Chapter 3

Newtonian Mechanics

3.1 Describing and representing interactions

OALG 3.1.1 Observe and represent

Equipment: A heavy and a light object. See the experiment below.

Find a heavy and a light object in your house (our physics textbook and a sheet of printing paper will do). While standing: hold the textbook in the palm of one hand and the paper in the palm of your other hand. Focus on what you need to do to hold each object still. The goal of this activity is to learn to draw a new representation called a "force diagram." Do the following on a piece of paper:

a. Centered at the top of your page, draw a sketch of a person standing on the ground, holding the textbook and the paper. To draw a force diagram, you first need to identify systems/objects of interest. In this case, the textbook is the system for one diagram and the paper is the system for the other. Draw a circle around each object to signify this. Divide the rest of your page into a left column for the textbook as a system and a right column for the paper as the system.

b. The next question you need to ask yourselves is what other objects are interacting with each system? If you are stuck, think of the following: Is your hand interacting with the system? Is Earth interacting with the system? List the objects interacting with each the textbook and the paper at the top of the respective column.

c. Drawing the force diagram: Below your lists of interacting objects, leaving enough space, draw a dot that represents the book and a separate do that represents the paper as point-like objects. On each dot, draw an arrow to show how your hand pushes on the book and on the paper. Let the tail of the arrow start on the dot. This arrow represents the force that your hand exerts on the book or on the paper. How could you label this force arrow to show that it is the force your hand exerts on the book? Add this label to your representation for each of the systems.

d. Repeat this for the other interactions you identified. Try to make the lengths of the force arrows in the two diagrams represent the relative magnitudes of the forces. The arrows on a force diagram represent force vectors - physical quantities that have both magnitude and direction. If you are having trouble, consult Figure 3.2 on page 52 in the textbook. Also, read and interrogate Section 3.1 in the textbook. Especially pay attention to Physics Tool box 3.1, "Constructing a force diagram".

e. Consider the following ideas. The word "force" is used in physics for a physical quantity that characterizes the interaction between two objects. A single object does not have a force because a force requires an interaction between two objects. Using the definition of a force in physics, give three examples from everyday life when the use of the term force does not match the meaning of this word in physics.

OALG 3.1.2 Test your idea

[https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-3-1-2]

a. In the previous activity, did you think that air interacted with the ball?

b. If yes, do you think that the total force that the air exerts on the ball points up or down?

c. What experiment(s) can you perform to test your idea about whether the air pushes up or down on the ball? Describe the experiment(s) and state the predictions of what should happen based on each hypothesis – (1) the air pushes up on the ball and (2) the air pushes down on the ball.

d. Watch the video of the experiment using the link above. Which hypothesis about the air pushing on the ball does the experiment reject? If you are having trouble answering this question, read and interrogate subsection "Testing a hypothesis" on page 53 of the textbook.

OALG 3.1.3 Read and analyze

Work through Conceptual Exercise 3.1 on page 54 in the textbook, do the *Try it yourself* example, and compare your answer to the answer in the textbook. Revise your work if necessary.

OALG 3.1.4 Read and interrogate

Read and interrogate Section 3.1 in the textbook and answer Review Question 3.1.

3.2 Adding and measuring forces

OALG 3.2.1 Observe and find a pattern

The experiment in the video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-2-1 helps you investigate the relationship between the forces that the platform scale and the spring scale exert on the object when they are both supporting the object and the object is at rest. Watch the video and describe the pattern in words and mathematically using your knowledge of vectors.

Experiment	**List the objects interacting with the cylinder of interest.**	**Draw a force diagram for the cylinder.**	**Discuss the relationship between the direction(s) and magnitudes(s) of the vectors on your force diagram.**
(a) You hang a cylinder from a string attached to a spring scale; the scale reads 5 N.			
(b) You lower the cylinder onto a platform scale. The spring scale reads 3 N, the platform scale reads 2 N.			
(c) You remove the spring scale and leave the cylinder on the platform scale; it reads 5 N.			

OALG 3.2.2 Read and interrogate

Read and interrogate Section 3.2 in the textbook and explain the meaning of the title of this section. In other words, why is the method of measuring forces based on their addition?

3.2.3 Practice

Solve problem 4 on page 80 in the textbook.

3.3 Conceptual relationship between force and motion

3.3.1 (ALG 3.3.1) Observe and find a pattern

Watch the video [http://islephysics.net/pt3/experiment.php?topicid=3&exptid=172] and use it to fill in the table. The system is the bob.

Observational experiment	**Analysis**	
	Motion diagram for the bob	**Force diagram for the bob**
Experiment 1. A bob is supported by a spring scale. The bob is at rest.		
Experiment 2. The bob accelerates up (being pulled by the scale).		
Experiment 3. The bob is moving up at constant speed.		
Experiment 4. The bob moves up slowing down to a stop.		
Experiment 5. The bob accelerates down.		
Experiment 6. The bob slows to a stop when moving down.		
Patterns What patterns did you notice between the direction of the $\Delta\vec{v}$ arrow on the motion diagram and the vector sum of the forces exerted on the bob? Make sure that all of your forces are labeled with two subscripts.		

OALG 3.3.2 Observe and find a pattern

Find a heavy object that you can hold in one hand. Safely throw it up vertically using one hand, and catch using the same hand (it can be a medicine ball if you have one, a 1-L bottle of water or something of that kind). Read the descriptions of the experiments below and perform them, paying attention to how your hands feel holding, throwing, or catching the ball. Then construct a motion diagram and a force diagram for the ball's motion during each experiment. Based on our investigation in Activity 3.1.2, you can ignore any force or forces that the air might exert on the ball.

a. Hold the object at rest in your hand. Focus on how heavy it feels.

b. Throw the object upward. Focus on the time interval when it is still in your hand going up.

c. Observe its motion *after* it leaves your hand until it reaches the top of its flight.

d. Observe its motion *after* it reaches the top of its flight.

e. Catch the object. Focus on how heavy it feels while you are stopping it with your hand.

f. Examine the results of all 5 experiments. Is there the same pattern in the directions of the sum of the forces that other objects exert on the ball and in the directions of the $\Delta\vec{v}$ arrows on the motion diagram as in the previous activity? If so, describe the pattern.

g. Use the pattern that you found in Activity 3.3.1 and in this activity to formulate a statement relating the direction of the sum of the forces exerted on an object by other objects and on one or more of the kinematics quantities that describe its motion.

OALG 3.3.3 Read and interrogate

Now that you have done the activities, read Section 3.3 in the textbook and answer the following question: Alan says that a prediction is an educated guess. Eugenia says that a prediction is the same as a hypothesis, it explains some observed phenomenon. And David says that a prediction is a description of an outcome of a specific experiment. Use Testing Experiment Table 3.2 to resolve the argument and give examples of the predictions from this table that refute Alan's and Eugenia's ideas.

OALG 3.3.4 Test an idea

a. Watch the video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-3-4a

to note the reading of the scale when the person puts a bean bag on it.

b. Use the pattern formulated in activity 3.3.1 to make a prediction about the reading of the scale when you drop the bean bag on it. Will it be more, less or the same compared to the reading you recorded? Use motion and force diagrams to make the prediction.

c. Watch the video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-3-4b

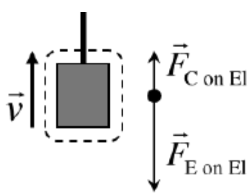
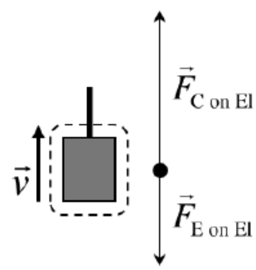
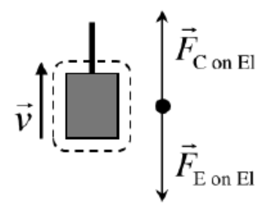
and compare your prediction to the outcome of the experiment. What can you say about the pattern formulated in Activity 3.3.1? Does it hold for this experiment too?

OALG 3.3.5 Represent and reason

Below you see three different situations and the corresponding force diagrams for the circled system (an elevator).

a. For each situation, describe the motion of the elevator in words and draw a motion diagram.

b. Consider: How can you make sure the motion of the elevator is consistent with the given force diagram? (Hint: what is the direction of the sum of the forces in each force diagram?)

1	**2**	**3**
		

OALG 3.3.6 Read and interrogate

a. Read and interrogate Section 3.3 in the textbook.

b. Compare the observational experiments in Observational Experiment Table 3.1 to the experiments in the Activity 3.3.1. Then compare the testing experiments in Testing Experiment Table 3.2 to the experiments in Activity 3.3.4. What is the same about them? What is different?

c. Answer Review Question 3.3.

OALG 3.3.7 Observe and analyze (ALG 3.3.6)

[https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-3-3-6]

Watch the video and observe the man catching a heavy medicine ball. Consider the motion of the ball from the instant it touches his hands (when the ball's downward speed starts to decrease) until the instant it stops (his hands have moved down with the ball while stopping it).

a. Sketch the process for the time interval from the instant the ball touches your hands until the instant it stops. Choose the ball as the system.

b. Construct a motion diagram for the stopping process.

c. Construct three force diagrams for the ball for three different instants during the slowing down motion. Be sure each force diagram is consistent with the motion diagram.

d. Which object exerts a greater force on the ball as he is stopping it – the man or Earth?

e. If you have a similar object at home, ask somebody to drop it into your hands. Focus on how hard you need to push on the ball to stop it. Can you stop the ball instantly? Explain.

OALG 3.3.8 Evaluate

Ulani is solving a physics problem involving a paratrooper, whose parachute did not open, landing in a deep snow bank. He sinks about one meter into the snow while stopping. Ulani draws the (unlabeled) force diagram shown on the right and says, "this force diagram could represent a paratrooper moving downward into the snow bank." José disagrees. Looking at the force diagram he says "the way you've drawn the force diagram, the paratrooper *cannot* be moving downward. He *must* be moving upward because the force pointing up is bigger than the force pointing down."

a. Correctly label the force diagram.

b. Who do you agree with and why? For the person you disagree with, how would you convince them that they are incorrect?

OALG 3.3.9 Practice

Answer Questions 1, 5, and 16 on pages 78-79 in the textbook and Problems 1, 2, 6-9, 11 and 12 on page 80.

3.4 Inertial reference frames and Newton's first law

OALG 3.4.1 Represent and reason

Imagine you're sitting on a stationary train and your friend is standing on the platform looking through the window. On the table in front of you is a tennis ball. The train accelerates away from the station.

a. Draw motion and force diagrams for the ball as observed by you as the train accelerates.

b. Draw motion and force diagrams for the ball as observed by your friend as the train accelerates. Remember the rule for force diagrams: A force describes an interaction between two objects. If you can't identify the object that is exerting a force on the object of interest, you can't put it in the force diagram!

	Motion diagram	**Force diagram**
a. For the ball, as observed by you on the train, i.e., draw the diagrams as seen in your reference frame.		
b. For the ball, as observed by your friend on the platform. i.e., draw the diagrams as seen in your friend's reference frame.		

c. Is there a reference frame in which the force and motion diagrams are inconsistent with the rule you've developed in Section 3.3 relating force and motion diagrams?

d. What do you think is the characteristic of this reference frame that makes the force and motion diagrams inconsistent with each other?

e. Think of other examples of reference frames in everyday life where the motion and force diagrams for an object in that reference frame are inconsistent with the rule you've developed. Should you discard the rule you've developed? Or (more preferably), come up with a statement (called an "assumption") about when the rule will and won't work.

OALG 3.4.2 Read and interrogate

Read and interrogate Section 3.4 in the textbook and answer Review Question 3.4.

OALG 3.4.3 Practice

Answer Questions 2, 3 and 4 on page 78 in the textbook.

3.5 Newton's second law

TIP In all experiments and problems, you should focus your attention on the forces exerted by other objects on the object of interest (the system), not on forces that the system exerts on other objects. Only forces exerted on the system are drawn on force diagrams.

OALG 3.5.1 Observe and find a pattern

Analysis of video experiment 1	
Acceleration (m/s^2)	Sum of the forces (N)
0.38	0.2
0.74	0.3
1.67	0.5
2.8	0.75
4.3	1.2
Analysis of video experiment 2	
Acceleration (m/s^2)	Mass (kg)
0.27	0.56
0.20	0.76
0.15	0.96
0.13	1.16
0.10	1.36

Watch (video experiment 1, [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-3-5-1a]) and (video experiment 2, [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-3-5-1b])

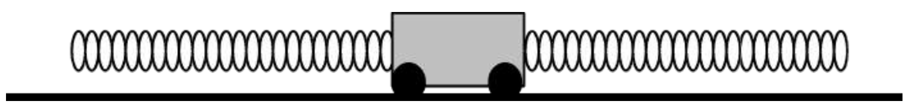
a. Draw a force diagram for the cart in Experiment 1 and another for the cart in Experiment 2.

b. Then use the data in the table at right to devise a relationship that shows how each cart's acceleration depends on the cart's mass and on the net force exerted on the cart by the string or fan, Earth, and the track. Note: When doing such an analysis, devise a relationship for each independent variable one at a time and for the dependent variable. For example, use some of the data to see how the acceleration depends on the net force exerted and then use other parts of the data to see how the acceleration depends on the mass of the cart. Then combine these relationships to get a final relationship. For the dependence of the acceleration on the mass, think of how you can linearize the data to help find the relation (hint: plot acceleration-*vs*-1/*m*).

If you need help, read and interrogate pages 61-64 in Section 3.5 in the textbook, especially paying attention to Observational Experiment Table 3.5.

OALG 3.5.2 Find a pattern

Imagine there are springs attached to both ends of a cart. The springs can pull the cart left and right. Each spring pulls with the same strength, but the number of springs on each side of the cart can vary.



Examine the data in the following table and draw a force diagram for the cart in each experiment.

Number of springs pulling to the right	Number of springs pulling to the left	Acceleration of the cart	Draw a force diagram; show horizontal forces only
3	3	0	
1	2	$-1.03\ m/s^2$	
3	1	$1.98\ m/s^2$	
4	1	$3.03\ m/s^2$	
2	6	$-3.95\ m/s^2$	

a. Explain why we use negative signs in the acceleration column of the table.

b. Use the data in the table to devise a relationship between the cart's acceleration and the forces exerted by the springs, Earth, and the track on the cart.

c. Is this relationship consistent with the relationship you devised in Activity 3.5.1? Explain.

OALG 3.5.3 Explain

In Activities 3.5.1 and 3.5.2 you analyzed experiments in which the motion of an object was affected by other objects. Represent mathematically the relationship between the object's acceleration, the net force exerted on it by other objects, and its mass.

OALG 3.5.4 Read and interrogate

Read and interrogate Section 3.5 in the textbook and answer Review Question 3.5. Work through Example 3.3 to learn how to use force components.

OALG 3.5.5 Practice

Answer Questions 7, 17, 18 and 19. Solve Problems 18-21 in the textbook.

3.6 Gravitational force law

OALG 3.6.1 Reason

You learned in Chapter 2 that in the absence of air, all objects on Earth fall with the same acceleration of 9.8 m/s^2 independently of their mass. How is this possible if the acceleration of an object is inversely proportional to its mass? Construct a mathematical relationship for the magnitude of the force that Earth exerts on an object of mass m. Think of different possibilities.

OALG 3.6.2 Test your idea

You have a spring scale calibrated in newtons and a set of objects of known masses. Imagine that you hang objects of different masses on the spring scale and record its reading. Then you plot the graph of the data. The mas of the objects in kilograms is on the horizontal axis and the reading of the scale in newtons is on the vertical axis.

a. Draw a force diagram for each of the hanging objects when each is at rest. What can you say about the magnitude of the force that the scale exerts on the object and the magnitude of the force that Earth exerts on the object?

b. Use the mathematical relationship that you constructed in Activity 3.6.1 to predict the slope of the graph. Explain how you made your prediction.

c. Observe the video of the experiment https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-6-2 , collect the data, and plot the data using the same axes as in your prediction. Did your prediction match the outcome of the experiment? What does the match/mismatch tell you about the relation you devised in Activity 3.6.1?

OALG 3.6.3 Read and interrogate

Read and interrogate Section 3.6 in the textbook and consider the following question: Is the following statement true? "Because *g* is the same for all objects, Earth must exert the same force on all objects". How would you convince a person studying physics of your opinion on this matter?

OALG 3.6.4 Observe and explain

Observe and explain the two experiments in the video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-6-4. What could be the reasons for why the two objects did not fall at the same rate in both experiments? Use force diagrams to support your explanations.

3.7 Skills for applying Newton's second law for one dimensional processes

OALG 3.7.1 Practice problem solving strategy

To practice applying the 4-step problem solving strategy for solving complex problems, solve the problem below by following the steps in the table, and then consult the textbook solution in Example 3.4. After that, work through the *Try it yourself* problem on page 68.

Michael Holmes (70 kg) was moving downward at 36 m/s (80 mi/h) and was stopped by 2.0-m-high shrubbery and the ground. Estimate the average force exerted by the shrubbery and ground on his body while stopping his fall.

Sketch and translate ● Sketch the process. ● Choose the system. ● Choose a coordinate system.	

● Label the sketch with everything you know about the situation. ● Identify the unknown that you need to find. Label it with a question mark on the sketch.	
Simplify and diagram ● Make appropriate simplifying assumptions about the process. For example, can you neglect the size of the system? Can you assume that forces or acceleration is constant? ● Then represent the process with a motion diagram and/or force diagram(s). Make sure the diagrams are consistent with each other.	
Represent mathematically ● Convert these qualitative representations into quantitative mathematical descriptions of the situation using kinematics equations and Newton's second law for motion along the axis. Determine the signs for the force components in the equations. Add the force components (with either positive or negative signs) to find the sum of the forces.	
Solve and evaluate ● Substitute the known values into the mathematical expressions and solve for the unknowns. ● Finally, evaluate your work to see if it is reasonable (check units, limiting cases, and whether the answer has a reasonable magnitude). Check whether all representations—mathematical, pictorial, and graphical—are consistent with each other.	

OALG 3.7.2 Regular problem

An official World Record speed for ice-board windsurfing in 2012 was about 98.7 km/h and it was achieved on Lake Winnipesaukee, New Hampshire. From the YouTube video you can find out that the surfer's speed at time 114 min 35.0 sec was 50.1 mi/h and at 114 min 59.3 sec, 61.2 mi/h. Estimate the average sum of the forces exerted on the system during this time interval if the mass of the surfer is 80 kg and the mass of the sail, mast, and board is 20 kg. Indicate any assumptions you made.

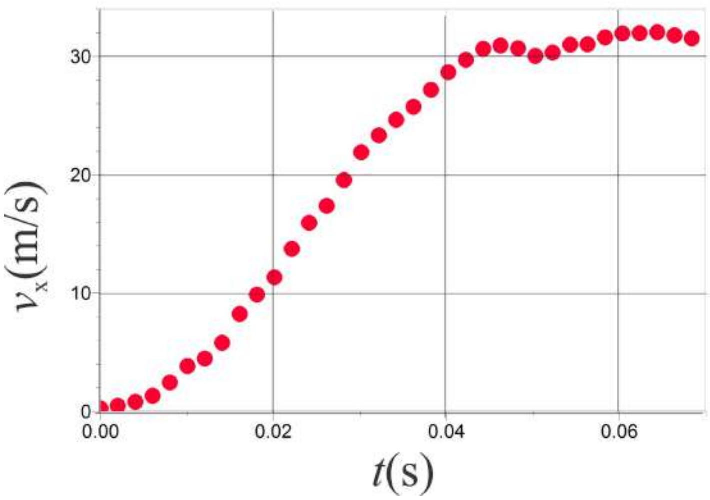
OALG 3.7.3 Practice

Solve Problems 22-26, 31, 32 and 35 in the textbook.

OALG 3.7.4 Observe and analyze

a. Watch the video of a man shooting an arrow https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-7-4 and study the graph of the arrow's motion to tell a story about what happened to the arrow.

b. Find the maximum acceleration and the maximum force exerted by the bow on the arrow, assuming the mass of the arrow is about 30 g.



OALG 3.7.4 (ALG 3.7.3) Reading and interrogate

Make sure you work through the worked examples in Section 3.7 in the textbook. Afterwards, answer Review Question 3.7.

3.8 Forces come in pairs: Newton's third law

OALG 3.81 Observe and explain

Hold your forearm horizontally and your hand perpendicular to the arm so that your palm faces away from you. Try to bend your wrist so that your hand bends closer to your forearm. Notice how far you can bend it. Then, holding your forearm the same way, push a vertical wall with your hand (see the photo below) and observe how far it bends. Explain why you can bend your hand much more when it pushes against the wall.

OALG 3.8.2 Observe and find a pattern

Watch this video of several experiments of two people pulling on scales https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-8-2.

a. Stop the video at any moment and record the readings of the scales. Make a data table for the readings.

b. Describe the pattern you find in words and mathematically.

c. Devise and state a general hypothesis about the relationship between the force that object A exerts on object B to the force that object B exerts on object A.

OALG 3.8.3 Test your idea

The videos show collisions of carts of different masses and speeds (do not watch them yet). The carts have force probes attached to them. Each probe records the force that the other car exerts on the force probe.

a. Use the hypothesis that you devised in part **c** of Activity 3.8.2 (not your intuition) to predict which force probe (if any) will have a higher reading during the collision in the following experiments:

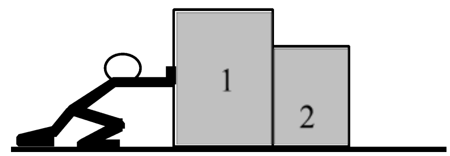
1. A moving cart hits a stationary cart. Both cars have the same masses.
2. A moving heavy cart hits a light stationary cart. The heavy cart is twice as heavy as the light one.
3. Two carts move toward each other with about the same speeds. One cart is twice as heavy as the other.

b. Watch the videos https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-3-8-3 and explain the meaning of the graphs shown after each experiment. What does the blue curve mean? What does the yellow curve mean? How do the graphs allow you to compare the outcomes of the experiments to your predictions?

c. What is your judgment of the hypothesis being tested?

d. Formulate a rule relating the forces that two interacting objects exert on each other. If you are having trouble, read and interrogate Section 3.8 in the textbook up to Conceptual Exercise 3.6.

OALG 3.8.4 Represent and reason



You push horizontally on two crates of different mass. The surface on which the crates move is smooth. Draw separate force diagrams for crates 1 and 2 for the two scenarios **a.** and **b.** below. When drawing force diagrams, use the rule relating the forces that two interacting objects exert on each other (devised in Activity 3.8.2, part c.).

a. You first push crate 1, which pushes against the smaller crate 2.

b. You now reverse the positions of the crates and push crate 2, which pushes against the larger crate 1.

c. Based on your diagrams in parts a. and b., should it be easier to push the crates in one of these two situations? Explain.

d. Is your answer to part c. consistent with the idea that you are pushing the same amount of mass, independent of the order of the crates?

e. If it is equally difficult to push the crates independent of their order, then how should the *sum* of the forces exerted by crate 1 on crate 2 and by crate 2 on crate 1 for part a. compare to the *sum* of these forces for part b.? What does this imply about the magnitude of the force that one crate exerts on the other and vice versa? (Note: the sum of the forces used here is the sum of the forces exerted on different objects, and thus it does not determine the acceleration of any object.)

OALG 3.8.5 Represent and reason

A book rests on a table.

a. Draw a sketch of the situation and identify objects that interact with the book.

b. Draw forces representing these interactions (a force diagram for the book).

c. If the book is stationary, these forces are equal in magnitude and opposite in direction. Can we say that they represent a Newton's third law pair of forces? If not, why not?

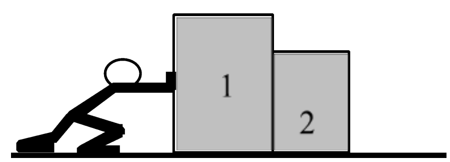
d. Draw the Newton's third law force pair (using the same color pen for each pair) for each force shown in the force diagram in part b. Then, identify the cause of each of these forces and the objects on which each of these forces is exerted. If you are having trouble, read and interrogate Conceptual Exercise 3.6 on page 73 in the textbook.

OALG 3.8.6 Practice

Carefully study Examples 3.7 and 3.8 in the textbook on pages 73-75. They not only help you see how to apply Newton's third law to problem solving, but also help you learn how to linearize data. This skill is very useful and is applied again in the activity 3.9.2 that follows. Then answer Questions 6 and 8 on page 78 in the textbook and solve Problems 36 – 39.

3.9 Seat belts and airbags

OALG 3.9.1 Reason



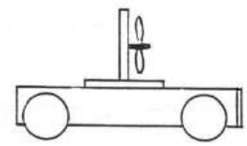
Block 1 has a mass of 5 kg and block 2 has a mass of 3 kg. The person pushing the blocks exerts a force of 80 N on block 1. Assume the surface is smooth.

a. Treating the two blocks together as a system, draw a force diagram for the combined two-block system. Remember to mark the perpendicular *x*- and *y*-axes. Use your force diagram to apply Newton's second law to determine the acceleration of the system.

b. Now draw separate force diagrams for block 1 and block 2. Apply Newton's second law to block 1 and use the acceleration you found previously to determine the magnitude of $\vec{F}_{2\text{ on }1}$.

c. Evaluate the answer you found for $\vec{F}_{2\text{ on }1}$ by applying Newton's second law to block 2 to find the acceleration of block 2. (If you know $\vec{F}_{2\text{ on }1}$, you know $\vec{F}_{1\text{ on }2}$.) Make sure the acceleration you find is consistent with the other accelerations you found in earlier parts. If not, try to figure out where a difficulty might have occurred.

OALG 3.9.2 Linearize



Alex was investigating the motion of a low-friction fan cart on a horizontal track. As the fan blades rotate, they exert a force on the air and therefore the air exerts an equal and opposite force on the blades (see the sketch on the right). Using a motion detector, he found out that the cart was moving with constant acceleration. He also measured how the acceleration of the cart depends on the mass of the weights that he added to the cart. His measurements are shown in the following table:

Added mass (kg)	**Acceleration of the cart (m/s^2)**
0	0.30
0.10	0.25
0.20	0.21
0.30	0.19
0.40	0.17
0.50	0.15

What are the two unknown quantities in Alex's experiment that also determine the motion of the fan cart? Try to determine these two quantities using the data above. (Hint: rearrange the mathematical expression for the acceleration of the cart to obtain a linear dependence on added mass, and then plot the graph using the data in the table.)

OALG 3.9.3 Application experiment

Equipment: The Phyphox app on your phone, an elevator, and a bathroom scale.

a. Take the phone with you into an elevator and hold it vertically when recording "total acceleration without *g*".

b. Use the graph and the force diagram for you in the elevator to draw several force diagrams for your trip (as seen by the observer on the ground): when the elevators starts going up, when it moves between the floors, and when it approaches a stop on the top floor.

c. Use the diagram to estimate the changes of the reading of the bathroom scale if you stand on it during the same journey. Make your predictions here. Do not forget that the scale readings are in pounds and not in newtons.

d. Conduct the experiment and record the readings. Were they close to your predictions?

OALG 3.9.4 Practice

For practice, try to solve as many General Problems on page 82 in the textbook as you can. Especially pay attention to problems 49 – 52.