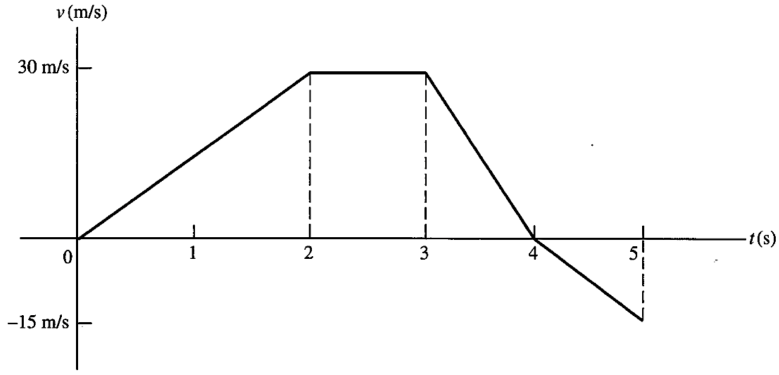
Subject Code	PHY 1	**Physics 1**
Module Code	2.0	**Motion Graphs**
Lesson Code	2.3	**Acceleration-Time Graphs**
Time Frame		30 minutes

Components	**Tasks**	**TA[1] (min)**	**ATA[2] (min)**
Target	By the end of this learning guide, the student should be able to: ● interpret acceleration-time graphs ● illustrate motion using acceleration-time graphs	1	
Hook	In the previous lesson, you learned how to illustrate motion using velocity-time or *v-t* graphs. It is a visual representation of how the velocity of a moving object changes over time. You also learned that the slope of a velocity-time graph tells us about the acceleration of the object. The picture below is an example of a roller coaster located in one of the fascinating amusement parks in the Philippines. This is Enchanted Kingdom's Space Shuttle. Every passage on a hill or a turn on a loop brings excitement to any rider. Visiting the amusement park without experiencing this breathtaking ride is like missing half of the EK experience.  The excitement that we experience in riding a roller coaster is due to the variations of velocity in different sections of the ride. Let us consider the following *v-t* graph and assume that it shows the velocity of the carts during the first five seconds of the roller coaster experience.	5	

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



The *v-t* graph shows that the object is undergoing varying accelerations at different time intervals. Using the concept of slope, we can determine the acceleration of the cart at different periods on the graph and describe its course of motion.

Time Interval	Slope (Acceleration)	Description
0 – 2 s	$m = 15\ m/s^2$	Constant positive acceleration.
2 – 3 s	$m = 0\ m/s^2$	Zero acceleration. Cart is moving at a constant velocity.
3 – 4 s	$m = -30\ m/s^2$	Constant negative acceleration.
4 – 5 s	$m = -15\ m/s^2$	Constant negative acceleration. Relatively slower change in velocity compared to the previous time interval.

We can see that the acceleration of the cart is changing over time. Trends in the changes in acceleration of a moving body can be better visualized if we plot these values over time. In this case, we generate another form of motion graph that we can use to describe the patterns of movement of an object. This is called an acceleration-time graph or *a-t* graph.

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An acceleration-time graph shows how the acceleration of an object changes over a given period. The acceleration now becomes the dependent variable and is plotted on the vertical or *y*-axis of the graph. Using the slopes of the *v-t* graph from our previous example, we can plot these values in our *a-t* graph. Since the values of the acceleration at certain time intervals are constant, we can just draw horizontal lines. The corresponding *a-t* graph would look like this.

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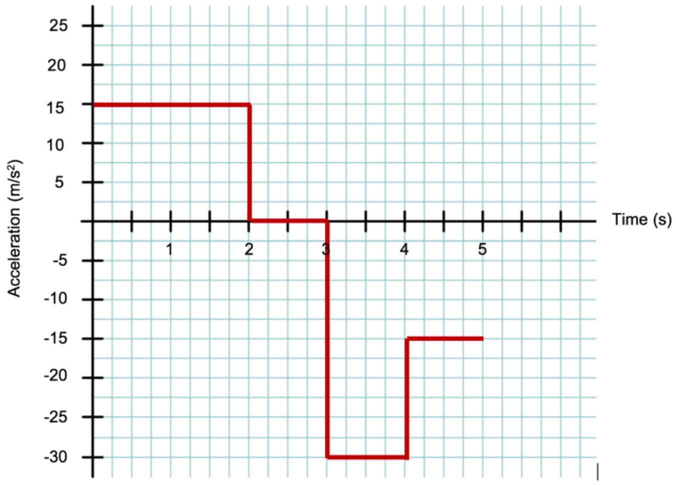
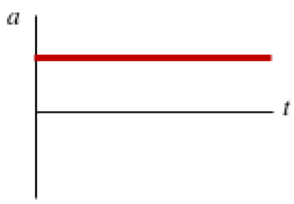
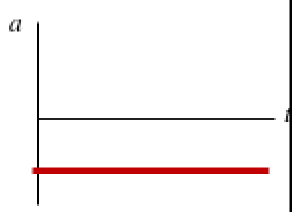


Uniformly accelerated motion is represented as horizontal lines in an *a-t* graph. Depending on where these are positioned in an *a-t* graph, such horizontal lines may mean different things:

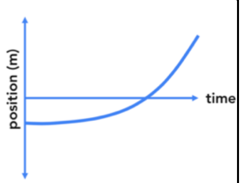
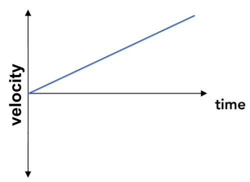
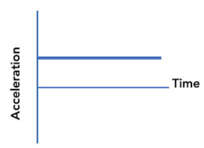
Sample a-t graph	Description	Meaning
	Horizontal line above the *x*-axis	▪ Constant positive acceleration ▪ The object has increasing velocity
	Horizontal line on the *x*-axis	▪ Zero acceleration ▪ The object is moving at constant velocity
	Horizontal line below the *x*-axis	▪ Constant negative acceleration ▪ The object has decreasing velocity

The motion graphs that you learned from the previous lessons had kinematic quantities attached to their slopes. The slope of an *x-t* graph shows the object's velocity while the slope of a *v-t* graph shows the object's acceleration. How about *a-t* graphs? Physicists use the term **jerk** to describe the slope of an *a-t* graph. Its unit is m/s^3.

An object experiences jerk when there is a change in force (Eager, Pendrill, & Reistad, 2016). It can be felt as an increasing or decreasing force on a body. This is more manifested in amusement rides like the roller coaster. A roller coaster is designed to stimulate the human sensory system, primarily visual, auditory, and vestibular (about balance). The ride is purposely intended for elevated acceleration.

When the acceleration changes over time, non-horizontal lines or curves can be generated on an *a-t* graph. Like on the previously discussed motion graphs, the slope of a curve on an *a-t* graph can be determined using a more sophisticated mathematical technique in calculus known as **differentiation.** You'll learn more about this as you progress to higher physics courses.

Curved position-time graphs, as discussed in our previous lesson, imply accelerated motion. A parabolic segment in an *x-t* graph indicates changing velocity. This change in velocity is uniform over time thus it implies constant acceleration. The following table can be used to describe qualitatively the corresponding *v-t* and *a-t* graphs for a curved or parabolic *x-t* graph.

***x-t* graph**	**Corresponding *v-t* graph**	**Corresponding *a-t* graph**
 An object that is speeding up in the positive direction. (parabolic)	 The velocity of the object increases uniformly over time. (linear)	 Acceleration is constant and positive. (constant)

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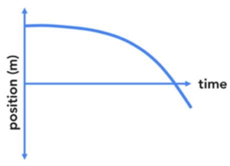
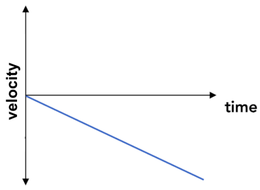
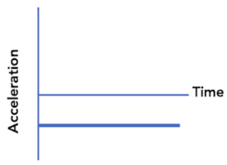
<td>

An object that is speeding up in the negative direction. (parabolic)</td>
<td>

The velocity of the object decreases (or the speed increases in the negative direction) uniformly over time. (linear)</td>
<td>

Acceleration is constant and negative. (constant)</td>
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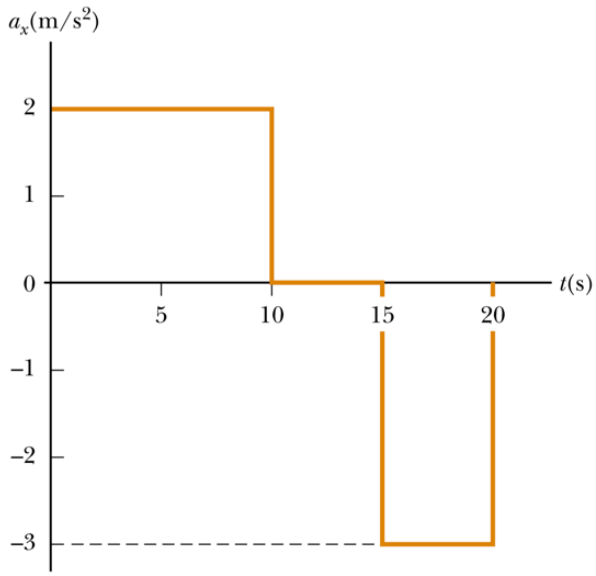
Work on the following exercises to find out if you understood the lesson on acceleration-time graphs. Write your answers on a clean sheet of paper. Follow your teacher's instructions regarding submission.

1. Describe the acceleration and velocity of the object in motion, as described by the segments of the following a-t graph.


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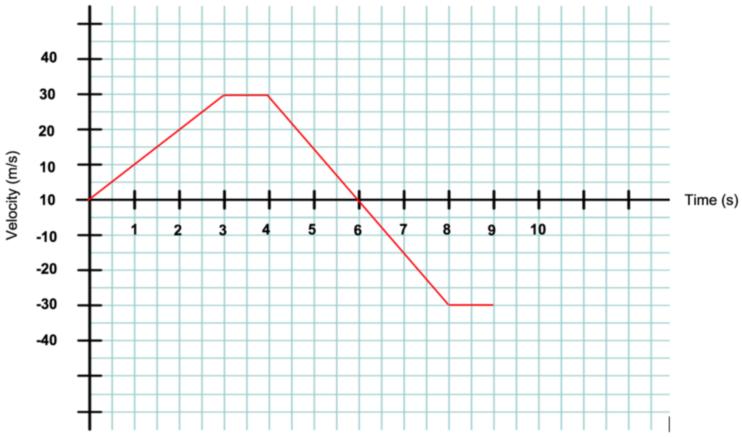
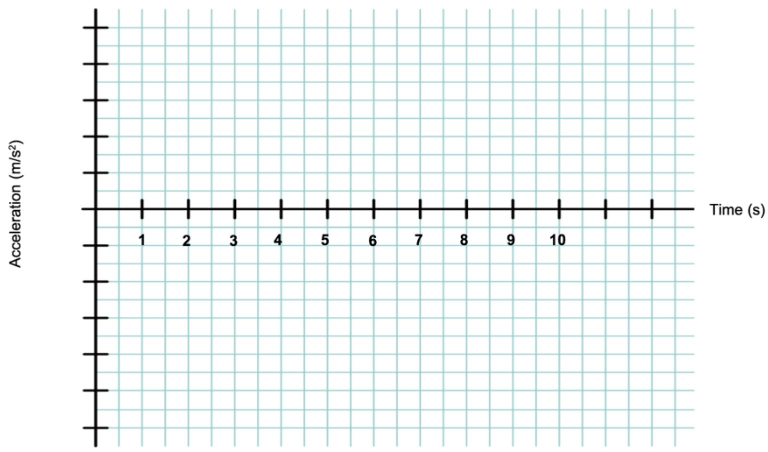
Segment of a-t graph	Acceleration	General description of motion
Between 0 – 10 s		
Between 10 – 15 s		
Between 15 – 20 s		

2. Draw the corresponding a-t graph for the following v-t graph.





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Here are some of the significant key ideas that you should remember about acceleration-time graphs.

- An acceleration-time graph or *a-t* graph shows how the acceleration of an object changes over time.
- A horizontal *a-t* graph implies constant acceleration. If it is found above the x-axis, the object has constant positive acceleration. If it is below the x-axis, the object has constant negative acceleration. If it lies exactly on the x-axis, the acceleration of the object is zero, hence moving at constant velocity.

2

	• The slope of an *a-t* graph is called the jerk. It indicates a change in force applied to a moving object (can be increasing or decreasing).		

References

1. Eager, D., Pendrill, A., & Reistad, N. (2016). Beyond velocity and acceleration: jerk, snap, and higher derivatives. European Journal of Physics, 37. https://iopscience.iop.org/article/10.1088/0143-0807/37/6/065008
2. Serway, R., & Jewett, J. (2004). *Physics for Scientists and Engineers.* Thomson Brooks/Cole.

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