Subject Code PHY 1 **Physics 1**
Module Code 3.0 **Motion with Uniform Acceleration**
Lesson Code 3.4 **1D Free Fall**
Time Frame 30 minutes

Components	**Tasks**	**TA[1] (min)**	**ATA[2] (min)**
Target 	By the end of this learning guide, the student should be able to: ● define free fall ● describe the the position, velocity, and acceleration of an object in free fall	1	
Hook 	In the previous lesson, we were able to explore concepts on 1D motion with constant acceleration along the horizontal axis. It could be an accelerating car or a sprinter on a race track. We have discussed what will happen to an object's motion or to its velocity and displacement as it moves along a straight line. Now we will look into a special 1D motion with constant acceleration in which the acceleration is directed along the vertical axis. Maybe you have heard of the story of Isaac Newton and the falling apple that prompted his discovery of gravity. It is said that while the young Isaac Newton was sitting under an apple tree, an apple fell straight into his head which led him to discovering his law of gravitation.  **Figure 1.** Isaac Newton under the apple tree *(retrieved from: https://www.tutortonight.com/category/physics/basic-physics)* Gravity is the reason why we believe that "what goes up must come down". Any object thrown straight up will eventually come back down due to gravity.	3	

[1] Time allocation suggested by the teacher.
[2] Actual time allocation spent by the student (for information purposes only).

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<td>If a person drops a ball from the top of your academic building, gravity will accelerate it downward. And if you throw a rock straight up, it will eventually fall down as gravity continually pulls it downward.

When an object is being accelerated/decelerated by gravity alone (ignoring air resistance), then we can say that the object is undergoing free falling motion.</td>
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<td>What are the conditions for a motion to be in free fall? An object is considered to be in free fall if only the force of gravity acts on it. In order for us to achieve this, we will be ignoring the effect of air resistance (air friction) for our discussions on free fall.

We will only be discussing one dimensional free fall for now. The object should only have vertical (y-axis) velocity, meaning it has zero velocity along x-axis. 2D free fall (projectile motion) will be discussed later.

Let us try to examine closely what will happen to the acceleration, velocity, and displacement of objects under 1D free fall.

<u>Acceleration</u>

The acceleration tied with the force of gravity, or gravitational acceleration, has a magnitude denoted as g, and whose value is approximately $g = 9.8m/s^2$ near earth's surface. This value varies with elevation with a decreasing value as we go at higher altitudes. The gravitational acceleration is always pointing downward, towards the center of the earth, regardless if the ball is going up or falling down. By notation, "$\vec{a} = -g$", in which the negative sign indicates the direction of the acceleration.

The magnitude of gravitational acceleration is not dependent on the mass of the object under free fall. Near Earth's surface, assuming there is no air resistance, both a lighter tennis ball and a heavier bowling ball will be accelerated downward with the same magnitude of $g = 9.8\,m/s^2$. For a more concrete visualization on the concept, kindly visit the link below.

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Retrieved *from* https://www.youtube.com/watch?v=KDp1tiUsZw8

It can be seen from the video that it is true for any object regardless of how light its mass is, i.e. a metal ball and a feather.

But although these objects are accelerated at the same magnitude of gravitational acceleration, g, it doesn't mean they experience the same magnitude of **gravitational force**. We will discuss this concept further together with how we came up with the value of g, when we talk about forces in our upcoming lessons.

Velocity

Consider a ball being dropped from the top of a building as shown in Figure 2 below.

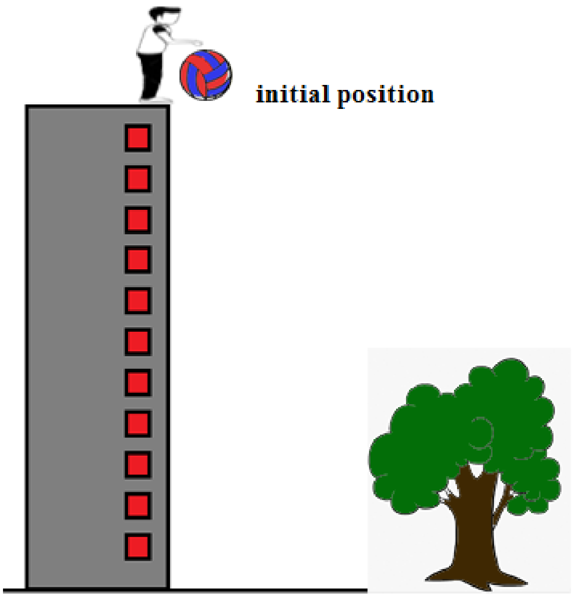

Figure 2. A ball directly dropped from the top of a building

When the object is released from rest, what do you think will happen if no gravity is acting on the object?

Well, without gravity the object will not fall to the ground. Upon release, its initial velocity at the top, which is zero, will remain zero since the object experiences no acceleration.

But due to gravitational acceleration, the ball will accelerate downward. In this case, both the object's acceleration and velocity are pointing downward. Thus the object will have an **increasing negative velocity**, in which the negative indicates a downward direction. With $g = 9.8 m/s^2$, this means that the velocity increases in magnitude by $9.8 m/s$ for every second.

The greater the height from which the ball is being dropped, it will take a longer time to fall and the greater the magnitude of its velocity will be as it reaches the ground.

Let us examine another example of free fall in which a ball is being tossed straight up as shown in Figure 3 below.

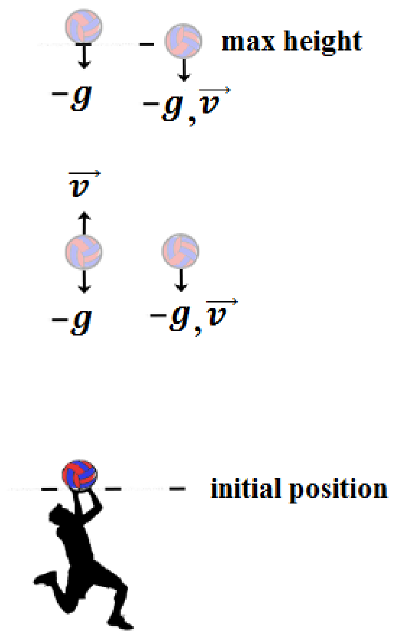

Figure 3. A ball being thrown straight up.

Upon release, the ball will have a positive (upward) initial velocity, $\vec{v}$, given by the thrower. As it rises up, with its upward velocity opposite the gravitational acceleration, it slows down until its velocity becomes zero. At this point, the ball has reached its maximum height and is then propelled to fall back down due to the gravitational acceleration.

As the ball starts to fall back to the ground, it will be accelerated by the same acceleration. With the ball's downward velocity in the same direction as the gravitational acceleration, its speed continually increases.

Since the acceleration of the object is the same both going up and down, the rate at which the ball's velocity decreases and increases in magnitude are the same. Thus the ball should have the same magnitude of velocity as when it was released when it falls back to the thrower's hand.

<u>Displacement and Time of Flight</u>

As we recall the concepts on displacement, we can easily see that the displacement of the object would be positive going up and negative going down, and that the total displacement of an object going up and back to its initial position is zero.

The maximum height is reached when the object's velocity becomes zero. Noting that velocity decreases in magnitude by $9.8 m/s$ for every second, the time it takes to reach the maximum height, as well as the maximum height, is completely dependent on the object's initial velocity.

Since the acceleration experienced by the object is the same both going up and down, the time it would take the object to reach the maximum height should also be equal to the time for it to come back down to the thrower's hand. That is because the object is being slowed down at the same rate as it is sped up.

Let us consider the example below and apply what we have learned so far.

Ex. A student released a ball from the top of a building with height h. The ball felt negligible air resistance during its fall.

a) What is the velocity of the ball at point (1)?
b) What is the magnitude and direction of the acceleration of the ball at point (1)? point (2)? point (3)?
c) At which point (1, 2, or 3) is the magnitude of the ball's velocity smallest? Greatest?

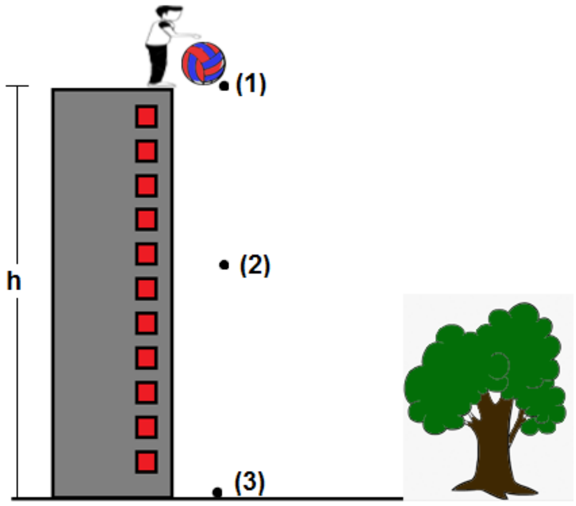

Figure 5. A ball dropped from the top of a building.

a) We are tasked to determine the velocity of the ball at point (1). Since we know that it is released from rest, then the velocity of the ball at point (1) is zero. We have no way of telling the magnitude of the velocity for point (2) and (3) since we do not know the exact position and the time of fall for the ball at these points. But we can be sure that the direction of the velocity of the ball is downward (negative).

b) Since our ball is accelerated by gravity alone, we can say

	that at any point along its path, point (1), (2), and (3) the downward gravitational acceleration, $\vec{a}$, has a magnitude equal to g. c) The ball is being dropped initially from rest at the top of the building. As it falls, the magnitude of its velocity continues to increase. Thus the magnitude of the ball's velocity is minimum at point (1) and maximum at point(3).		
Navigate 	Now it is time to test your understanding about the concepts of free falling objects. Write your answers on a clean sheet of paper. Follow your teacher's instructions regarding submission. This will be graded. 1. From the top of a tall building you throw one ball (*ball 1*) straight up and another ball (*ball 2*) straight down. The two balls leave your hand with the same magnitude of velocities. Answer each of the following questions and explain a. Which ball has greater magnitude of velocity when it reaches the ground? b. Which ball gets to the ground first? c. Which ball has a greater displacement when it reaches the ground? d. Which ball has traveled the greater distance when it hits the ground? (Young et.al, 2012) 2. A dripping water faucet steadily releases drops 1.0 s apart. As these drops fall, will the distance between them increase, decrease, or remain the same? Explain your answer. (Young et.al, 2012) 3. Explain why the time of flight of an object thrown from the ground is twice the time it takes to get to its highest point. Explain. (Young et.al, 2012)	6	
Knot 	In summary, we've learned that for any object under 1D free fall, ● The object experiences a constant gravitational acceleration, $\vec{a} = -g$ in which g is the magnitude of the downward gravitational acceleration equal to $9.8\ m/s^2$. ● While the object is going up, its **positive velocity** decreases in magnitude and as it falls down, its **negative velocity** increases in magnitude. ● The time it will take for an object to reach its maximum height is the same as the time it will fall back to its original position.	1	

References:

1. Nix, Elizabeth. *Did an apple really fall on Newton's Head?*. Retrieved from: https://www.history.com/news/did-an-apple-really-fall-on-isaac-newtons-head. 2018.
2. Young, Hugh D. and Freedman, Roger A. (2012). *University Physics with Modern Physics 13th ed*. United States of America: Pearson Education, Inc.
3. Cutnell, John D. and Johnson, Kenneth W. (2012). *Physics 9th ed*. United States of America: John Wiley & Sons, Inc.

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