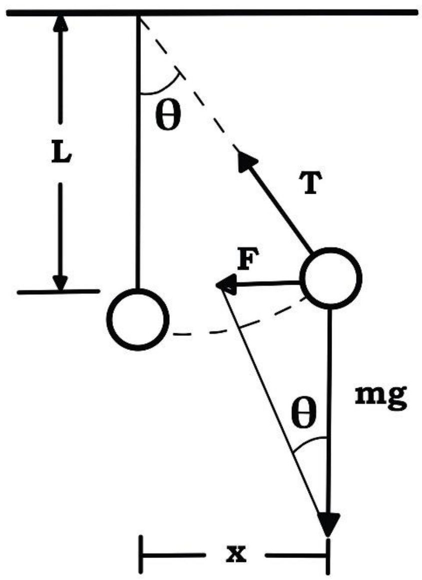
Questions:

1. Which of the three bounce faster?
2. Why is it the three balls bounce differ to each other?

What is It

One of the most relatable phenomena that shows the concept of Simple Harmonics Motion (SHM) is a pendulum. Now let us define what is it.

Simple Pendulum



A simple pendulum consists of a bob of relatively large mass hanging on a string with negligible mass. The string is normally in a vertical position. The Bob hangs along a vertical line and is in equilibrium under the action of two forces, its *weight* and the *tension* in the string.

The pendulum bob will swing when it is displaced sideward and released. It oscillates along the arc. When the bob is displaced and the string makes an angle θ with the vertical, the force F which tends to restore the bob to its equilibrium position is given by $F = -mg \sin \theta$ which is the component of the weight mg along the line tangent to the arc, as seen on the figure. The displacement x of the bob from the equilibrium position $x = L\theta$ where L is the length of the string, and θ is the angular displacement in radians. For small angles, θ is very nearly equal to sin θ. Therefore,

$$F = -mg\sin\theta$$

And using $\sin\theta = \frac{x}{L}$

$$F = -mg\frac{x}{L}$$

Since from the second law of motion by Newton, F = ma, we can equate the two equations for the force. We can have then,

$$ma = -mg\frac{x}{L}$$

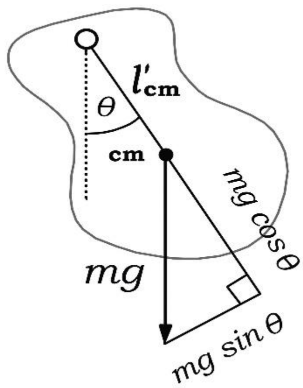
$$\frac{x}{a} = \frac{-L}{g}$$

Since $T = 2\pi\sqrt{-x/a}$, we substitute $\frac{L}{g}$ to $\frac{-x}{a}$.

Therefore, the **period of a simple pendulum** is $\mathbf{T = 2\pi\sqrt{L/g}}$.

**Where L is the length of the string and g is gravitational acceleration ($g = 9.81\ m/s^2$).*

Physical Pendulum



Any object which is acted upon by a restoring torque will move in angular harmonic motion when given an angular displacement. A physical pendulum an illustrate this effect. As seen on the figure, it shows that a body of an arbitrary shape which is free to rotate about a fixes point, in the illustration the body is pivoted at point O. When it is displaced at an angle θ from the vertical, a restoring torque act on it. The distance from the center of gravity (c.g.) to the point O is *L'*, the moment of inertia about point O is *I*, and the mass of the body is *m*. The restoring torque on the body is N = mgL'.

The expression mgL' corresponds to the restoring torque k_t,

$$k_t = mgL'$$

Therefore, the **period of the physical pendulum** is given by $\mathbf{T = 2\pi\sqrt{I/k}}$ **or**

$$\mathbf{T = 2\pi\sqrt{L/mgL'}}$$

Example:

You need to know the height of a tower, but darkness obscures the ceiling. You note that a pendulum extending from the ceiling almost touches the floor and that its period is 6 s. How tall is the tower?

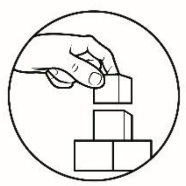
Given: T = 12 s ; g = 9.81 m/s

Solution:

$T = 2\pi\sqrt{L/g}$

$\sqrt{L} = (T\sqrt{g})/2\pi$;

$L = T^2g/4\pi^2 = (6\ s)^2(9.81\ m/s^2)/4\pi^2 =$ **8.95 m**



What's More

Activity SWAY WITH ME!

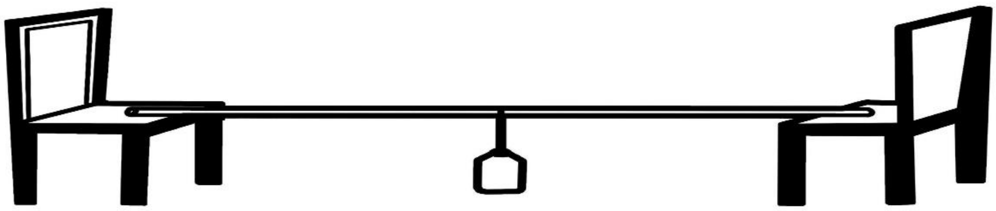
Instruction: Perform the activity and observe it properly. And fill in the table to answer the following questions below.

Materials:

1-meter yarn
1- Foot of connected rubber bonds
1pc. 330 ml mineral bottle filled with water
1 meter wooden or bamboo stick
2 chair
1 tape

Procedures:

1. Using the 1-meter yarn, tie the mineral bottle that is filled with water with a length of around 50 cm (approximately an arm's length).
2. Put the wooden or bamboo stick between a distant chair. Using the tape assure the stick will not move.
3. Tie the homemade pendulum prepared in procedure No. 1 at the middle of the wooden or bamboo stick suspending it at a length of about an elbow's length.
4. Hold the suspended improvised pendulum at a height equal to the height of the stick making sure that the string does not sag or bend.
5. Release the improvised pendulum.
6. Observe its movement.



Length of yarn (L)	Period (T)	Frequency (f)	Angular Frequency (w)
50 cm			
30 cm			

Questions:

1. Which length of string had the greater period?
2. Which length of string had the greater frequency? Angular frequency?
3. What can be concluded between the length of the string to the value of period, frequency, and angular frequency?

What I Have Learned

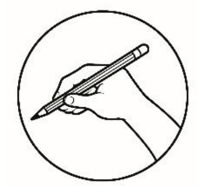
Instruction: Underline the correct answer that will satisfy the statements below.

A 1. _______________ (*simple pendulum, physical pendulum*) consists of a bob of relatively large mass hanging on a string with negligible 2. ________________ (*weight, mass*). The string is normally in a 3. _________________(*vertical, horizontal*) position. The Bob hangs along a vertical line and is in equilibrium under the action of two forces, its weight and the 4. ____________________(*tension, frequency*) in the string. However, any object which is acted upon by a restoring torque will move in angular harmonic motion when given an angular displacement is called 5. ________________________(*simple pendulum, physical pendulum*).

What I Can Do

Activity 3.3 Let's Solve It!

1. You need to know the height of a tower, but darkness obscures the ceiling. You note that a pendulum extending from the ceiling almost touches the floor and that its period is 12 s. How tall is the tower?
2. A body is pivoted so that its center of gravity is 1.0 m from the axis of rotation O. The body's radius of gyration about point O is 60 cm. The body acts like a pendulum. Find the period of vibration of the body.



Assessment

POST-TEST. Choose the letter of the correct answer. Encircle the letter of you chosen answer on the answer sheet provided.

1. The length of a simple pendulum oscillating with a period T is quadrupled, what is the new period of oscillations in terms of T?

   A. 2T B. 4T C. ½ T D. ¼ T

2. The length of a simple pendulum oscillating with a period T is quartered, what is the new period of oscillations in terms of T?

   A. 2T B. 4T C. ½ T D. ¼ T

3. A simple pendulum has a period of 1 s. What is the length of the string?

   A. 1 m B. 2 m C. 4 m D. ½ m E. ¼ m

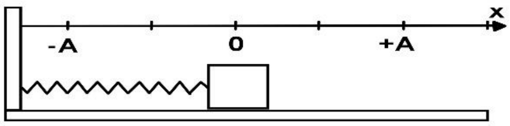
4. A simple pendulum has a period of 2 s. What is the length of the string?

   A. 1 m B. 2 m C. 4 m D. ½ m E. ¼ m

5. A simple pendulum has a period of 4 s. What is the length of the string?

   A. 1 m B. 2 m C. 4 m D. ½ m E. ¼ m

For numbers 6-9, refer to the diagram below:



6. When the mass reaches point x = +A its instantaneous velocity is?

   A. Maximum and positive C. Maximum and Negative
   B. Zero D. Less than maximum and positive

7. When the mass reaches point x = 0 its instantaneous velocity is?

   A. Maximum and can be positive or negative
   B. Constant and doesn't depend on the location
   C. Zero
   D. Slightly less than maximum and positive

8. When the mass reaches point x = 0 its instantaneous acceleration is?

   A. Maximum and can be positive or negative
   B. Constant and doesn't depend on the location
   C. Zero
   D. Slightly less than maximum and positive

9. A mass on a spring undergoes SHM. The maximum displacement from the equilibrium is called?

   A. Period B. Frequency C. Amplitude D. Wavelength

10. In a periodic process, the number of cycles per unit of time is called?

   A. Period B. Frequency C. Amplitude D. Wavelength

11. Which of the following in a periodic process, which the time required to complete one cycle?

A. Period B. Frequency C. Amplitude D. Wavelength

12. What is the instantaneous acceleration, when the mass reaches point x = +A?

A. Maximum and can be positive or negative
B. Constant and doesn't depend on the location

C. Zero

D. Slightly less than maximum and positive

13. An object with a mass M is suspended from an elastic spring with a spring constant k. The object oscillates with maximum amplitude A. If the amplitude of oscillations is doubled, how it will change the period of oscillations?

A. The period is increased by factor two
B. The period is increased by factor four

C. The period is decreased by factor two

D. The period is decreased by factor four

14. An object with a mass M is suspended from an elastic spring with a spring constant k. If the mass of oscillations is quadrupled, how it will change the period of oscillations?

A. The period is increased by factor two
B. The period is increased by factor four

C. The period is decreased by factor two

D. The period is decreased by factor four

15. An object with a mass M is suspended from an elastic spring with a spring constant k. The object oscillates with period T on the surface of Earth. If the oscillating system is moved to the surface of Moon, how it will change the period of oscillations? Acceleration due to gravity on moon= 1.6 m/s^2

A. The period is increased by factor $\sqrt{6}$
B. The period is increased by factor four

C. The period is decreased by factor $\sqrt{6}$

D. The period is decreased by factor four

Additional Activities

Aside from a pendulum as an example for simple harmonic motion, give three (3) examples of phenomenon or motion that shows simple harmonic motion and draw and label what acts as its restoring force and point of equilibrium.

Answer Key

PRE-TEST

1. C
2. B
3. A
4. B
5. A
6. C
7. A
8. E
9. A
10. A
11. A
12. C
13. E
14. A
15. C

POST-TEST

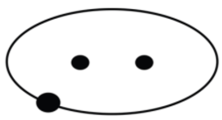
1. A
2. C
3. E
4. A
5. C
6. B
7. A
8. C
9. C
10. B
11. A
12. A
13. E
14. A
15. A

Lesson 1. What I Have Learned

1. Periodic motion
2. Amplitude
3. Period
4. Frequency

Lesson 1.1 Complete Me!

1. equal areas in equal amounts of time
2. Slingshot effect
3. $K = R^3/T^2$



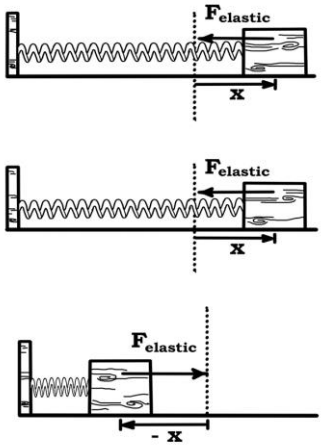
Lesson 2. What I Have Learned

1. Stiffer
2. Stretch
3. Greater
4. Decrease
5. Less

Activity 2.1 Match Me!

1. A
2. B
3. C
4. D
5. E

Lesson 3.1 Know Me!



Lesson 3. What I Have Learned

1. Simple pendulum
2. Mass
3. Vertical
4. Tension
5. Physical pendulum

Lesson 1
Activity 1.3

a. T = 1.404 s
b. A max = -200.3 cm/s^2
c. A = -100 cm/s^2

Lesson 2
Activity 2.3

1. k = 2.00 x10^4 N/m

Lesson 3
Activity 3.3

1. L = 36 m
2. T = 1.2 s

References

Holzner, S., 2011. *Physics I For Dummies*. 2nd ed. Indianapolis, Indiana: Wiley Publishing Inc., pp.251-267.

Serway, R. and Faughn, J., 2006. *Holt Physics*. 10801 N. MoPac Expressway, Building 3, Austin, Texas 78759: Holt, Rineheart and Winston, pp.368-403.

Young, H. and Freedman, R., 2008. *University Physics With Modern Physics*. 12th ed. 1301 Sansom.e St.. San Francisco, CA 94111: Pearson, pp.419-439.

Young, H. and Freedman, R., 2021. *University Physics With Modern Physics*. 13th ed. 1301 Sansome Street, San Francisco, CA, 94111: Pearson Education Inc., pp.437-456.

EDITOR’S NOTE

This Self-learning Module (SLM) was developed by DepEd SOCCSKSARGEN with the primary objective of preparing for and addressing the new normal. Contents of this module were based on DepEd’s Most Essential Learning Competencies (MELC). This is a supplementary material to be used by all learners of SOCCSKSARGEN Region in all public schools beginning SY 2020-2021. The process of LR development was observed in the production of this module. This is version 1.0. We highly encourage feedback, comments, and recommendations

For inquiries or feedback, please write or call:

Department of Education – SOCCSKSARGEN
Learning Resource Management System (LRMS)

Regional Center, Brgy. Carpenter Hill, City of Koronadal

Telefax No.: (083) 2288825/ (083) 2281893

Email Address: region12@deped.gov.ph