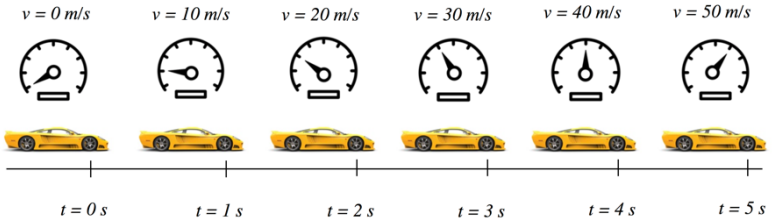
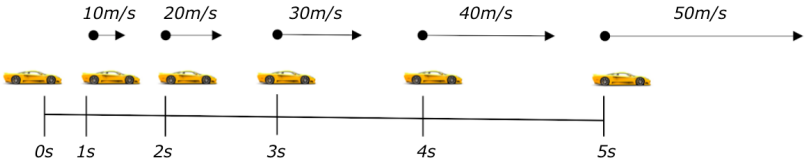
Subject Code	PHY 1	**Physics 1**
Module Code	2.0	**Motion Graphs**
Lesson Code	2.2	**Velocity-Time Graphs**
Time Frame		30 minutes

Components	Tasks	TA[1] (min)	ATA[2] (min)
Target 	By the end of this learning guide, the student should be able to: • interpret velocity-time graphs • illustrate motion using velocity-time graphs	1	
Hook 	In the previous lesson, we learned that a position-time graph provides essential information about an object's course of motion. Analysis of an *x-t* graph enables us to determine the velocity of a body at specific time intervals since the slope of an *x-t* graph is the object's velocity. Have you ever seen this device on the car's dashboard? This is called the **speedometer.** It is a device that measures and displays the **instantaneous speed** of a vehicle. It provides the speed of the car at a particular moment in time. If you're interested also with the direction, you get **instantaneous velocity.** A speedometer tells us the magnitude of the instantaneous velocity.  Now, let us consider the motion of a car on the road during the first 5 seconds. The figure below shows the speedometer readings of the car at specific points in time. Let us assume that the speedometer is calibrated in m/s.  	3	

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

We can visualize the motion of the car in the given example using the following motion diagram where the motion of the car is represented by a series of dots.



You would notice that the speedometer reading increases by 10 m/s for every 1-second interval. In its accompanying motion diagram, it can be gleaned that the spacing between each second is increasing which implies a continuous gain in speed. Just like what we did in the previous lesson on *x-t* graphs, we can organize this data set into a table and transform it into a graph. Doing so allows us to make another kind of motion graph. It is called the **velocity-time graph or a *v-t* graph.**

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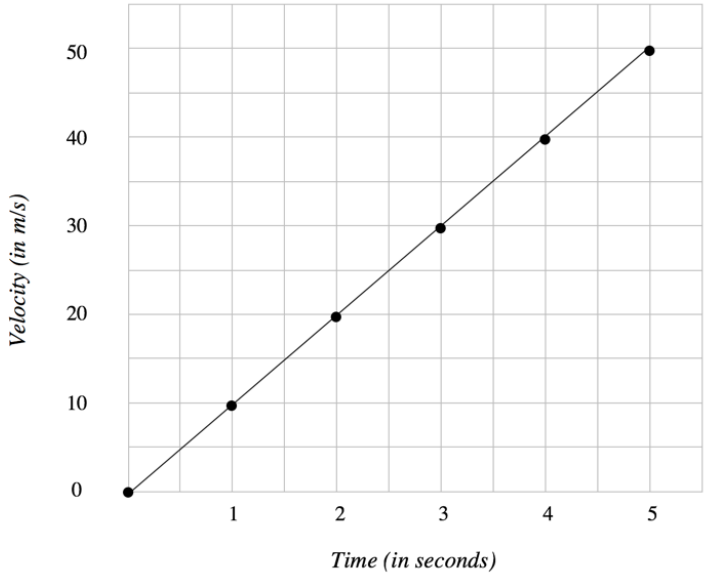
A velocity-time graph or *v-t* graph is a visual representation of an object's motion that shows how an object's velocity varies over time. In this kind of graph, the velocity depends on time. The velocity of the object is placed on the vertical axis or *y*-axis of the *v-t* graph, while time is found on the horizontal or *x*-axis. This goes to show that velocity is our dependent variable, while time is our independent variable.

Organizing our data about the moving car, we will arrive with the following table.

Time (in seconds)	Velocity (in m/s)
0	0
1	10
2	20
3	30
4	40
5	50

Based on our data set, our *v-t* graph would look like this.



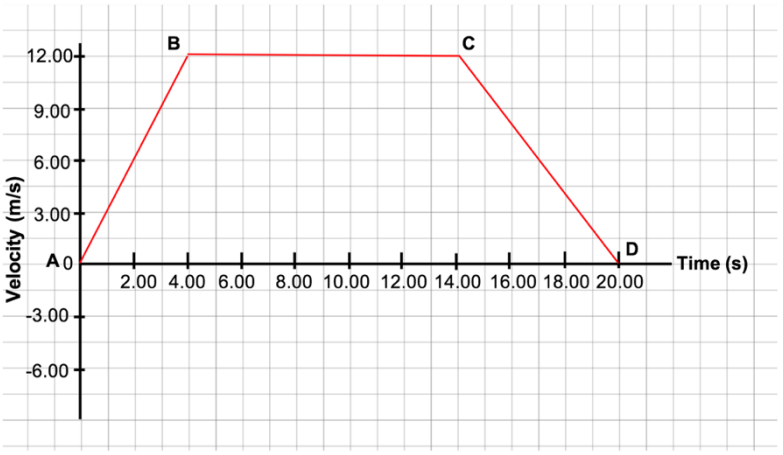
Similar to an *x-t* graph, a *v-t* graph generates lines or curves. We can describe the rate of the change in velocity of a moving object by observing and calculating the steepness of the lines. The slope, in this case, will be the change in velocity, plotted along the y-axis (vertical), over the time interval, plotted along the x-axis (horizontal). It tells us that the **slope of a v-t graph is the average acceleration** of the moving object at that specific time interval.

For instance, we can determine the rate of change in velocity during the first 5 seconds of motion. Applying our formula for slope, we arrive with this.

$$m = \frac{y - y_0}{x - x_0} = \frac{50\ m/s - 0\ m/s}{5\ s - 0\ s} = \frac{50\ m/s}{5\ s} = 10\ m/s^2$$

Therefore, the slope of the *v-t* graph is 10 m/s^2. Notice that the unit of our slope is in m/s^2 – a unit of acceleration. This constant positive value of acceleration means that the velocity is increasing at a steady rate, consistent with what is represented by the graph

Let's have another example of a *v-t* graph showing the motion of a car along a straight road for 20 seconds.



It can be gleaned from the *v-t* graph that there are three line segments of interest. It implies that the acceleration of the car is changing during the 20-second interval. Applying our equation for slope, we can calculate the acceleration of the car in these time intervals.

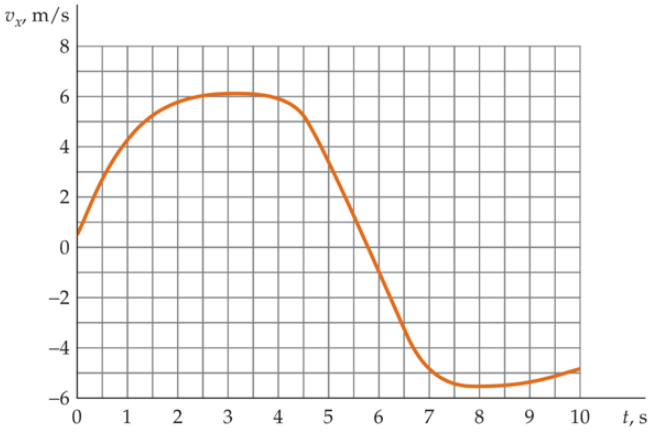
Points	Slope	Description
A to B	$m = \frac{12.00\ m/s - 0\ m/s}{4.00\ s - 0\ s} = 3.00\ m/s^2$	▪ Positive constant slope ▪ Acceleration is constant and positive. ▪ The velocity of the car during this time interval is increasing at a fixed rate. ▪ The car is speeding up at a fixed rate.
B to C	$m = \frac{12.00\ m/s - 12.00\ m/s}{14.00\ s - 4.00\ s} = 0\ m/s^2$	▪ Zero slope (zero acceleration) ▪ It means that the object is not accelerating. ▪ Its velocity is constant equal to 12.00 m/s, as shown in the *v-t* graph.
C to D	$m = \frac{0\ m/s - 12.00\ m/s}{20.00\ s - 14.00\ s} = -2.000\ m/s^2$	▪ Negative constant slope

		▪ Acceleration is constant and negative. ▪ The velocity of the car during this time interval is decreasing at a fixed rate. ▪ The car is slowing down at a fixed rate.

Just like what learned in the previous lesson on *x-t* graphs, a straight line upward indicates a constant positive slope. In the case of *v-t* graphs, it implies constant positive acceleration. A straight line downward indicates a constant negative slope. In the case of *v-t* graphs, it implies constant negative acceleration.A horizontal slope means no acceleration, or the object is moving at constant velocity.

In some cases, **curves** are generated on a *v-t* graph instead of straight lines, as shown in the diagram below. *It means that the acceleration is not fixed and is changing over time.* We can say that the velocity is increasing but at a slower rate between the 1 to 3 seconds of its motion. The same trend can also be observed during the object's motion between 7 to 8 seconds. It is decreasing but at a slower rate. We can find the exact values of acceleration using a more sophisticated technique in calculus known as **differentiation.**

In this technique, we make use of the slope of the tangent line to characterize the velocity at specific time intervals because the velocity is not constant.



Navigate

Let's see if you understood our lesson on *v-t* graphs by working on the following exercises. Write your answers on a clean sheet of paper. Follow your teacher's instructions regarding submission.

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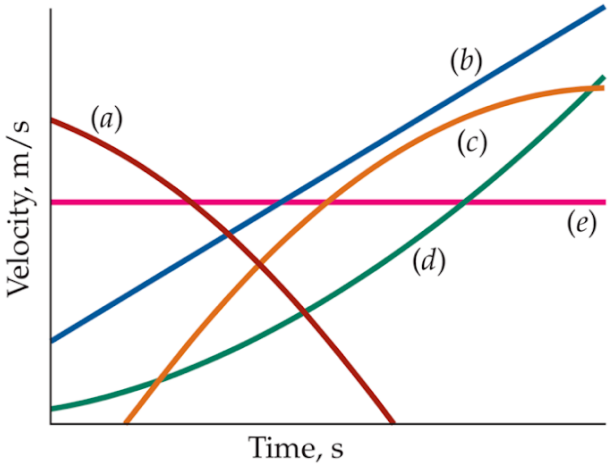
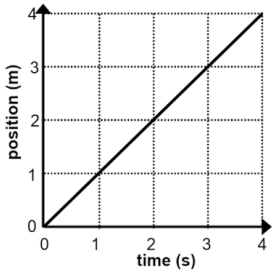
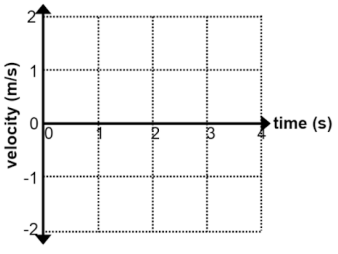
1. Which of the following velocity-time graphs best describes the motion of an object (with the following descriptions (Tipler & Mosca, 2008)

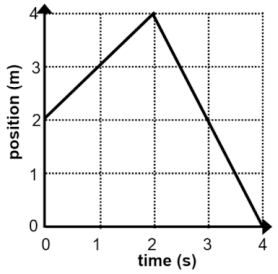


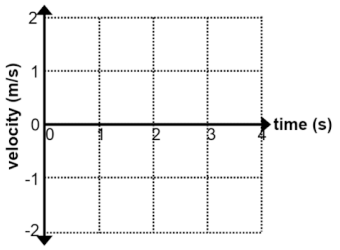
Description	Corresponding v-t graph
(a) With constant positive acceleration	
(b) With positive acceleration that is decreasing with time.	
(c) With positive acceleration that is increasing with time	
(d) With no acceleration	

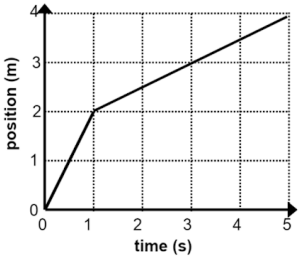
2. Draw the appropriate v-t graph for motion of an object described by the x-t graph on the left.

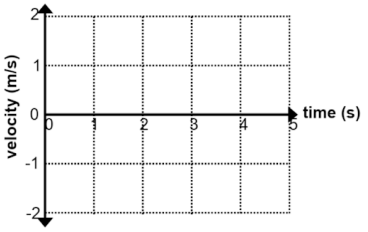




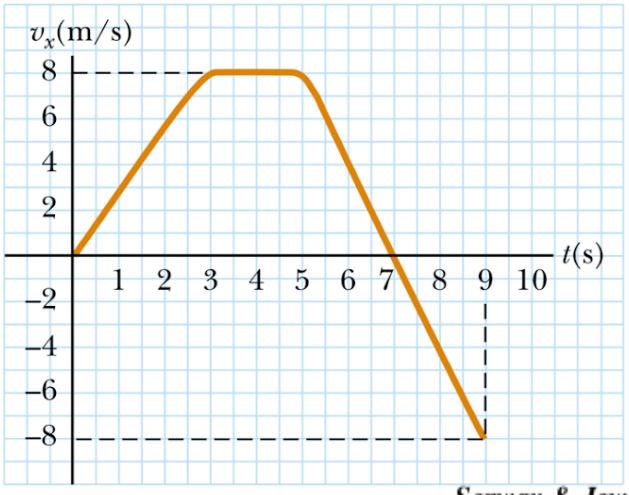








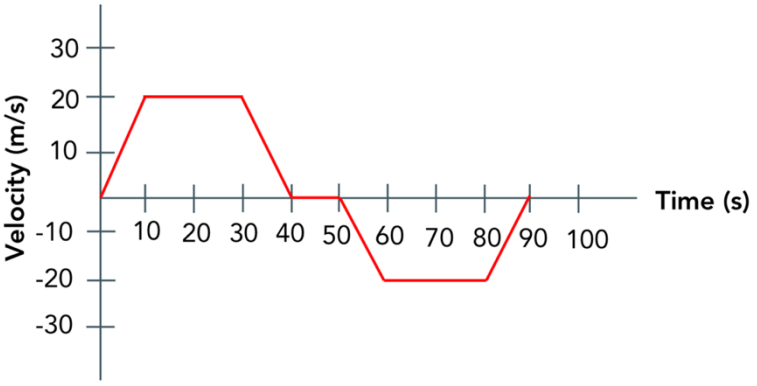
3. Determine the acceleration of an object described by the following v-t graph at the following time intervals.



Serway & Jewett

Time interval	Acceleration
(a) Between 0 to 3 s	
(b) Between 3 to 5 s	
(c) Between 5 to 9 s	

4. 4. Characterize (quantitatively and qualitatively) the motion of the object described by the following v-t graph at each segment of the trip.



Segment	Acceleration	Description of Motion

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

- Velocity-time or *v-t* graphs provide meaningful insights about the motion of an object. It describes the rate of how the velocity of an object changes with respect to time.
- The slope of a *v-t* graph represents the acceleration of an object at a specific time interval.
- A straight line on a *v-t* graph denotes constant acceleration. Upward straight lines indicate constant positive acceleration, while negative straight lines indicate constant negative

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	acceleration. A horizontal line indicates that the object is moving at constant velocity. • Curves on a *v-t* graph indicate acceleration that changes over time.		

References

1. Giancoli, Douglas C. (2014). *Physics: Principles with Applications.* Pearson Education, Inc.
2. Serway, R., & Jewett, J. (2004). *Physics for Scientists and Engineers.* Thomson Brooks/Cole.
3. Tipler, P., & Mosca, G. (2008). *Physics for Scientists and Engineers with Modern Physics.* W. H. Freeman and Company.

Prepared by: Joni M. Albarico	Reviewed by: Joseph P. Hortezuela
Position: SST III	Position: SST IV
Campus: CALABARZON Region Campus	Campus: Central Visayas Campus