Chapter 2

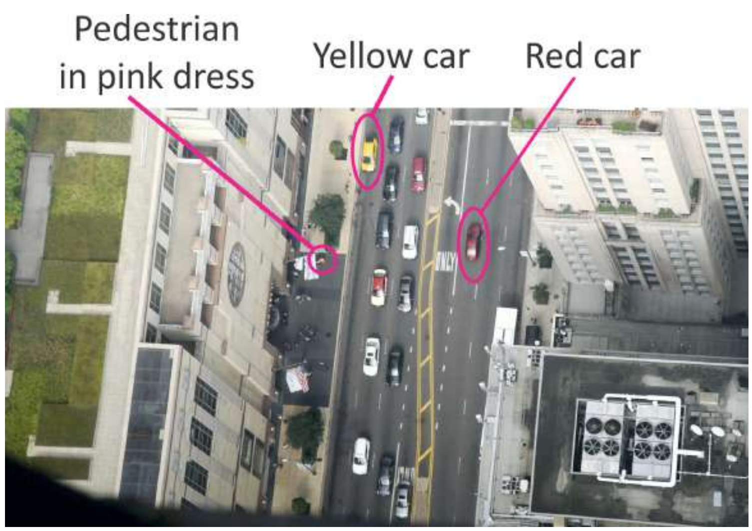
Kinematics: Motion in One Dimension

2.1 What is motion?

OALG 2.1.1 Describe

Watch the video of cars moving on a street [https://youtu.be/Hut8HINHWZ8]

Use the comma and period keys on your keyboard to play the video frame by frame. Notice the yellow and red cars and a pedestrian in the pink dress on the street (see photo below).



a. Describe how a passenger in the yellow car sees the motion of the driver of the yellow car, the driver of the red car, the pedestrian on the sidewalk.

b. How does the pedestrian describe the motion of the driver of the yellow car?

c. Why would the passenger in the yellow car and the pedestrian disagree about the motion of the driver of the yellow car?

d. Based on your answers in parts a. through c., explain what it means when someone says an object is “moving” and what it means when we say “motion is relative”.

e. To help with the answer to part **d.** Read and interrogate Section 2.1 Chapter 2 text on page 14 (up to Modeling motion) in the textbook .

OALG 2.1.2 Describe

Devise several situations in which

a. you *can* model Earth as a point-like object,

b. you *cannot* model Earth as a point-like object,

c. To help answer parts a. and b. read and interrogate the subsection ‘Modeling Motion’ on pages 14-15 in Section 2.1 of the textbook.

2.2 A conceptual description of motion

OALG 2.2.1 Observe

Watch the four experiments in video OET 2.1 on page 15 in the textbook [https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-experiment-video-1]. Use the data from the video to sketch the position of the bean bags by representing them as dots.

a. What patterns did you notice in the placement of the dots?

b. How can you use the distances between the dots to describe the motion of the bowling ball?

c. If you have trouble answering parts a. and b., read and interrogate Observational Experiment Table 2.1 on page 15 in the textbook.

OALG 2.2.2 Represent and reason

You have two battery-operated toy cars that you can release simultaneously on a smooth floor and a metronome set to 1-second intervals. You and a friend each walk next to one of the cars, and at every “blip” of the metronome, you place a sugar packet at your car’s location. The dots in the figure below represent the locations of the sugar packets for the two cars. The cars start simultaneously at the dot on the left and move to the right.

• • • • • • • • • • • Car 1

 Car 2

a. Were the cars ever next to each other? If so, where?

b. If there were a passenger in car 1, how would the passenger describe the motion of car 2?

c. If there were a passenger in car 2, how would the passenger describe the motion of car 1?

OALG 2.2.3 Observe

Equipment: a ball, sugar packets, a distance measuring device.

For this activity you will need any ball that you can find in the house. A basketball, a tennis ball – any rolling object (even a mechanical toy car will work). Using your computer or your phone, find a metronome that beeps every second. You will also need sugar packets or any objects that you can place on the floor to mark the position of the ball. Place the ball (or a toy car) at rest on the floor. Push the ball abruptly and, as it rolls, place the sugar packets to mark its location every second. Make sure that the ball rolls in a straight line. Take a picture of the sugar packets and paste it into the document you are working on. Use it to draw a corresponding dot diagram representing the packets. Describe the relative distances between the packets. How does the distance between the packets correspond to the observed motion of the ball?

OALG 2.2.4 Explain

Examine Figure 2.2 in the textbook. Explain the changes in the light traces of the LED in each experiment (do not forget to state your assumption about the direction of motion). In particular:

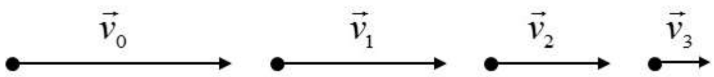
a. What can the length of the light trace tell you about the motion of the cart?

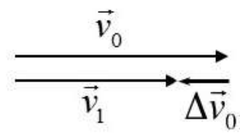
b. If each subsequent light trace gets shorter, what does that tell you about the motion of the cart?

c. If each subsequent light trace gets longer, what does that tell you about the motion of the cart?

OALG 2.2.5 Represent and reason

The illustration below relates to the experiment you performed with the ball in Activity 2.2.3. The dots represent the locations of the ball measured each second. The arrows represent the direction of motion and how fast the ball was moving (we call them *velocity arrows*). Consider velocity arrows 0 and 1. Move them side by side with their tails at the same horizontal position. Decide what change arrow $\Delta\vec{v}_{01}$ you would have to add to arrow 0 to make it the same length as arrow 1. Repeat for arrow 1—what change arrow is needed to change it into arrow 2, and what change arrow is needed to change arrow 2 into arrow 3? We call these *velocity change arrows.*

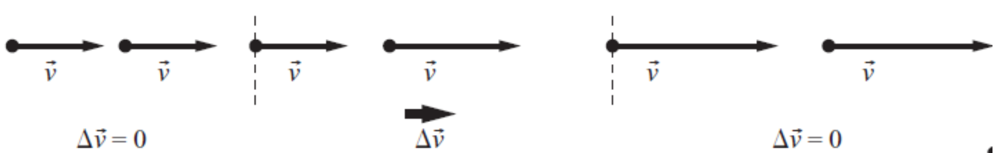


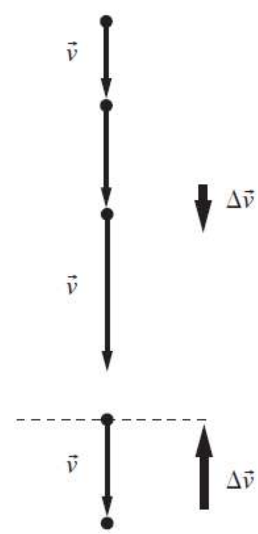


Use the Physics Tool Box 2.1 to learn how to represent motion using qualitative motion diagrams.

OALG 2.2.6 Represent and reason

The illustration below is a motion diagram for an object. Remember that the dots represent the object's position after equal time intervals. Describe the object’s motion in words by devising a story that is consistent with this diagram. Note that the process has three distinct parts: vertical dashed lines separate each part.





OALG 2.2.7 Represent and reason

The illustration to the right is a motion diagram for an object. Describe the object’s motion in words by devising a story that is consistent with this diagram. Note that the process has two distinct parts: the horizontal dashed line separates each part.

OALG 2.2.8 Read and Interrogate

Read and interrogate Section 2.2 in the textbook and answer Review Question 2.2.

OALG 2.2.9 Practice

Solve Problems 1-3 in the textbook (page 45).

2.3 Operations with vectors

OALG 2.3.1 Read and Interrogate

Read and interrogate Section 2.3 in the textbook. Write here what a vector is and how operations with vectors are different from operations with numbers.

OALG 2.3.2 Practice

Equipment: a ruler.

Use a ruler to draw arbitrary vectors $\vec{A}$, $\vec{B}$, $\vec{C}$, $\vec{D}$, and $\vec{E}$ that have different magnitudes and directions.

a. Think about what operations with vectors you know. Consult textbook Section 2.3. Make a list.

b. For each operation, draw at least two examples on the board using your vectors A to E.

OALG 2.3.3 Evaluate

How does finding the direction and magnitude of the $\Delta\vec{v}$ arrow on the motion diagram relate to an operation with vectors? Can you use vector addition to find $\Delta\vec{v}$? Can you use vector subtraction? Explain.

OALG 2.3.4 Practice

Solve problems 5 and 6 in the textbook (page 45).

2.4 Quantities for describing motion

OALG 2.4.1 Read and Interrogate

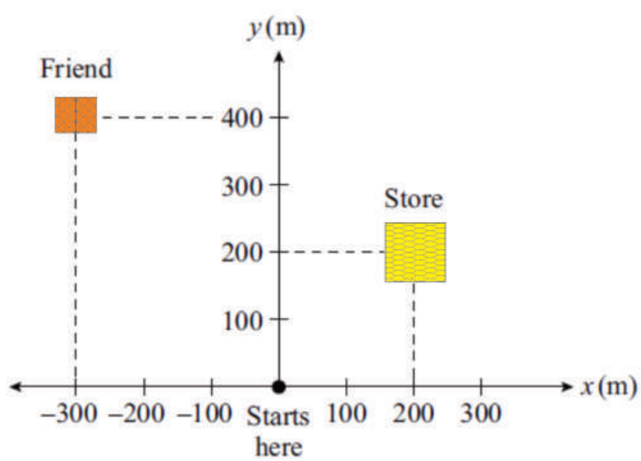
a. Work with Chapter 1 Sections 1.3 and 1.5 in the textbook to learn the meaning of a physical quantity. What is the difference between a physical quantity and a unit? Give examples of physical quantities that have different units in the SI system and the British system. What are quantities that have the same units in both systems?

b. Read and interrogate Chapter 2 Section 2.4. Answer Review Question 2.4.

c. Explain the difference between a vector and its scalar component.

OALG 2.4.2 Represent and reason

Henry is traveling to a store and then to his friend's house. His trip is represented on a sketch below (with a bird's eye view).



a. What is Henry's initial position? Final position? What is the position of the store?

b. Draw a vector to represent his total displacement. Determine the scalar *x*-component of the displacement, the total distance traveled, and the path length.

c. Choose a different origin for the coordinate system and repeat parts a. and b. What quantities changed? What quantities remained the same?

OALG 2.4.3 Reason

In each of the following measurements, how many significant figures does the measurement have and what is the absolute uncertainty in each measurement? If you have trouble answering these questions, read and interrogate the subsection "Significant digits" on page 22 in the textbook.

a. Ulani says that she used a meter stick and measured her pencil to be 0.153 m long.

b. Hermes says that the college swimming pool is 50 m long.

c. Ulani used a chemical balance to weigh her pencil and says that her pencil has a mass of 0.00478 kg.

d. Hermes says that he estimates that there are about 2 million liters of water in the college swimming pool.

OALG 2.4.4. Explain

Suppose your friend tells you that she measured her bed to be 2 m long, and then she tells you that she looked up on Wikipedia that the circumference of Earth is 40,075,017 m. How many significant figures does each of these measurements have? Which of these two measurements is more precise? Discuss why. Evaluate both values and their number of significant figures.

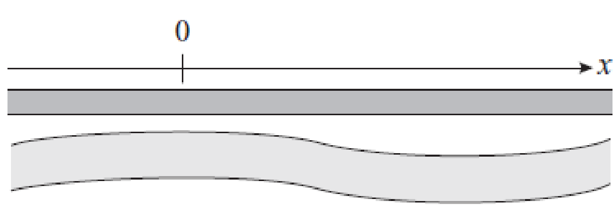
OALG 2.4.5. Practice

Answer Questions 3 and 4 on page 43 and solve Problems 7, 8 and 9 on page 45 in the textbook.

2.5 Representing motion with data tables and graphs

OALG 2.5.1 Observe and describe

Imagine that you and your friend ride bicycles along a straight path beside a river. A coordinate axis is shown alongside the path.



Clock reading *t* (s)	**Your position *x* (m)**	**Your friend's position**
$t_0 = 0$	$x_0 = 640$	$x_0 = 640$
$t_1 = 20$	$x_1 = 500$	$x_1 = 490$
$t_2 = 40$	$x_2 = 360$	$x_2 = 340$
$t_3 = 60$	$x_3 = 220$	$x_3 = 190$
$t_4 = 80$	$x_4 = 80$	$x_4 = 40$
$t_5 = 100$	$x_5 = -60$	$x_5 = -110$
$t_6 = 120$	$x_6 = -200$	$x_6 = -260$

The table indicates your position along the path at different clock readings.

a. Write everything you can about the bike rides and indicate any pattern in the data. What was happening at the clock reading of zero?

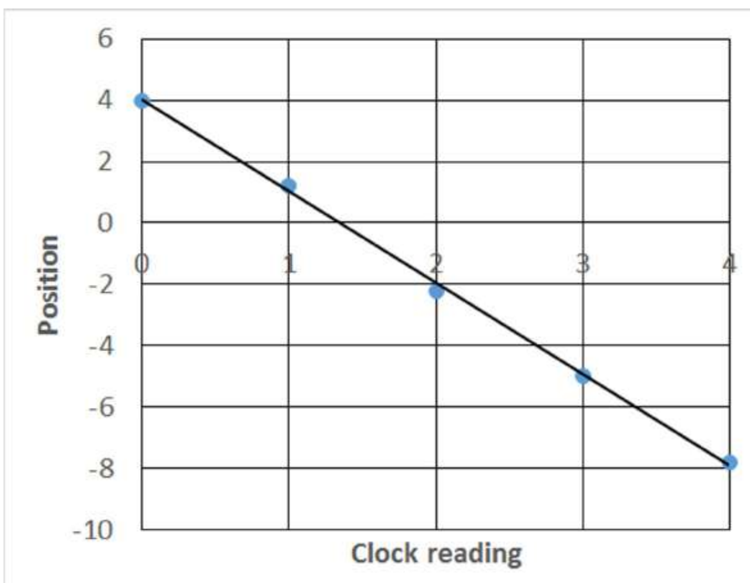
b. Draw motion diagrams for both bikes.

c. Construct position-versus-clock-reading graphs for both bike trips using the same coordinate axes in which x is a dependent variable and t is an independent variable. Compare and contrast the graphs – how do the graph lines represent the differences in the bikes' motions? If you are having trouble, read and interrogate section 2.5 in the textbook.

d. How do the motion diagrams in part b. correspond to the graphs in part c? How do you need to position the motion diagrams with respect to the graph axes so that it helps you visualize the motions?

OALG 2.5.2 Represent and reason

Examine the graph below. Is the graph complete? If not, complete it and represent the same information with a table and a motion diagram.



OALG 2.5.3 Read and Interrogate

Read and interrogate Section 2.5 in the textbook and answer Review Question 2.5.

2.5.4 Practice

Solve problem 10 on page 45 in the textbook.

2.6 Constant velocity linear motion

OALG 2.6.1 Represent mathematically

a. Examine the graphs you drew in Activity 2.5.1c. Write two functions $x(t)$ for the graphs. Consider your labeling system: how can you distinguish the function for your bike from the function for your friend's bike?

b. What are the physical meanings of the slope of each function and the intercepts? What common name can you use for the slope? Explain the meanings of positive or negative values for these physical quantities. If you are having trouble, read and interrogate Section 2.6 in the textbook. Especially pay attention to the sub-section "*Equation of motion for constant velocity linear motion.*"

c. Compare and contrast how we write linear functions in mathematics to how you just wrote the position-versus-time functions for these motions. What is the same between them? What is different?

OALG 2.6.2 Test your idea

Observe the video of a snail [https://youtu.be/aJKRq2zjZeg]. Use the arrow keys on the keyboard to advance the video frame by frame.

a. Decide if the snail moves with constant velocity. If it does, determine the magnitude of the velocity (the snail's speed). Record the data below in a table and plot a position-vs-time graph for the snail.

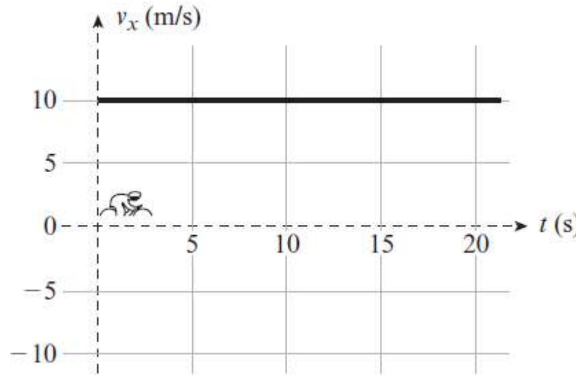
b. Predict where the snail would be in 26 minutes. What assumptions did you make?

c. Design an experiment to test whether or not you walk across a room in your house (apartment) at constant speed. Describe the experiment and the materials you will need to conduct it. If you do not have a meterstick or bean bags, use available materials to improvise. Record and analyze your data here.

d. If you determined that you walk at approximately constant speed, what is your speed? What assumption(s) did you use to make this estimate (Hint: think of what happens when you just start your motion.)

OALG 2.6.3 Analyze

The figure at the right shows a *velocity*-versus-time graph that represents the motion of a bicycle moving along a straight bike path. The positive direction of the velocity coordinate axis is toward the east.



a. Use the graph to estimate the bike's displacement during the time interval from clock reading 10 s to clock reading 15 s.

b. Use the graph to estimate its displacement during the time interval from 0 s to 20 s.

c. Formulate a general rule for using a velocity-versus-time graph to determine an object's displacement during some time interval specifically if the object is moving at constant velocity. If you are having trouble, read and interrogate sub-sections "*Graphing Velocity*" and "*Finding displacement from a velocity graph*" in Section 2.6 on page 29 in the textbook.

OALG 2.6.4 Test an idea

[https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-2-6-7]

Use the video to test if the position of the object that you drop from a certain height can be described mathematically as $y = v_y t$. Consider the location from which the object is dropped to be the origin.

a. Think what it means to test an idea. In physics, experimental testing consists of the following steps:

1) you accept the idea (the hypothesis) being tested as true;

2) you design an experiment whose outcome you can predict using this idea;

3) you make the prediction of the outcome (here you also need to think of what you assume to be true in addition to the idea you are testing—these are called *assumptions*);

4) you perform the experiment and compare the outcome to the prediction, and based on the comparison, you make your judgment concerning the idea being tested.

b. In this case, the experiment is performed already but you still need to make a prediction of its outcome based on the idea under test. Write your prediction down.

c. Now use the video to collect the data and compare the outcome to the prediction. Use the arrow keys on the keyboard to advance the video frame by frame. Record the data in a table. Examine the data you collected. Are they sufficient to gain confidence or reject the idea that a falling object moves at constant speed?

OALG 2.6.5 Apply

A total solar eclipse is a rare phenomenon that happens at the same location once in about 200 years. During this phenomenon, the Moon passes directly in front of the Sun as seen from Earth. Given that the visible diameter of the Moon is very close to the visible diameter of the Sun, the Moon covers the Sun completely and the part of Earth in the Moon's shadow plunges into darkness during the daytime. The average shadow of the Moon on Earth is about 200 km wide and it slowly travels across Earth during the day of the eclipse. On August 21st 2017, this rare phenomenon occurred in the US. Below are the data about the eclipse. Answer the questions below. (The photo above shows the Sun in Franklin, NC, about 5 minutes before the total solar eclipse in 2017).

a. The 2017 total solar eclipse started on Monday, August 21 in Madras, Oregon at about 10:20 am (Pacific daylight time) and ended in Columbia, South Carolina at 2:44 pm (Eastern daylight time). Estimate the average speed of the Moon's shadow moving across the United States and compare it to the speed of sound in air (340 m/s). Indicate any assumptions that you made.

b. During the same total solar eclipse in Franklin, North Carolina, the Moon cast on Earth a circular shadow with a diameter of about 109 km. The total solar eclipse in Franklin lasted for 2 minutes and 30 seconds. Estimate the speed of the Moon's shadow moving across Franklin. Compare this answer with your answer from part a. and try to explain any discrepancies.

OALG 2.6.6 Read and Interrogate

Read and interrogate Section 2.6 in the textbook and answer Review Question 2.6.

OALG 2.6.7 Practice

Solve Problems 11, 16, 17, 19, 24, 26, 32, and 33.

2.7 Motion at constant acceleration

OALG 2.7.1 Analyze

Clock reading t (s)	**Position y (m)**
0.000	0.00
0.133	0.44
0.267	0.71
0.400	0.80
0.533	0.71
0.667	0.42
0.800	- 0.04

Work with the data recorded in the table at the right for the up and down motion of the center of a ball thrown upward (the y-axis points up).

a. Sketch a motion diagram for the ball.

b. Draw a position-versus-time graph for the ball. Discuss whether the graph resembles a position-versus-time graph for an object moving at constant velocity.

c. Determine the scalar component of the average velocity for the ball for each time interval by completing the following table.

Time interval $\Delta t = t_n - t_{n-1}$	Displacement $\Delta y = y_n - y_{n-1}$	Average time $(t_n + t_{n-1})/2$	Average velocity $\Delta y / \Delta t$

d. Plot the average velocities v_y on a velocity-versus-time graph. The time coordinate for each average velocity coordinate should be in the middle of the corresponding time interval (the average time for that time interval). Draw a best-fit line for your graph. If you have trouble making the graph, read and interrogate instructions on page 31 in the textbook for a similar activity.

e. Consider the shape of the graph: How does the velocity change as time elapses? Suggest a name for the slope of the graph.

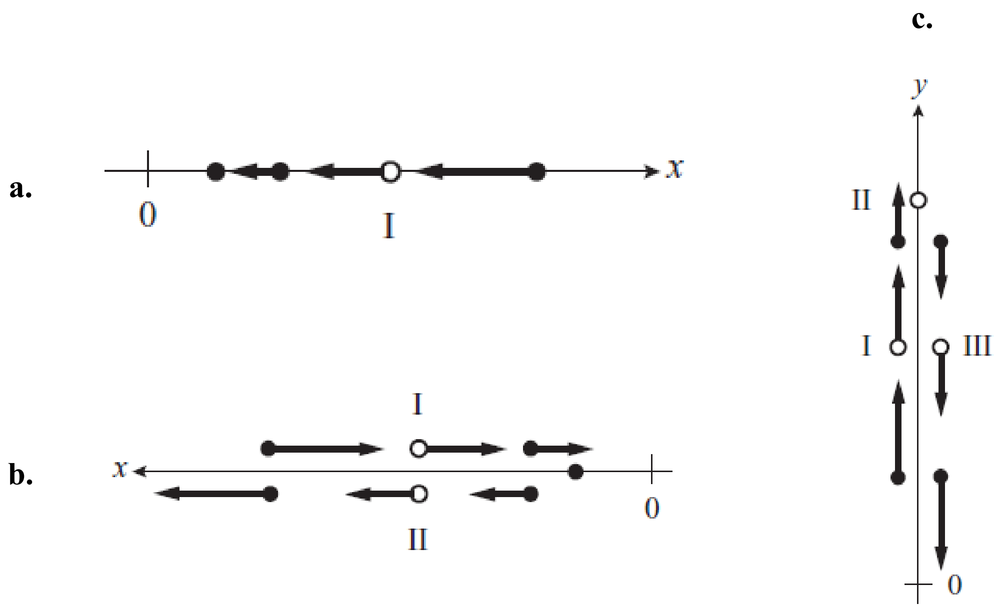
f. Use the velocity-versus-time graph to determine the ball's acceleration at the very top of its trajectory.

g. What is the ball's velocity at the top? Can you reconcile this answer with the answer in part f? Explain.

h. Use the velocity-versus-time graph to determine the distance that the ball traveled during the trip from clock reading 0.000 s to 0.800 s.

OALG 2.7.2 Represent and reason

The motion diagrams in the illustrations below represent the motion of different objects. The arrows are velocity arrows.



A different coordinate axis is provided for each of the three motion diagrams. An open circle indicates a location of interest (there are three locations: I, II, and III). Add a single velocity change arrow for each diagram. Then, determine the signs of the position, velocity component, velocity change component, and acceleration component at the position(s) of the open dots for each diagram. Note: what assumptions about motion do you need to make in order to use only *one* velocity change arrow for part b. and one for part c?

OALG 2.7.3 Read and Interrogate

Read and interrogate Section 2.7 in the textbook and answer Review Question 2.7.

OALG 2.7.4 Practice

Answer Question 24 on page 45 and solve Problems 34, 35, and 39 on page 47.

2.8 Displacement of an object moving at constant acceleration

OALG 2.8.1 Derive

Think of how you can construct a function $x(t)$ for a cart that moves at constant acceleration. Choose a simplified case first: when the cart starts at the origin of the coordinate system and has zero initial speed. There are many ways of doing constructing such function. Think of average velocity or a velocity-versus-time graph. Once you agree on the method, follow through and derive the expression. Evaluate the expression using limiting case analysis – for example, does your equation work for constant-velocity motion? If you are having trouble, read and interrogate Section 2.8 in the textbook. Make sure you interrogate two different ways to derive the function.

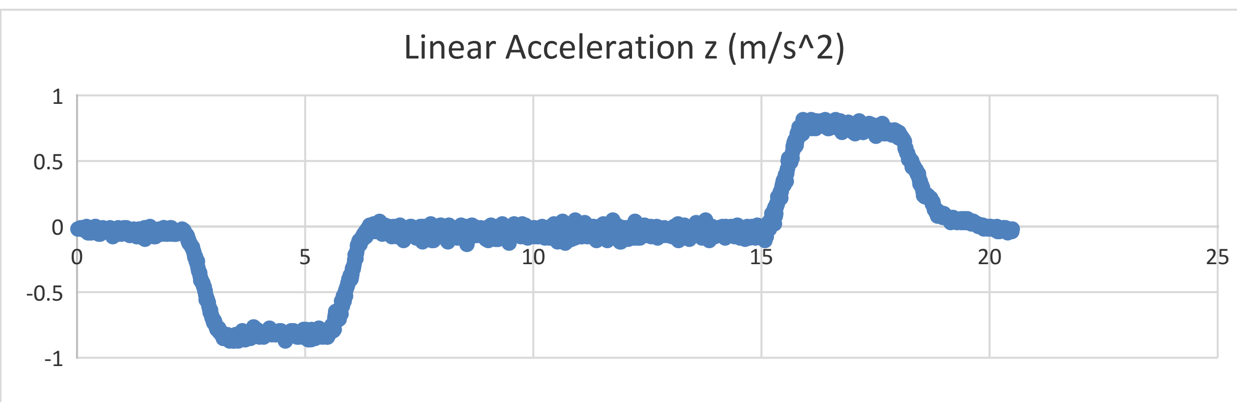
OALG 2.8.2 Linearize

Use the data in Table 2.7 on page 31 in the textbook to make a graph of the position of the ball-vs-time squared (y-vs-t^2). What shape of the graph do you expect? Explain. How can you find acceleration from the graph?

The process that you used is called linearization.

OALG 2.8.3 Analyze and interpret data

You visited Westin Boston Waterfront Hotel and rode one of the elevators from the bottom floor to the 11th floor. While in the elevator you used the Phyphox app on your phone to record the acceleration of the elevator. The graph created by the app is displayed below.



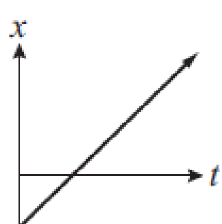
a. What can you determine from the graph? Make a list of physical quantities and describe how you will determine each of them.

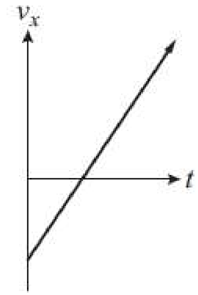
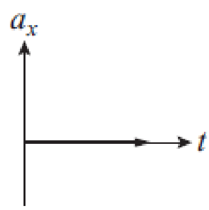
b. We estimated that the maximum speed of the elevator was 2.6 m/s and the total distance traveled was 33 m. How did we arrive at these numbers?

c. What else can you determine from the graph?

OALG 2.8.4 Summarize

This is a really helpful activity. Use different representations of the two types of motion we have studied to fill in the empty cells in the table. Some cells are completed to give you an idea of the motions and the direction of the coordinate axis for each case. Your responses should relate to the motion already described. Completing the table will help you summarize everything you have learned about the description of motion. If you are having trouble, consult the Chapter 2 Summary in the textbook on page 42.

Motion with constant velocity	**Motion with constant acceleration**
Describe the motion in words and provide an example.	Describe the motion in words and provide an example. The object's velocity is decreasing by the same amount every second—for example, a cart going up a smooth track tilted at an angle.
Provide a motion diagram that describes this type of motion.	Provide a motion diagram that describes this type of motion.
Provide a position-versus-time graph that describes this type of motion. 	Provide a position-versus-time graph that describes this type of motion.
Describe the motion mathematically as $x(t)$.	Describe the motion mathematically as $x(t)$. $x = -v_0 t + \frac{1}{2} a_{x0} t^2$
Provide a velocity-versus-time graph that	Provide a velocity-versus-time graph that

describes this type of motion.	describes this type of motion. 
Describe the motion mathematically as $v_x(t)$. $v_x = v_{x0}$	Describe the motion mathematically as $v_x(t)$.
Provide an acceleration-versus-time graph that describes this type of motion. 	Provide an acceleration-versus-time graph that describes this type of motion.
Describe motion mathematically as $a_x(t)$.	Describe motion mathematically as $a_x(t)$. $a_x = a_{x0}$

OALG 2.8.5 Read and interrogate

Read and interrogate Section 2.8 in the textbook and answer Review Question 2.8.

OALG 2.8.6 Practice

Answer Questions 6, 7, 19, 15, 22, and 24 on pages 43-45 in the textbook and solve Problems 41, 42, 51 and 54.

2.9 Skills for analyzing situations involving motion

OALG 2.9.1 Read and interrogate

Section 2.9 in the textbook contains several worked examples.

a. Try these examples on your own and then compare your solutions to the ones in the textbook. Especially pay attention to Example 2.12.

b. What steps of the problem-solving strategy are used in each of these examples? What is the purpose of each step?

c. Answer Review Question 2.9.

OALG 2.9.2. Observe and analyze

The photo above shows Eugenia's footprints on sand. Analyze the footprints to

a. Tell a story about Eugenia's motion.

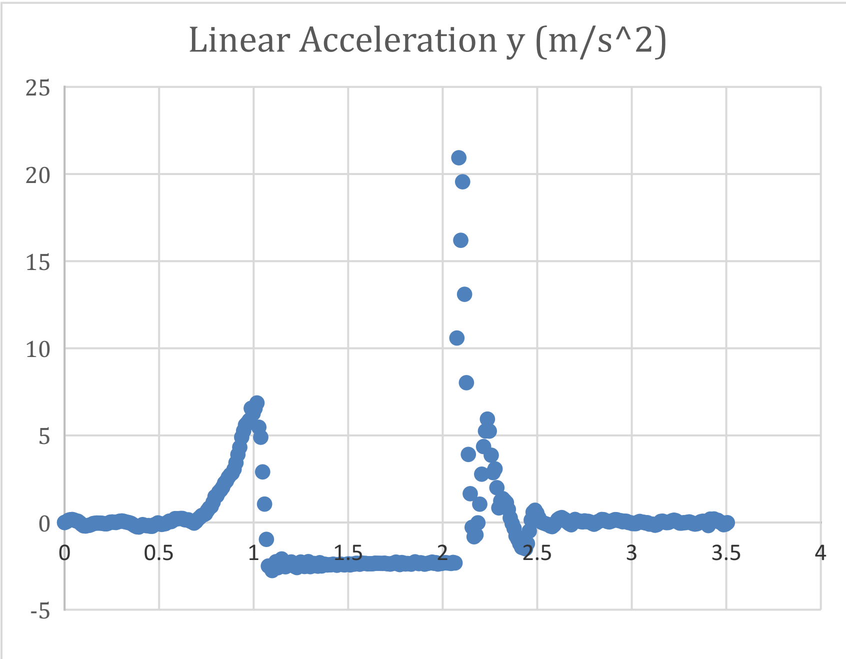
b. Draw a motion diagram. What assumptions did you make?

c. Watch the video of Eugenia walking on the sand [https://youtu.be/faEMgURzNfc] and estimate how fast she was walking. Eugenia's shoe size is 7. What assumptions do you need to make?

OALG 2.9.3 Observe and analyze

a. Download the Phyphox app on your phone. Attach the phone to a mechanical toy car and push the car up an inclined plane (you can tilt a table at home) and let it go up and down. Collect acceleration-vs-time data and analyze the graph Phyphox created. What can you determine from the graph?

b. In case you cannot perform the experiment, below is the data collected by the Phyphox a similar experiment (the cart with the phone on top went up and down the plane). The *y*-axis of the app is along the inclined plane. On the graph the vertical axis is along the direction of motion of the cart and the horizontal axis is time. Examine the graph and determine everything you can about the motion of the cart.



OALG 2.9.4 Practice

You travel by car on a highway from A to B. At t location C, which is about half way between A and B, there is roadwork, which stops you for 20 min. If there were no delays, the ride from A to B would have taken you 40 min.

a. Draw a qualitative position-versus-time graph for the motion described above. Assume the motion is linear (a straight road) and that the speed of the car on the highway (when there are no delays) is constant.

b. Draw a corresponding velocity-versus-time graph.

c. On the graphs that you drew in parts a. and b. add a curve/line that describes the motion of the car that would travel the same distance with an *average speed*.

d. Devise a general rule for how one can determine the average speed from the $x(t)$ graph and from the $v(t)$ graph.

OALG 2.9.5 Represent and reason

You have two identical billiard balls at the top of an inclined track. Assume that the balls move along the incline in the same way a small cart does (i.e., with constant acceleration). Now imagine you release one ball and it moves down the track. When it is about 10 cm down the track, you release the second ball. Draw a picture of the situation and describe it using motion diagrams, graphs, and mathematical equations. Use those representations to predict what will happen to the distance between the two balls – will it increase, decrease, or stay the same (about 10 cm) and explain how you arrived at your prediction.

OALG 2.9.6 Represent and reason

Practice representing a process involving motion. A stoplight turns yellow when you are 20 m from the edge of an intersection. Your car is traveling at 12 m/s. After you hit the brakes, your car's speed decreases at a rate of 6.0 m/s each second until the car stops. Ignore the reaction time needed to move your foot from the floor to the brake pedal.

a. Sketch the process. Indicate the origin of the coordinate system and the direction of the x-axis.

b. Draw a motion diagram representing the process. What are the signs of v_x , Δv_x and a_x ?

c. Construct an $x(t)$ graph for the process.

d. Construct a $v_x(t)$ graph for the process.

e. Write $x(t)$ and $v_x(t)$ expressions representing the process.

OALG 2.9.7 Evaluate

Students were solving the following problem:

You are traveling in your car at 20 m/s at a distance of 20 m behind a car traveling at the same speed. The driver of the other car slams on the brakes to stop for a pedestrian who is crossing the street. Will you hit the car? Your reaction time is 0.60 s. The maximum acceleration (slowing down) of each car is 9.0 m/s^2.

Dina and Jeanette presented their solutions:

*Dina's solution***:**

Assuming that the driver of the car in front of you applies the maximum acceleration of

9 m/s^2 to stop their car, it would take $t = \Delta v / a = \dfrac{20\text{ m/s}}{9\text{ m/s}} = 2.2\text{ s}$ for the car to stop. Driving 20 m behind the car you have total of 2.2 s to respond to avoid a collision. With a reaction time of $\Delta t_{\text{delay}} = 0.6\text{ s}$, you must be able to stop your car within $\Delta t_{\text{stop}} = 2.2\text{ s} - 0.6\text{ s} = 1.6\text{ s}$. The minimum acceleration to stop is therefore $a_{\text{min}} = \dfrac{\Delta v}{\Delta t_{\text{stop}}} = \dfrac{20\text{ m/s}}{1.6\text{ s}} = 12.5\text{ m/s}^2$. Because the magnitude of this acceleration is significantly larger than the maximum possible acceleration of 9 m/s^2 for the car, you will not be able to avoid the collision.

Jeanette's solution:

The car in front of you will stop after traveling the distance of $x_{\text{f}} = \dfrac{v^2}{2a} = \dfrac{400\text{ m}^2/\text{s}^2}{2 \cdot 9\text{ m/s}^2} = 22.2\text{ m}$. If you hit the brakes after a 0.6 s delay, you move $x_{\text{delay}} = v \cdot \Delta t_{\text{delay}} = 20\text{ m/s} \cdot 0.6\text{ s} = 12\text{ m}$. Therefore, you have total distance of $x = 20\text{ m} - 12\text{ m} + 22.2\text{ m} = 30.2\text{ m}$ to stop the car. Because the maximum acceleration of your car is the same as that for the car in front, your shortest stopping distance is also 22.2 m, which means that you will stop before hitting the front car.

Comment on both solutions and decide which one is correct. For the solution that is not correct explain which steps of the reasoning are incorrect.

OALG 2.9.7 Regular problem

You ride your bike west at a speed of 8.0 m/s. Your friend, who is located 400 m east of you, is riding her bike west at a speed of speed 12 m/s. Complete the following steps to determine when your friend passes you.

a. *Sketch and Translate* Draw a sketch of the initial situation and choose a coordinate system to describe the motion of both bikes. Put all given information on the sketch; identify the unknown.

b. *Simplify and Diagram* Draw a motion diagram for each bike. Sketch a position-versus-time graph for each bike using the same coordinate axes.

c. *Represent Mathematically* Construct equations that describe the positions of each bicycle as a function of time relative to the chosen coordinate system.

d. *Solve and Evaluate* Use the equations to determine when the bicycles are at the same position. Does your result make intuitive sense? How do you know?

OALG 2.9.8 Represent and reason

An imaginary object moves horizontally. The position-versus-time function represents the object's motion mathematically. Describe a process that the equation below might represent. (The equation could represent many different processes.)

$$x(t) = (-200.0\text{ m}) + (-20.0\text{ m/s})t + (1.0\text{ m/s}^2)t^2$$

a. Describe the motion in words. Note that it is important to focus on what was happening at $t = 0$. Use physical quantities to write down all of the information that you can "extract" from the function. If you can write other functional dependencies – do it!

b. Draw a motion diagram that represents the process.

c. Draw a position-versus-time graph that represents the process.

d. Draw a velocity-versus-time graph that represents the process.

e. Determine when and where the object for your chosen process stops.

f. If you decided to let the process continue beyond the point where it stops in part e. above, what would the object be doing?

OALG 2.9.9 Evaluate

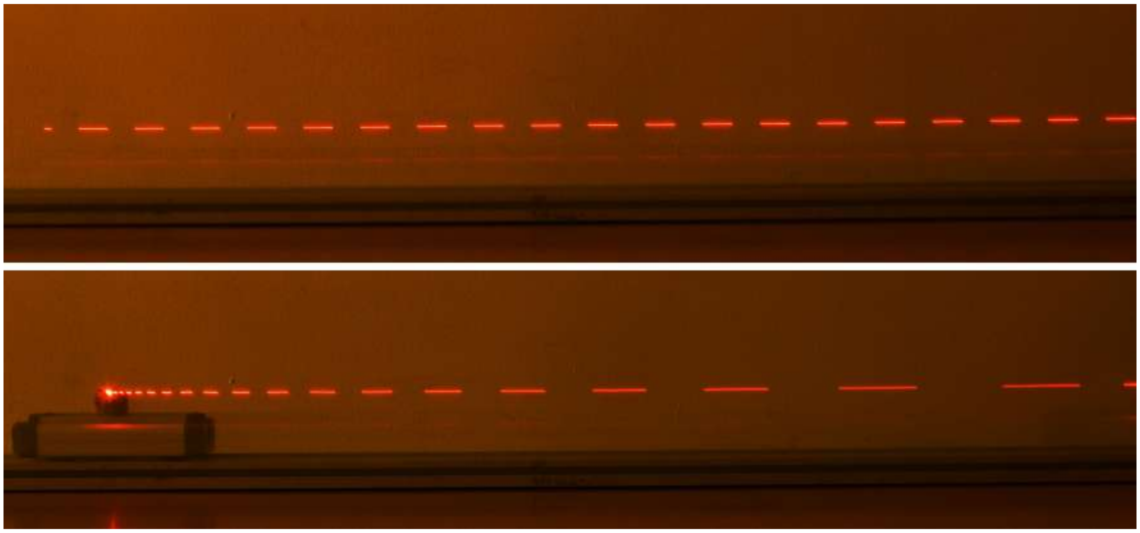
You learned that the equation describing position-versus-time of an object moving at constant acceleration is $x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$. Use both algebraic and graphical approaches to show that, in a limiting case of $a_x = 0$, this equation describes the motion of an object that is traveling at constant velocity.

OALG 2.9.10 Evaluate

You learned that in the equation describing an object moving at constant acceleration, the position as a function of time is $x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$. Use algebraic and graphical approaches to show that, in the case where $x_0 = 0$ and $v_{x0} = 0$, the successive displacements of the object change in proportion as the integers squared: 1, 4, 9, 25, etc.

OALG 2.9.11 Observe and analyze

The figure below shows long-exposure photos of two experiments with a blinking LED that was fixed on a moving cart. In both cases, the cart was moving from right to left. The duration of the ON and OFF times for the LED is 154 ms, and the length of the cart is 17 cm.

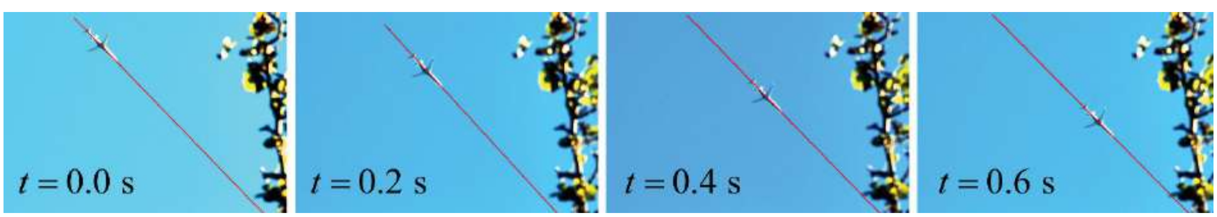


a. Specify a coordinate system and draw a qualitative velocity-versus-time graph for the motion of the cart in both experiments.

b. Estimate the speed of the cart in the first experiment. Both photos were taken from the same spot and with the same settings. Indicate any assumptions that you made.

OALG 2.9.12 Observe and analyze

Daniel fixed a camera on a tripod and took four successive photos of an airplane that was flying above him. The time interval between the photos was 0.2 s (see the first figure below; a straight line was added later to help you compare the position of the airplane in the different photos).



a. Draw a motion diagram for the airplane.

b. Estimate the length of the airplane using the magnified photo (shown in the second figure below) of the airplane and data that you can find on the Internet. Indicate any assumptions that you made.

c. Draw labeled position-versus-time and velocity-versus-time graphs for the airplane's motion. Indicate your assumptions (they will relate to the airplane you choose and the direction of motion) and the choice of a coordinate system. Make sure the axes of your graphs contain units. Note that you will need a ruler to solve this problem.

OALG 2.9.13 Linearize

You are testing your new motion detector at an open window when suddenly a stuffed Piglet passes by. While Piglet is moving downward, you manage to record the data shown in the table at right about its motion with your motion detector.

Estimate how far above your window is the window of the child who dropped Piglet. What else can you estimate from these data? Indicate any assumptions that you made (Note: the acceleration of falling Piglet may be significantly less than *g*).

t **(s)**	***v*** **(m/s)**
0.00	10.9
0.05	11.3
0.10	11.7
0.15	12.0
0.20	12.4
0.25	12.8

OALG 2.9.14 Observe and analyze

[https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-2-9-14]

Watch the video using link above. Take relevant data from the video, draw motion diagram(s), and plot appropriate graphs to fully analyze the motion of the cotton ball. Write a short report of your results and analysis. In conclusion, what can you say about the motion of the cotton ball from your analysis?

OALG 2.9.15 Practice

Solve Problems 71, 75, 76, 83 and 85. Test your reading comprehension and understanding of this chapter by answering the questions to the reading passage problems.