Key Concepts
Part 1 - Motion in a Straight Line (One Dimension)

After completing this chapter you will be able to:

• explain how distance, position, and displacement are different

• explain how speed, velocity, and acceleration are different

• explain how vectors and scalars are different

• add and subtract vectors using scale diagrams and algebraic methods

• obtain motion information from position–time, velocity–time, and acceleration–time graphs

• solve uniform velocity and uniform acceleration problems using algebraic methods

• describe how the acceleration due to gravity affects the motion of objects close to the surface of Earth

• assess the impact on society and the environment of a technology that applies concepts related to kinematics

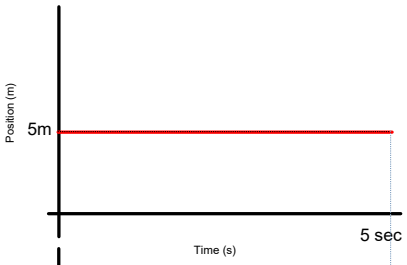
Sep 4-9:02 PM

Types of Motion - Recap

Position - Time Graphs

• Object starts 5 m from the reference point;

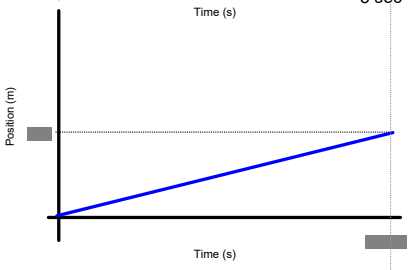
•position does not change over time, therefore object is NOT moving (rate of change of 0 m/s, the line has a slope of Zero)



• Object starts 0 m from the reference point;

•position **is** changing over time (increasing - moving AWAY from ref. pt.) in a linear or constant manner, therefore the object is moving at a constraint velocity.

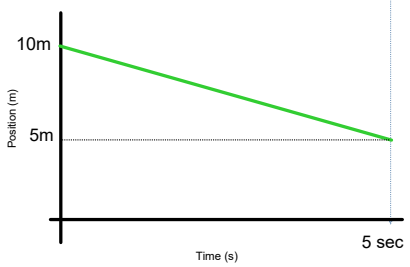
Vel = 5m / 5sec
Vel = 1m/s



• Object starts 10 m from the reference point;

•position **is** changing over time (decreasing - moving TOWARDS the ref. pt) in a linear or constant manner, therefore the object is moving at a constraint velocity.

Vel = -5m / 5sec
Vel = -1 m/s



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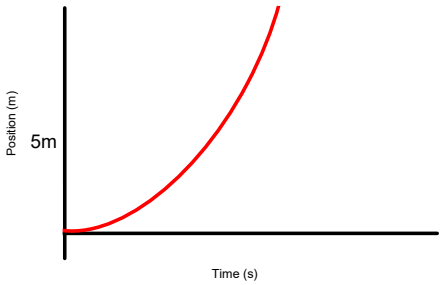
Type of Motion - Non Uniform

- Object starts 0 m from the reference point;

- position is changing over time, therefore object is moving AWAY from the ref. pt
- graph is NOT linear, therefore the rate of change is NOT constant
- therefore NON uniform velocity,which means the object is accelerating



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Velocity is the change in position over time. ie. 5 m/s, 30 km/hr, 45 mi/hr

Acceleration is the change in velocity over time. ie. 3 m/s per second, 5 km/hr per second.

If the time units for acceleration are the same, we tend to write the time values squared.

For example, 4 m/s per second would be written as 4 m/s^2.

t=0	t=1s	t=2s	t=3s
v=0	v=4 ms^{-1}	v=8 ms^{-1}	v= 12ms^{-1}

For example, 5 km/hr per second would be written as 4 km/hr/s.

t=0	t=1s	t=2s	t=3s
v=10km/hr	v=15 km/hr	v=20 km/hr	v=25 km/hr

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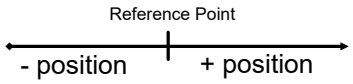
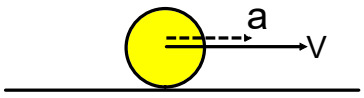
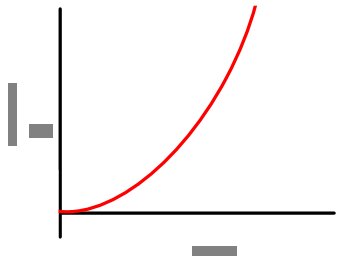
Representing Velocity and Acceleration with Vector Diagrams.



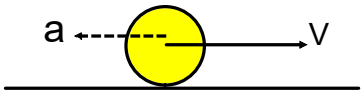


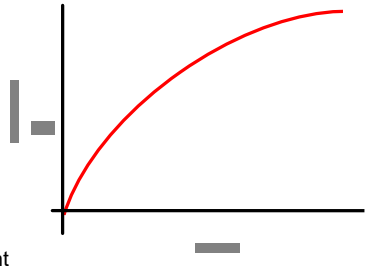


Case 1 - velocity and acceleration are BOTH in the same direction

Object will continue to travel in its current direction AND will increase in speed.

Object is moving AWAY from reference point in a positive direction.





Case 2 - velocity and acceleration are in the OPPOSITE directions

Object will continue to travel in its current direction BUT will decrease in speed.

Object is moving away from the reference point in a positive direction.

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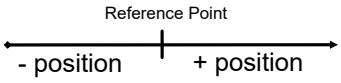
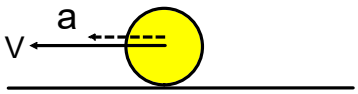
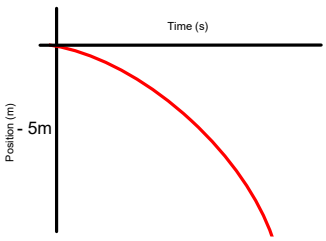
Representing Velocity and Acceleration with Vector Diagrams.



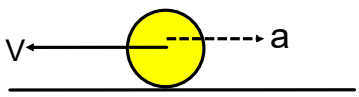


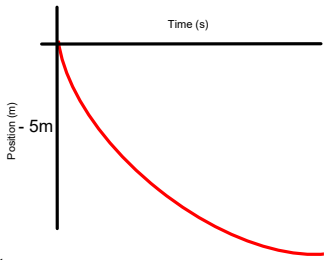


Case 3 - velocity and acceleration are BOTH in the same direction

Object will continue to travel in its current direction AND will increase in speed.

Object is moving AWAY from the reference point in a Negative direction.





Case 2 - velocity and acceleration are in the OPPOSITE directions

Object will continue to travel in its current direction BUT will decrease in speed.

Object is moving AWAY from the reference point in a Negative direction.

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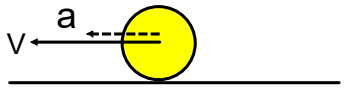
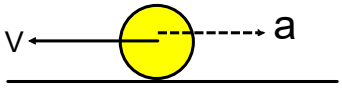
Semantics - Confusing Words in Science and Day to Day Living



When an object is experiencing both acceleration and velocity in the same direction we say the object is "speeding up" or "accelerating".



When an object is experiencing both acceleration and velocity in OPPOSITE directions we say the object is "slowing down" or "decelerating".

Decelerating implies that the acceleration is in the opposite direction than the velocity, but the object is still in fact accelerating.

For example, when a model rocket is launched into the air, we describe the motion typically in the following way:

- the rocket "decelerates until it stops at its highest point, then it accelerates back to earth

- the truth is, the rocket is accelerating TOWARDS Earth over the entire flight, it's only when the velocity changes direction that we can SEE the difference

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*accelerating towards the earth the entire flight

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Position - Time Graphs

A position - time graph plots the position of a moving object with respect to time.

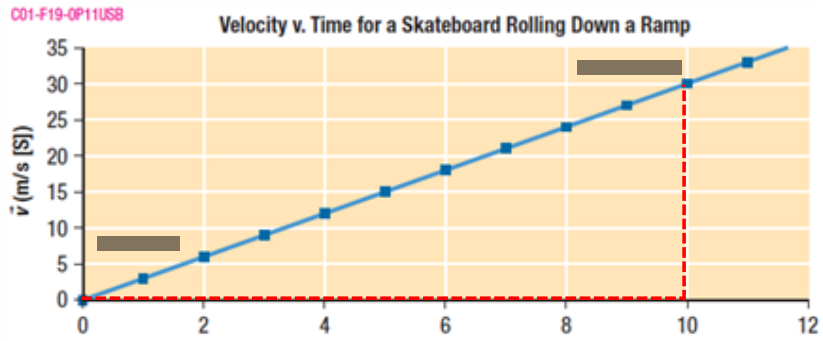
The rate of change of a Position - Time graph is the VELOCITY.

Velocity - Time Graphs

A velocity - time graph plots the velocity of a moving object with respect to time.

The rate of change of a Velocity - Time graph is the acceleration.

$$a_{ave} = \frac{\Delta v}{\Delta t} \qquad a_{ave} = \frac{v_f - v_i}{\Delta t} \qquad a_{ave} = \frac{v_f - v_i}{t_f - t_i}$$



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Practice:

A catapult accelerates a rock from rest to a velocity of 15.0 m/s [S] over a time interval of 12.5 s.

What is the rock's average acceleration? [

As a car approaches a highway on-ramp, it increases its velocity from 17 m/s [N] to 25 m/s [N] over 12 s.

What is the car's average acceleration? [

A squash ball with an initial velocity of 25 m/s [W] is hit by a squash racket, changing its velocity to 29 m/s [E] in 0.25 s.

What is the squash ball's average acceleration? [2

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Using the Acceleration Relationship to solve for a missing Velocity

A racehorse takes 2.70 s to accelerate from a trot to a gallop. If the horse's initial velocity is 3.61 m/s [W] and it experiences an acceleration of 2.77 m/s^2 [W], what is the racehorse's velocity when it gallops?

$$a_{ave} = \frac{v_f - v_i}{\Delta t}$$

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Practice

How long does it take a radio-controlled car to accelerate from 3.2 m/s [W] to 5.8 m/s [W] if it experiences an average acceleration of 1.23 m/s^2 [W]?

A speedboat experiences an average acceleration of 2.4m/s^2 [W]. If the boat accelerates for 6 seconds and has a final velocity of 17m/s, what was the initial velocity of the speedboat?

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Using the Velocity - Time Graph to determine the Displacement on an Object

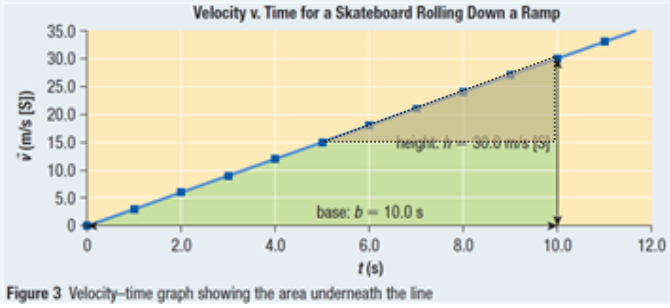

Figure 3 Velocity–time graph showing the area underneath the line

If an object moved at 4 m/s for 5 seconds, it would travel a distance of 20m. The object above has different velocities at different times throughout its motion. We determine the distance travelled by (i) finding the average velocity of the object over the given period of time, or (ii) we can find the area underneath the given graph.

What is the distance travelled in 10 sec?

(i) Average Velocity - rearrange the triangle to create a rectangle and multiply the velocity by the time.

(ii) Find the area under the velocity graph (area of a triangle)

NOTE: finding the distance travelled by using the AREA under the curve only works
with Velocity - Time graphs, NOT position - time graphs.

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Practice

What is the displacement represented by the graph in Figure 4 over the time interval from 0 s to 10.0 s?

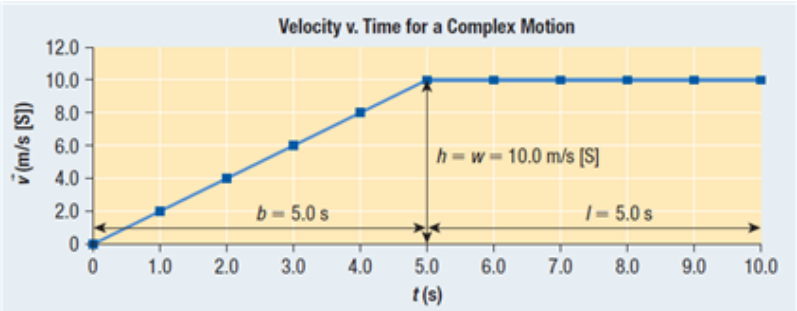

Figure 4 Velocity–time graph showing more complex motion

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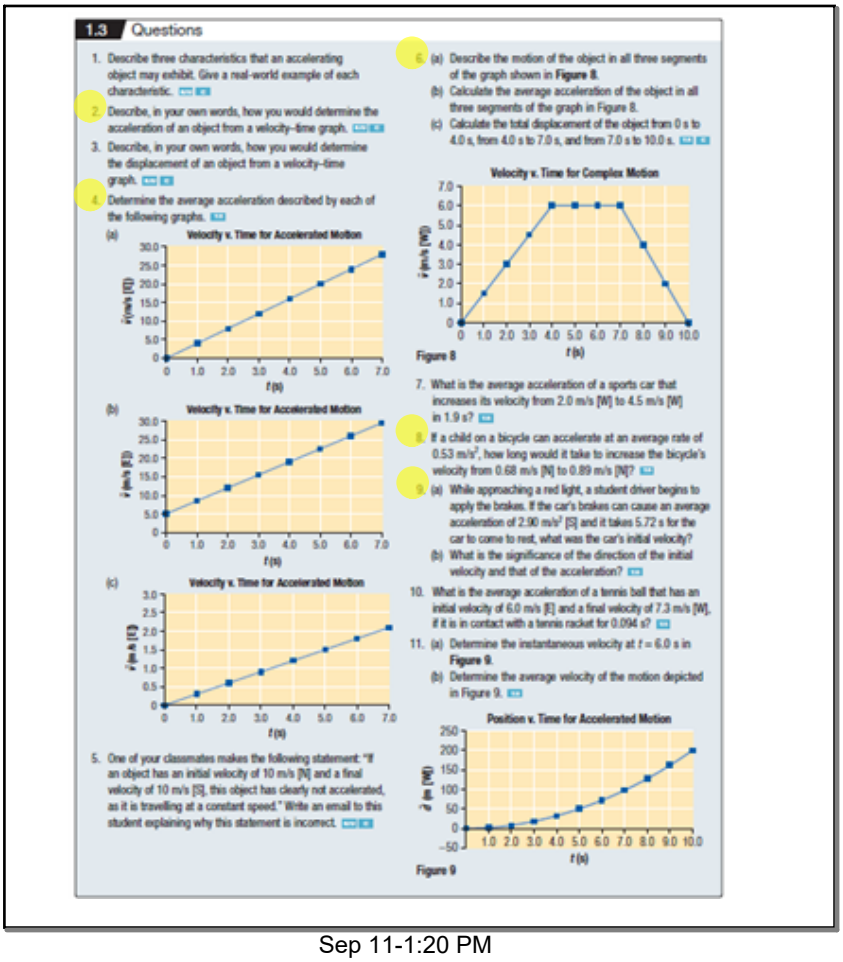

1.3 Questions

1. Describe three characteristics that an accelerating object may exhibit. Give a real-world example of each characteristic.
2. Describe, in your own words, how you would determine the acceleration of an object from a velocity–time graph.
3. Describe, in your own words, how you would determine the displacement of an object from a velocity–time graph.
4. Determine the average acceleration described by each of the following graphs.

(a) Velocity v. Time for Accelerated Motion

(b) Velocity v. Time for Accelerated Motion

(c) Velocity v. Time for Accelerated Motion

5. One of your classmates makes the following statement: "If an object has an initial velocity of 10 m/s [N] and a final velocity of 10 m/s [S], this object has clearly not accelerated, as it is travelling at a constant speed." Write an email to this student explaining why this statement is incorrect.
6. (a) Describe the motion of the object in all three segments of the graph shown in Figure 8.
(b) Calculate the average acceleration of the object in all three segments of the graph in Figure 8.
(c) Calculate the total displacement of the object from 0 s to 4.0 s, from 4.0 s to 7.0 s, and from 7.0 s to 10.0 s.

Velocity v. Time for Complex Motion

Figure 8

7. What is the average acceleration of a sports car that increases its velocity from 2.0 m/s [W] to 4.5 m/s [W] in 1.9 s?
8. If a child on a bicycle can accelerate at an average rate of 0.53 m/s², how long would it take to increase the bicycle's velocity from 0.68 m/s [N] to 0.89 m/s [N]?
9. (a) While approaching a red light, a student driver begins to apply the brakes. If the car's brakes can cause an average acceleration of 2.90 m/s² [S] and it takes 5.72 s for the car to come to rest, what was the car's initial velocity?
(b) What is the significance of the direction of the initial velocity and that of the acceleration?
10. What is the average acceleration of a tennis ball that has an initial velocity of 6.0 m/s [E] and a final velocity of 7.3 m/s [W], if it is in contact with a tennis racket for 0.094 s?
11. (a) Determine the instantaneous velocity at $t = 6.0$ s in Figure 9.
(b) Determine the average velocity of the motion depicted in Figure 9.

Position v. Time for Accelerated Motion

Figure 9

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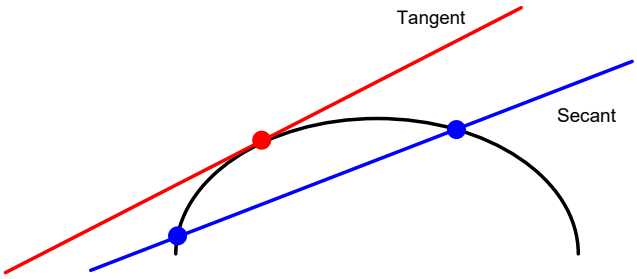
Advanced Practice - Time Permitting

A SECANT line is a line that contacts a curve at TWO different points.

A TANGENT line is a line that contacts a curve at ONE point only.



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Average Velocity vs Instantaneous Velocity

Average Velocity is the change in position over a given period of time. As we will see, the larger the period of time used, the more varied our solutions will be. The average velocity is represented by a SECANT line.

$$v_{ave} = \frac{s_f - s_i}{\Delta t}$$

Instantaneous (v_{inst}) velocity is the change in position at a specific INSTANCE in time (as if the problem was suddenly frozen). The instantaneous velocity is represented by a TANGENT line.

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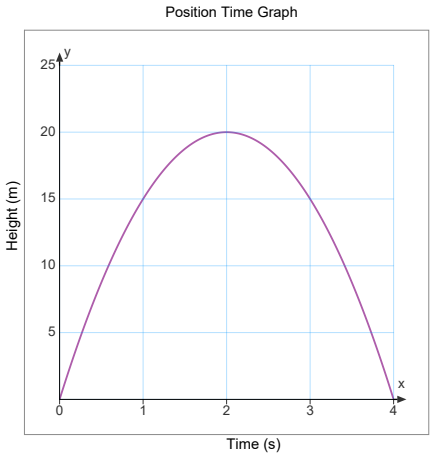
Example: A water powered rocket is fired straight up and its height is given by, $s = -5t^2 + 20t$ where (s) is in metres and (t) is in seconds.

$s = -5t^2 + 20t$

t (s)	s (m)
0	
1	
2	
3	
4	



What is the average velocity from 0 to 1 second?

What is the average velocity from 0 to 2 seconds?

What is the average velocity from 0 to 3 seconds?

What is the average velocity from 0 to 4 seconds?

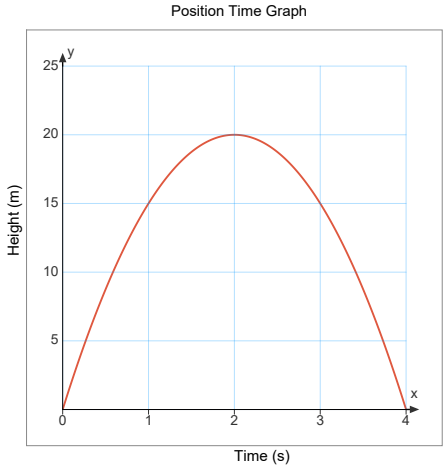
What factors should be considered when calculating the average velocity?

Sep 4-11:08 PM

Example: A water powered rocket is fired straight up and its height is given by, $s = -5t^2 + 20t$ where (s) is in metres and (t) is in seconds.

$s = -5t^2 + 20t$

t (s)	s (m)
0	
1	
2	
3	
4	



What is the average velocity from 0 sec to 1 second?

What is the average velocity from 1 sec to 2 seconds?

What is the average velocity from 1 sec to 1.5 seconds?

What is the average velocity from 1 sec to 1.1 seconds?

What is the average velocity from 1 sec to 1.01 seconds?

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