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General Physics 1
Activity Sheet
Quarter 1 – MELC 56-57
Week 7
Center of Mass and Momentum

REGION VI – WESTERN VISAYAS

General Physics 1
Activity Sheet No. 15 - Center of Mass and Momentum
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This **Learning Activity Sheet** is developed by DepEd Region 6 – Western Visayas.

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Introductory Message

Welcome to General Physics 1!

The **Learning Activity Sheet** is a product of the collaborative efforts of the Schools Division of Sagay City and DepEd Regional Office VI - Western Visayas through the Curriculum and Learning Management Division (CLMD). This is developed to guide the learning facilitators (teachers, parents and responsible adults) in helping the learners meet the standards set by the K to 12 Basic Education Curriculum.

The **Learning Activity Sheet** is self-directed instructional materials aimed to guide the learners in accomplishing activities at their own pace and time using the contextualized resources in the community. This will also assist the learners in acquiring the lifelong learning skills, knowledge and attitudes for productivity and employment.

For learning facilitator:

The **General Physics 1 Activity Sheet** will help you facilitate the leaching-learning activities specified in each Most Essential Learning Competency (MELC) with minimal or no face-to-face encounter between you and learner. This will be made available to the learners with the references/links to ease the independent learning.

For the learner:

The **General Physics 1 Activity Sheet** is developed to help you continue learning even if you are not in school. This learning material provides you with meaningful and engaging activities for independent learning. Being an active learner, carefully read and understand the instructions then perform the activities and answer the assessments. This will be returned to your facilitator on the agreed schedule.

Name of Learner: ____
Grade and Section:___________________________Date: _____________________

GENERAL PHYSICS 1 ACTIVITY SHEET No. 15
Center of Mass and Momentum

I. Learning Competency with Code

- Differentiate center of mass and geometric center (STEM_GP12WE-Ihi-56)
- Relate the motion of center of mass of a system to the momentum and net external force acting on the system (STEM_GP12MMICIh-57)

II. Background Information for Learners

In this lesson, you will be able to know what a center of mass is; how it differs from a geometric center; how is it affected by an external force. Furthermore, you will be able understand some actual events by studying the behavior of the center of mass in a system and the importance of it in product design.

● CENTER OF MASS and GEOMETRIC CENTER

The **Center of Mass (COM)** of an object is the point that moves as though all of the system's mass were concentrated and all external forces were applied. On the other hand, the **Geometric Center (Centroid)** of an object is the arithmetic mean position of all its points in the two coordinate directions.

Figure 1: The COM and the geometric center of the ball are located in the middle of the spherical-shaped ball because the mass is well distributed. But this is not the case for the smart phone.

In Figure 1, the COM of the ball is at its center because the mass is well distributed around it. The Geometric center of the ball is also located at the center because the ball has a symmetrical shape. But for objects with irregular mass distribution (such as a phone), the COM and the Geometric center will have different locations.

When objects are thrown like a projectile, the COM of the object will follow the parabolic path and the object will rotate on the COM. (Refer to Figure 2 below)

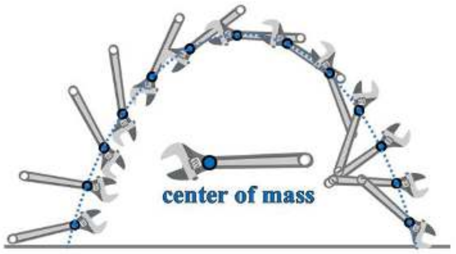


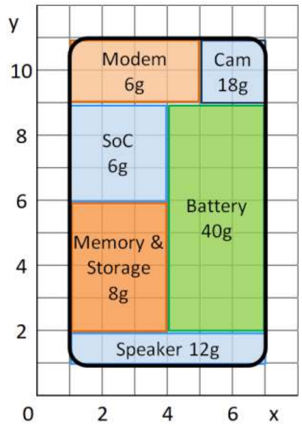
Figure 2: Different objects have different center of masses depending to the mass distribution of the object.

Understand this better using a 2-dimensional illustration. It is best to use the origin of the Cartesian plane as the reference point in locating for the COM along the x and y-axes. For a given mass-system, the mass (*m*) and the distance (*r*)

$$COM = \frac{\Sigma m_i r_i}{\Sigma m_i} = \frac{m_1 r_1 + m_2 r_2 + m_3 r_3 + \cdots}{m_1 + m_2 + m_3 + \cdots}$$

Note: You can use any unit for the mass quantity as long as they are all uniform.

Sample Problem: A motherboard of a hypothetical smartphone is composed of the Speaker (12g), Memory and Storage module (8g), System-On-a-Chip Module (6g), Modem (6g), Camera (18g) and a Battery (35g) as shown below. Locate for the center of mass (COM) of the motherboard along the x and y-axes.



Given:

m_1 (Speakers) = 12g

m_2 (Memory and Storage) = 8g

m_3 (SoC Module) = 6g

m_4 (Modem) = 6g

m_5 (Camera) = 18g

m_6 (Battery) = 40g

Solution:

(a) COM along the x-axis

$$COM_x = \frac{m_1 r_1 + m_2 r_2 + m_3 r_3 + m_4 r_4 + m_5 r_5 + m_6 r_6}{m_1 + m_2 + m_3 + m_4 + m_5 + m_6}$$

$$COM_x = \frac{(12 \text{ x } 4)+(8 \text{ x } 2.5)+(6 \text{ x } 2.5)+(6 \text{x} 3)+(18 \text{ x } 6)+(40 \text{ x } 5.5)}{12+8+6+6+18+40}$$

$$COM_x = \frac{(48)+(20)+(15)+(18)+(108)+(220)}{90}$$

$$COM_x = \frac{429}{90} = \boldsymbol{4.77}$$

(b) COM along the y-axis

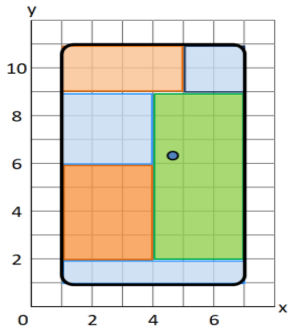
$$COM_y = \frac{m_1 r_1 + m_2 r_2 + m_3 r_3 + m_4 r_4 + m_5 r_5 + m_6 r_6}{m_1 + m_2 + m_3 + m_4 + m_5 + m_6}$$

$$COM_y = \frac{(12 \text{ x } 1.5)+(8 \text{ x } 4)+(6 \text{ x } 7.5)+(6 \text{x} 10)+(18 \text{ x} 10)+(40 \text{ x } 5.5)}{12+8+6+6+18+40}$$

$$COM_y = \frac{(18)+(32)+(45)+(60)+(180)+(220)}{90}$$

$$COM_y = \frac{555}{90} = \boldsymbol{6.17}$$

The center of mass (COM) of the motherboard is located 4.77 units along the x-axis and 6.17 units along the y-axis. The figure in the right shows that the COM is not directly at the center because it is dependent on the mass distribution of the object. When a force is applied on the motherboard and it causes it to rotate, its axis of rotation will be on its COM.



- **MOTION of COM**

In Figure 4.a, consider a system of the two identical balls A and B rolling at the same velocity. (a) In the beginning, ball A is at 0m mark and ball B is at 10m mark. Therefore, due to the distribution of the two balls in the system, the COM of the system is at 5m mark.

After one second (see Figure 4.b), ball A is now at the 2m mark and ball B is at 12m mark. Therefore, the COM is at 7m mark because the two masses that comprises the system moves in a constant velocity. Without any external force acting on the system, the COM will also have a constant velocity. Newton's first Law applies to this.

When 1 newton of external force (see Figure 4.c) was applied on ball A causing it to accelerate by $1m/s^2$, the motion of the COM also changes. Notice that after one second from the beginning, ball A is now at 3m mark. Because of the acceleration being introduced to mass A, it also affects the motion of the COM. In this case, ball A is moving at 3m/s and the COM is now at the 7.5m mark. As the external force affect the motion of ball A, it also affects the motion of the whole system by looking at the motion of the COM. The acceleration of the system is described as:

$$a_{COM} = \frac{F_{net}}{m_{total}}$$

Figures 4.a and Figure 4.b show a moving COM with constant velocity, thus momentum is conserved. The momentum of a moving system is described as:

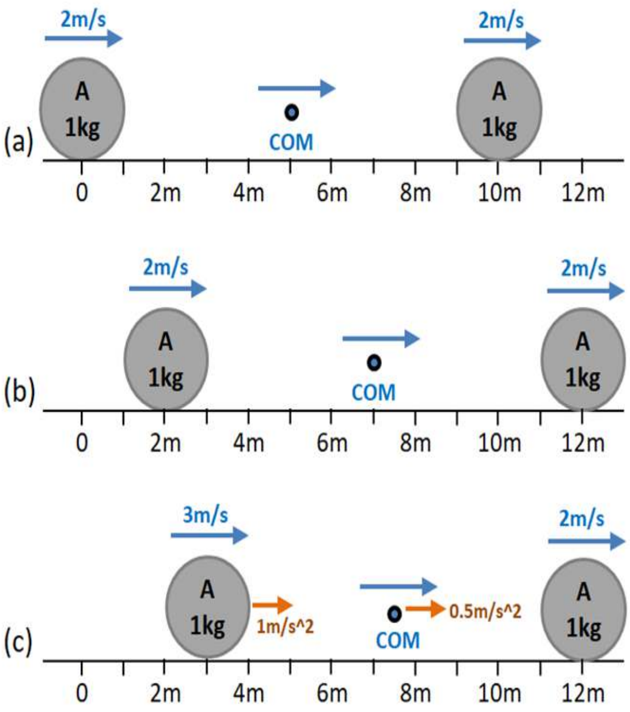


Figure 4. (a) A system of mass has its own COM and it seems like all the mass of the system is concentrated in the COM; (b) The COM moves at constant velocity; (c) When an external force is applied, the COM of the system accelerates.

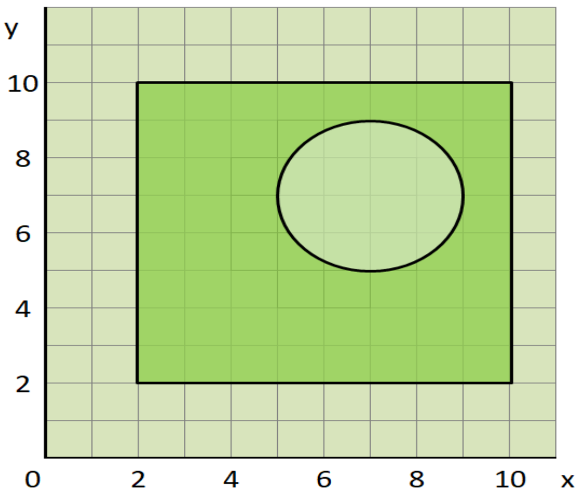
$$p = m_{total}v_{COM}$$

III. Activity Proper

Activity 1. Center of Mass:

A. Solve for the problem below:

Directions. Locate for the center of mass of the object on the right. Each m^2 of the object has a mass of 1g. Write your answer in a separate sheet of paper.



Guide Questions:

1) What is the area of the hole?

___

___

2) Where is the location of its COM along the x-axis?

___

___

3) Where is the location of its COM along the y-axis?

___

___

4) Is the COM at the center of the object? Why?

___

___

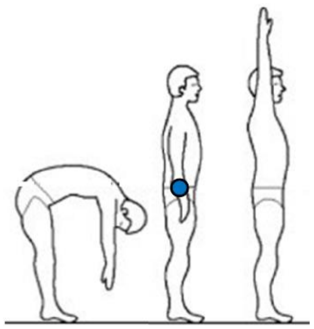
5) If the hole wasn't there, where will be the location of the COM?

___

___

B. Read the questions and write your answers on the space provided.

1) Given a reference COM of a man below, locate the COM of the other two men with different mass distribution.



2) Can the location of the COM change? Why?

___

___

3) What is the difference between the COM from the geometric center?

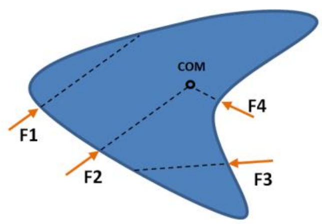
___

___

4) Four external forces act on a mass shown on the right. Which of the following forces will cause the mass to rotate?

___

___



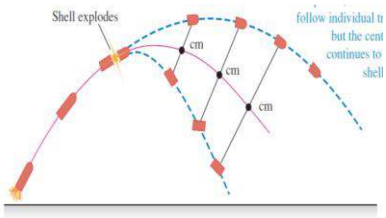
5) What happens to the motion of the COM if an external force is applied to the system?

6) When the external force causes the system to accelerate, what happens to the system's momentum?

7) Consider yourself and the raft you ride on as a system as shown in the right. While the raft floats motionless in the lake, you start walking to the left side of the raft. What will happen to the raft (the system is frictionless)?

8) Refer to question #7, what will happen to the COM of the system?

9) A projectile split into two particle mid-air as shown in the right. What happens to the COM of the system?



10) Refer to question #9. Why does the COM of the system continue to follow a parabolic path after splitting?

IV. Reflection

I understand

I don't understand

I need more information about

V. Key Answers

A. Solve the Problem

1. Mass of the hole (to be subtracted)

$m_2 = m_{hole} = \pi r^2 = \pi(2)^2 = 12.57m^2$

2. COM along the x-axis

$COM_X = \frac{m_1 r_1 - m_2 r_2}{m_1 - m_2} = \frac{(64 \times 6)-(12.57 \times 7)}{64-12.57} = \frac{(384)-(87.99)}{51.43} = \frac{296.01}{51.43} = \mathbf{5.76m}$

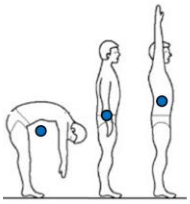
3. COM along the y-axis

$COM_Y = \frac{m_1 r_1 - m_2 r_2}{m_1 - m_2} = \frac{(64 \times 6)-(12.57 \times 7)}{64-12.57} = \frac{(384)-(87.99)}{51.43} = \frac{296.01}{51.43} = \mathbf{5.76m}$

4. NO, because of the missing part of the object, the COM has shifted towards the more massive portion of the object.

5. $COM_X = \frac{m_1 r_1}{m_1} = \frac{(64 \times 6)}{64} = 6m$ $\quad COM_Y = \frac{m_1 r_1}{m_1} = \frac{(64 \times 6)}{64} = 6m$

B. Read the questions and write your answers on the space provided.

1. 

2. Yes, depending on the mass distribution of the object.

3. The Center of Mass (COM) is the point that moves as though all of the system's mass were concentrated and all external forces were applied. On the other hand, the Geometric Center (Centroid) of an object is the arithmetic mean position of all its points in the two coordinate directions. The COM is the dependent on the mass distribution of the system and its shape while the geometric center depends mainly on the shape of the object.

4. External forces F1 and F3 will cause a rotating motion on the mass because these forces are applied in offset from the COM. These two forces will rotate the mass in a clockwise manner.

5. The COM of the system will experience a change in its velocity. If the external force is applied on the system in the direction parallel to the motion of the COM, the COM will accelerate. But if the external force opposes the direction of the COM's motion, the COM will decelerate.

6. An external force that causes acceleration of the system will increase the velocity of the system's COM; therefore the momentum will also increase.

7. As you walk to the left side, the raft will then move to the right side. Newton's 3rd law of motion applies to this.

8. Initially, the COM of the system is stationary; therefore as you walk to the left and the raft moves to the right, the system's COM remains in its original location because there is no external force applied to it.

9. Even though the projectile splits into two parts and traverse different paths, the particles are still part of the system. The COM of the system will still follow a parabolic path

10. The two particles still behaves as a single mass system and their total mass can still be concentrated on the location of the COM, thus the COM's path is parabolic.

IV. Reflection

VI. References

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ILLUSTRATION

Figure 1: The COM and the geometric center of the ball are located in the middle of the spherical-shaped ball because the mass is well distributed. But this is not the case for the smart phone.

Figure 2: Different objects have different center of masses depending to the mass distribution of the object.

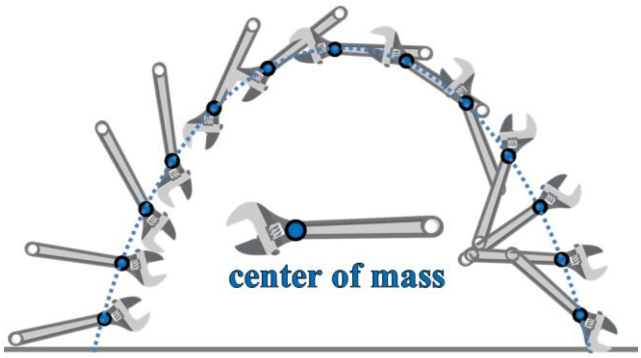
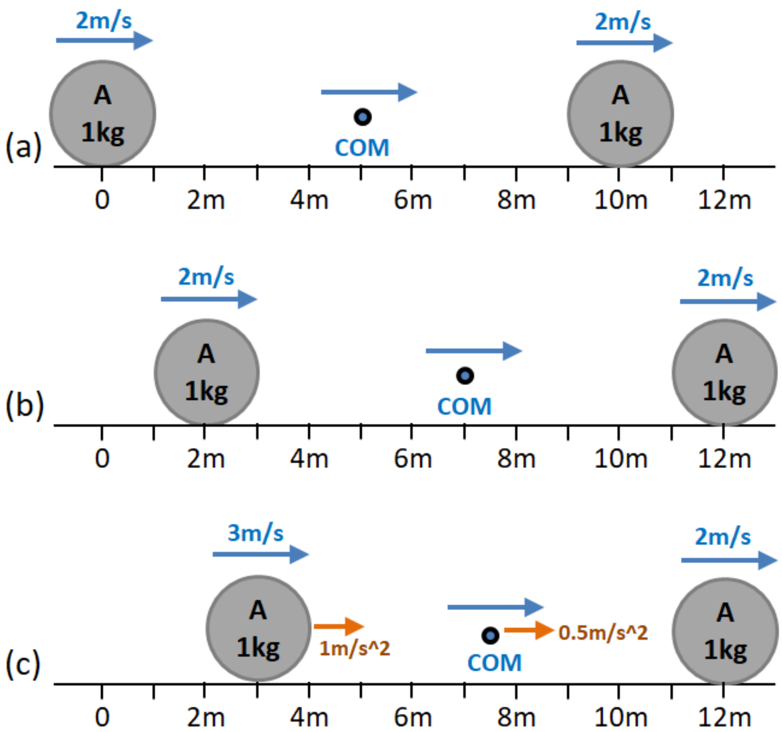


Figure 2: When an object is thrown, it acts like a projectile in mid-air. The center of mass will follow a parabolic path until it reaches the ground.



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