UNIT I: LEARNING CYCLE – NEWTON'S 2ND LAW
Learning Cycle Teacher Notes
GETTING STARTED

Overview

The goal of this cycle is to establish the relationship between force and acceleration. The exploratory activity, Carts With A Spring Balance, allows the students to personally experience the affect of an unbalanced force acting on a mass and to formulate a conceptual relationship between force and acceleration. This is followed by Can You Change Your Motion? that builds on the previous activity by having students observe the affect of changing force and mass on the resulting acceleration. The instructor has the option of choosing either Who Has the Pull Around Here? or Who Pushed that Speeding Car? or both for the application activity. Either activity will provide students with a more in depth quantitative view of Newton's 2nd Law by taking into account friction.

National Science Education Standard(s) Being Addressed

Content Standard 5–8: Physical Science B, Motions and Forces
The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.

If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

Content Standard 9–12: Physical Science B, Motions and Forces
Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F = ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

Benchmark(s) for Science Literacy Being Addressed

Benchmark 6-8: The Physical Setting 4F, Motion
An unbalanced force acting on an object changes its speed or direction of motion, or both. If the force acts toward a single center, the object's path may curve into an orbit around the center.

Benchmark 9-12: The Physical Setting 4F, Motion
The change in motion of an object is proportional to the applied force and inversely proportional to the mass.

Setting the Stage for Student Learning

This learning cycle allows students to develop and reinforce their understanding of the relationship between force and acceleration kinesthetically and with motion and force graphs. The student physical participation in the labs allows students not only to see but also feel that an increase in force results in an acceleration. This participation also allows them to understand that friction is a force that affects motion. The use of motion and force graphs to develop student conceptual understanding of this relationship provides students with concrete visual representations of Newton's 2^{nd} law. In addition, the use of motion and force graphs to develop and reinforce student understanding of the relationship between force and acceleration not only provides a conceptual bridge between kinematics and dynamics for the student but also provides students with much needed experiences in analyzing graphical representations to shape their intuition about motion and forces.

After introducing the operational definition of a force as being a push or pull acting on an object, you may want to identify student preexisting ideas (preconceptions) about the relationship between force and motion by asking the students to answer the questions found below. The purpose of asking these questions is not to get the correct answers but to get an idea of what your students are thinking before they begin this learning cycle. Free body diagrams then could be introduced at this point. After completing the learning cycle, these questions and initial student responses could be discussed and compared with their final thoughts and ideas.

For a stationary 1.0 kg block on a level surface in Figure TG 8.1, identify all the forces that are acting on the block. Sketch your predictions of what the resulting Displacement Vs Time, Velocity Vs Time, and Acceleration Vs Time graphs would look like for this object. Explain your reasoning. Identify and describe any and all assumptions you are making.

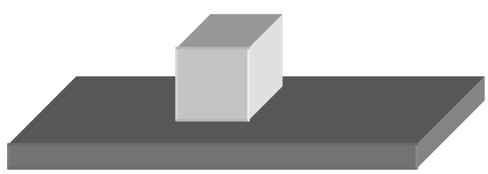
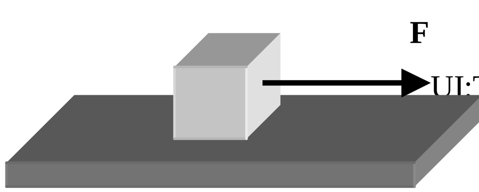


Figure TG 8.1

For a 1.0 kg block on a level surface that is being pulled with a constant horizontal force in Figure TG 8.2, identify all the forces that are acting on the block. Sketch your predictions of the resulting Displacement Vs Time, Velocity Vs Time, and Acceleration Vs Time graphs. Explain your reasoning. Identify and describe any and all assumptions you are making.



For a falling 1.0 kg block in Figure TG 8.3, identify all the forces acting on the block. Sketch your predictions of the resulting Displacement Vs Time, Velocity Vs Time, and Acceleration Vs Time graphs. Explain your reasoning. Identify and describe any and all assumptions you are making.

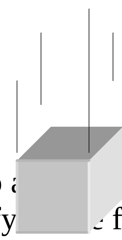


Figure TG 8.3

For a 1.0 kg block that is connected to an end of a vertical spring and is moving up and down in Figure TG 8.4, identify all the forces acting on the block. Sketch your predictions of the resulting Displacement Vs Time, Velocity Vs Time, and Acceleration Vs Time graphs. Explain your reasoning. Identify and describe any and all assumptions you are making.

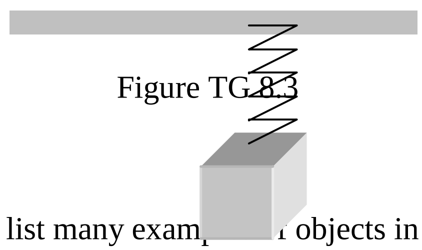


Figure TG 8.4

Taking Account of Student Ideas

1. Students will be able to list many examples of objects in motion and objects experiencing a force. They might even be able to state Newton's laws. However, writing down Newton's laws and being able to state them is not the same as understanding them. The terms used in describing these features of motion seem rather commonplace. However, the topic of force and its relationship to motion is typically filled with naïve conceptions. Great care needs to be given to developing conceptual understanding. Difficulty with these concepts could also be a detriment to a complete understanding of energy principles. Students often mistakenly believe that force is required for motion. This learning cycle provides students with opportunities to test this idea and come to the conclusion that force is required for a change in an object's motion, and that the greater the mass of the object, the smaller this change will be.
2. A commonly held belief by students is that a constant force is required to maintain constant motion. This belief is the result of everyday experiences associated with riding a bicycle or driving a car, when it takes greater effort to maintain a constant velocity at higher values than at lower values. This is in fact true because frictional forces, especially air resistance, are greater at larger velocities. It is extremely important for students to recognize that the force under consideration in these activities is the net (sum total) force on an object. Therefore, it is suggested that students immediately recognize this force and have a sense of the size of this force. The exploratory activity provides an opportunity for students to confront this belief by having them

compare the value on the spring scale or the stretch of the bungee cord just before motion occurs with the value when the cart is accelerating.

3. Associated with the previous idea students have, students will have difficulty understanding that the net force is the accelerating force. Students will confront this belief in this learning cycle by calculating the accelerating force of a person-cart and by comparing it to the actual force that is being applied.
4. Unfortunately, the notion that an object will continue to move in a straight line forever unless acting upon by an unbalanced (net) force is contrary to everyday experience with friction. As a result, this belief is very common for students. At best, we can provide situations in which friction is reduced (e.g., low friction carts, air tracks and gliders, etc.) that allow students to approximate what would happen if friction were completely eliminated. Students should be provided with opportunities to compare and contrast friction situations with that of high friction situations to understand the relationship that exists between a net force and acceleration.

Activity Teaching Notes

EXPLORATION: CARTS WITH A SPRING BALANCE

Lab setup	<u>easy</u>		moderate		difficult	
Calculations	easy		<u>moderate</u>		difficult	
Reliability	excellent		<u>good</u>		fair	
Interest	<u>excellent</u>		good		fair	
Lab time	-1 class		<u>1 class</u>		+1 class	
Process Skill	<u>A</u>	B	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
Reasoning	1	2	<u>3</u>	<u>4</u>	<u>5</u>	

Engaging Students with Phenomena

Materials

Carts and spring balance or bungee cord (stopwatch and meter stick if requested). Lab carts, skateboards, inline skates or wrestling mat carts also work well.

Teaching Strategies

1. We have various brain mechanisms for processing information and gaining understanding. This activity is rich in placing the student in the phenomena so that he or she physically feels the effect of providing acceleration and can experience learning kinesthetically. So ask the students whether and how they feel the variables that are part of this activity.
2. Four to five students working together as a group would work best for this activity.
3. It is extremely important for students to recognize that the force under consideration in these activities is the net (sum total) force on an object. Therefore, it is suggested that students immediately recognize this force and have a sense of the size of this force. You can do this by asking students to note the value on the spring scale or the stretch of the bungee cord just before the motion takes place and just after motion and compare the two.
4. It is important to assign a direction to the frictional force, such as negative, and assign a direction to the applied force, such as positive. It should then be recognized that the net force in this case is zero.
5. The applied force for all trials should be significantly greater than the frictional forces so that there is a significant acceleration. When students are a bit timid at applying a force via the spring scale or bungee cord they may set the cart in motion but apply a force that is nearly equal to the frictional forces and hence, experience nearly constant velocity. This reinforces the commonly held belief that a constant force produces a constant velocity.
6. Ask the students to observe what happens when the applied force is eliminated - when they stop pulling on the cart. Ask them to identify the forces that are now acting on the cart. Is the cart accelerating and in what direction? If they assigned a negative value for the frictional forces, how would they identify the direction of the acceleration caused by friction? This situation is very important to show that while the velocity is still in the forward or positive direction, the acceleration is now negative. Help students to build an intuitive

connection between acceleration and force, and have it be independent of the direction of velocity.

7. This lab should be treated more qualitatively than quantitatively. Calculations using Newton's 2^{nd} law will be addressed in later activities in which they are asked to measure and calculate forces.
8. Students are asked to design a method to compare the acceleration of the cart under varying circumstances. Do not give them a standard kinematics expression to calculate acceleration. Let them decide what values to compare. Students could measure the time it takes to travel a given distance and compare the times. The longer it takes to travel a given distance the less the change in velocity (or acceleration). Or they could be more quantitative and measure distance and time and calculate the average velocity. Some may recognize that since the initial velocity was zero, then the final velocity would be twice the average velocity. The total change in velocity divided by the time of travel would then be the acceleration. If computer-based or calculator-based laboratory tools and motion detectors are available, acceleration could be determined from generated Velocity Vs. Time graphs.
9. You may wish to have the students, in their small groups, think of the elements of designing the experiments. You may wish to bring the groups together to have them share methods of design, such as how they plan to compare accelerations, what variables might affect acceleration, etc. This will give some groups who had difficulty with this part an opportunity to modify their procedures and gain better results from which to make meaningful conclusions. Since this is an exploratory experience, allow the students the opportunity to be qualitative in their investigation, but building up their intuitive understanding of the patterns and relationships between acceleration, force and mass. If you feel a need to economize some time on this activity you could, after the class has shared the variables they feel could affect acceleration have different groups check the affect of different variables and then share the results.
10. The goal of this activity is to have the students be able to describe the motion of a cart in such a manner that the students see that acceleration is the most meaningful dependent variable to study, not velocity. That is to say, it is the variable that has some meaningful connections with other independent variables such as net force on the object and mass of the object. Since acceleration is the dependent variable, it is preferable to have it be the subject of the sentence in the relationship and on the left hand side of the equation. You should be able to glean from the students that acceleration is affected directly by the net force on the object and inversely by the mass of the object. This could be written as $a \propto F_{net}/m$. The unit of force can be defined in such a manner that one Newton of force provides an acceleration of one m/s^2 on a one kg mass. Hence $a = F_{net}/m$.

<u>Sample Data/Calculations</u>

Procedure answers:

2. Read and discuss the following with your instructor before continuing:

a) Does all of the force applied to the cart result in motion of the cart?
Ans. No – some of the force is needed to overcome friction.
b) How much force can you apply before the cart begins to move?
Ans. Some reasonable value dependent on equipment used.
c) Just before the cart begins to move, what is the net (sum total) of all of the forces on the cart?
Ans. This value should be the pulling force minus the frictional force.

3. Increase the force substantially above the force to overcome friction and maintain this force as long as you can possibly apply this same constant force on the cart. Describe this motion.
   Ans. The cart continuously increased its speed.
5. Identify the variables that you think will affect the acceleration (rate at which velocity changes) for a cart pulled along a path.
   Ans. Answers will very but should include mass of the cart and rider and force applied.

Please note that students may not have numerical answers. But if they did, they look like the following:

Mass of student and cart	72 kg
Force on cart by way of spring balance	15 N
Displacement of cart (d)	+15.0 m
Time of travel (t)	15.2 s

Average velocity (v_{ave}) = d/t = (+15 m)/(15.2 s) = +0.987 m/s
v_{ave} is also = (v_{final} + $v_{initial}$)/2 if the acceleration is constant (constant net force).
$v_{final} = 2v_{ave} - v_{initial}$
v_{final} = 2(+0.987 m/s – 0) = +1.97 m/s
Acceleration (a) = ($v_{final} – v_{initial}$)/t = (+1.97 m/s – 0 m/s)/(15.2 s) = +0.13 m/s^2

Developing and Using Scientific Ideas

1. If you add mass to a car and maintain the same force through the engine, what affect does that have on the rate at which the velocity will change?
   Ans. If mass is added to a car with the same force on the engine, the rate at which velocity will change will be decreased, or we can also say the acceleration will decreased.
2. If a car travels along on a roadway at a constant velocity, what can you infer about the forces on the car?
   Ans. If a car travels at a constant velocity, this means that the net force on the car is zero. The forward applied force just balances the frictional forces and hence, the net force is zero.
3. How does acceleration seem to be related to force?
   Ans. The acceleration of any object is directly related or proportional to the net force applied to the object.
4. How does acceleration appear to be related to mass?
   Ans. Acceleration is inversely proportional to mass. If the mass increases and the force remains constant, then the acceleration will be decreased.

5. If a 3 N force is applied to the cart and rider and no movement results, how can this be explained?
   Ans. If a 3 N force is applied to a cart and the cart does not more, this means that the frictional force on the cart is at least 3 N.

Extending the Activity

Suppose a new Olympic event called the "5 Meter Sprint" were introduced. What would be the most important attributes of an athlete most likely to win the event? Defend your answer based on your observations in this activity. If we were to hold this event among students in this class, who do you think would win and why?

Example/Answer A student with a small mass and a good reaction time should do well in this event. Students with larger masses will have a harder time accelerating. Endurance is not a significant factor over such a small distance.

Activity Teaching Notes

CONCEPT DEVELOPMENT: CAN YOU CHANGE YOUR MOTION?

Lab setup	easy		moderate		difficult	
Calculations	easy		moderate		difficult	
Reliability	excellent		good		fair	
Interest	excellent		good		fair	
Lab time	-1 class		1 class		+1 class	
Process Skill	A	B	C	D	E	F
Reasoning	1	2	3	4	5	

Engaging Students with Phenomena

Materials

Dynamics cart, laboratory masses or bricks, timing device, string, and spring scales if needed. This activity can be done with a variety of measurement tools. Forces can be measured with either force sensors or spring scales. Accelerations can be determined by using meter sticks and stopwatches, with ticker timers, or motion detectors with computer-based laboratory tools or calculator-based laboratory tools. It might be interesting to have each type of measuring method available and compare results, if possible.

Teaching Strategies

1. Create a situation in the classroom of having the students play the role of researchers. Students should hypothesize what variables will affect the acceleration and then they design an experiment to show the relationship. Suggest that they explore relationships of broad concepts. As an example, force is more inclusive than friction since friction is a particular type of force.
2. Give your students a chance to organize their own experiments. Ask questions such as the following: What factors do you think affect acceleration? How could you set up an experiment to show how force affects the acceleration? How would you change your experiment if you were to do it again?
3. If students need some help, you might suggest a way to measure a constant force over a distance with a dynamics cart and timer. Attaching a string to the cart and hanging a mass attached to the string over the edge of a table in Figure TG 8.5 could do this. Force sensors and spring scales can also be used to measure the force exerted on the cart. Note that the weight of the hanging mass is not the force exerted on the cart. Students must devise a method of measuring the acceleration achieved by a given force. Then the force is increased. This activity gives the teacher an excellent opportunity to evaluate how well students are able to control variables. Students then plot Force vs. Acceleration and evaluate the results. Students should collect data for at least five different forces in order to obtain a meaningful graph.

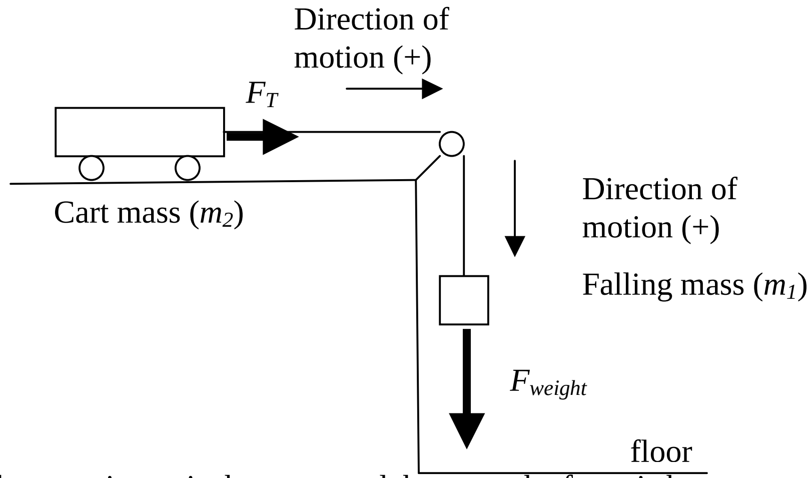


Figure TG 8.5

4. The experiment is then repeated, but now the force is kept constant and the mass of the cart is varied. Now a graph of Acceleration Vs Mass is possible.
5. You should recognize that controlling all the variables, sketching graphs, and analyzing them requires rather formal reasoning. You should allow all students to determine their own way to find solutions to the general questions posed and to exhibit different exit levels of learning by experimentation. You will have an opportunity to increase their understanding of Newton's 2nd Law during post lab discussions.
6. Dynamics carts generally have minimal friction so friction can be ignored. If you have more advanced students friction would not have to be ignored.
7. You may want to review with your students how to construct free-body diagrams.

Sample Observations/Calculations

The following data were collected using a motion detector, force probe, and a Vernier LabPro computer interface. (Sampling rate = 40 samples/sec.)

Cart Mass (kg)	Falling Mass (kg)	Accelerating Force (N)	Acceleration (m/s^2)
.74	.05	.18	.47
.74	.10	.54	.95
.74	.15	.66	1.0
.74	.20	.90	1.3
.74	.25	1.2	1.7
.74	.10	.54	.95
.84	.10	.54	.80
1.1	.10	.54	.70
1.2	.10	.54	.63
1.4	.10	.54	.57
1.7	.10	.54	.50

The following Velocity Vs. Time, Acceleration Vs. Time, and Force Vs. Time graphs in Figures TG 8.6 – 8.8, which were created by Logger Pro, were collected by using a force probe attached to the dynamics cart and a motion detector. The cart was accelerated by a 50-gram falling mass. The motion of the accelerated cart takes place before one second and the remainder of the graph takes place after the mass has hit the floor and is no longer causing a uniform acceleration. The remaining data (called noise) should be ignored when analyzing the cart's motion.

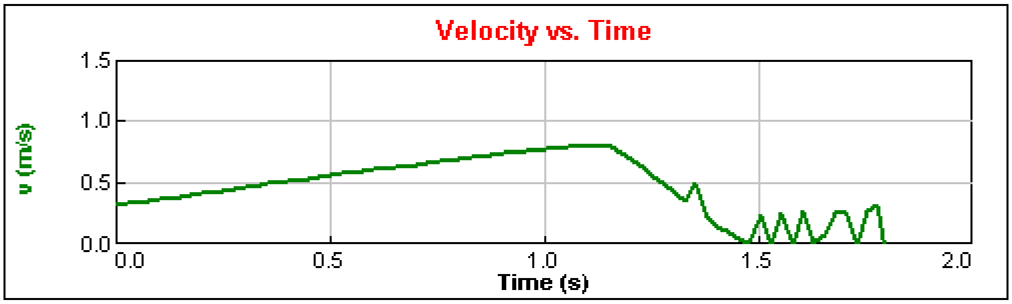


Figure TG 8.6

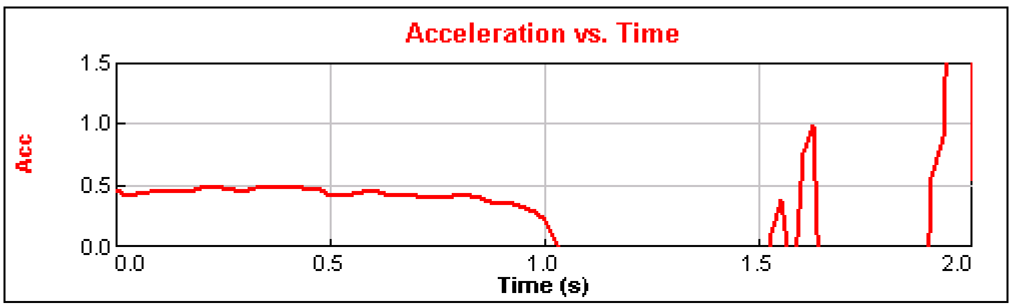


Figure TG 8.7

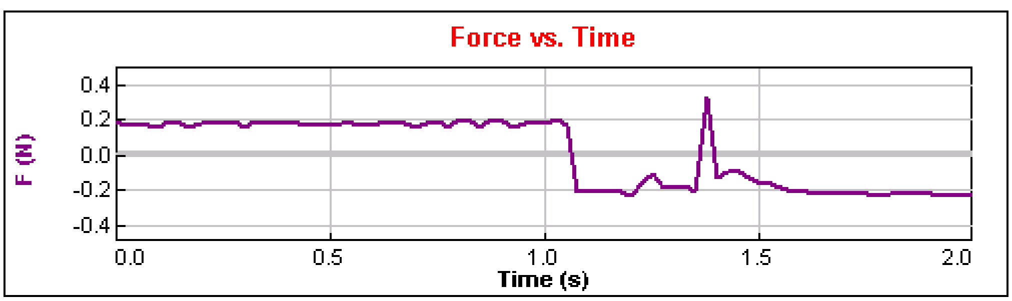


Figure TG 8.8

The following CBL graphs in Figures TG 8.9 and 8.10 show the relationship between force and acceleration and mass and acceleration:

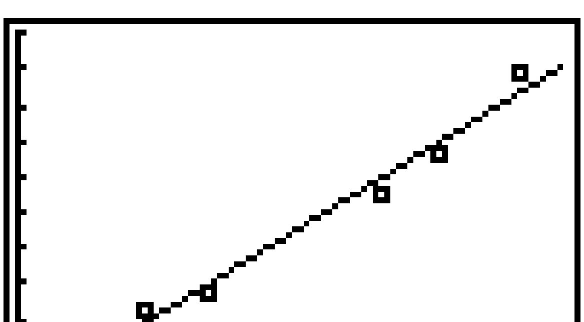
Force Vs Acceleration

Mass Vs Acceleration

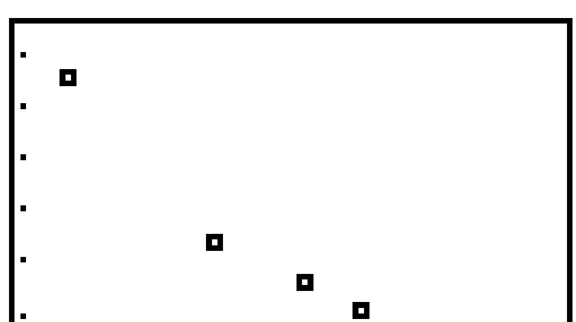
Acceleration (m/sec^2)

Acceleration (m/sec^2)

Force (N)



Mass (kg)



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The following data were collected using a stopwatch, meter stick and spring scale.

Cart Mass (kg)	Falling Mass (kg)	Accelerating Force (N)	Acceleration (m/s^2)
.90	.05	.20	.30
.90	.10	.25	.45
.90	.15	.50	.86
.90	.20	.60	1.0
.90	.25	.80	1.2
.90	.15	.50	.86
1.4	.15	.50	.57
1.7	.15	.50	.51
1.9	.15	.50	.45
2.4	.15	.50	.40

Graphs showing the relationships between force, mass, and acceleration are similar to those shown previously.

Developing and Using Scientific Ideas

1. Graph your results. Describe the appearance of each graph
   Ans. Acceleration increases as the force increases when the mass is constant. Acceleration decreases as the mass of the cart increases if the force remains constant.
2. What relationships exist between force and acceleration? Mass and acceleration?
   Ans. Force and acceleration are directly proportional to one another. Mass and acceleration are inversely proportional to one another.

Extending the Activity

Consider a cart on a horizontal surface as shown in Figure 8.1. The cart is propelled by the falling mass. Construct a free-body diagram for both the falling mass and the accelerating cart. Use the diagram with equations to calculate the acceleration of the cart and the mass. Keep in mind that the falling mass and the cart are connected, which means both objects have the same acceleration. Does the calculated acceleration agree with the experimental value? Show all work.

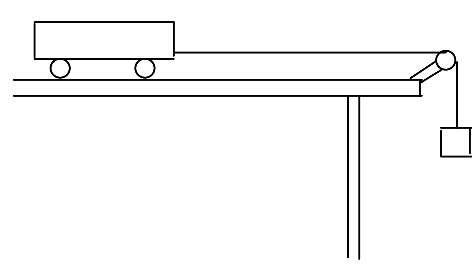
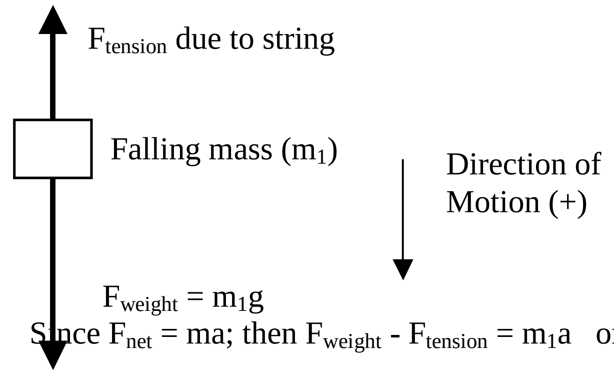


Figure 1.8.1

Example/Answer

For the falling mass:



Since F_{net} = ma; then $F_{weight} - F_{tension} = m_1a$ or $m_1g - F_{tension} = m_1a$

Figure TG 8.11

For the cart:

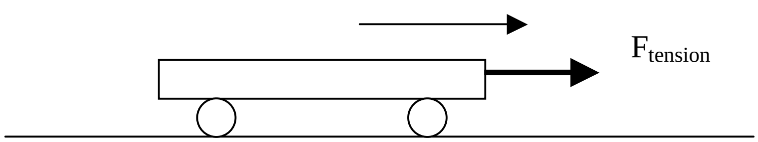


Figure TG 8.12

Since F_{net} = ma; then $F_{tension} = m_2a$

You now have two equations and two unknown variables. Substitute m_2a for $F_{tension}$ in the
first equation. The result is $m_1g - m_2a = m_1a$. This can now be solved for a.

$$a = (m_1g)/(m_1 + m_2)$$

Assume the hanging mass is 50 grams and the total mass of the cart and probe is 740 g.

The predicted acceleration would be

$$a = (.05 \text{ kg})(9.8 \text{ m/s}^2) / (.05 \text{ kg} + .740 \text{ kg}) = .62 \text{ m/s}^2$$

The measured acceleration was .47 m/s^2. The difference between these two values could be attributed to friction. The predicted acceleration was calculated with the assumption that friction could be ignored. Although low friction carts were used, friction cannot be completely eliminated.

If friction is not ignored, the net force on the cart becomes $F_{tension} + F_{friction} = m_2a$ where the force due to friction is (-) since it opposes the motion of the cart.

Adding the two equations, you would have get $m_1g - F_{friction} = m_2a + m_1a$ which then can be solved for a. The result is:

$$a = (m_1g - F_{friction})/(m_1 + m_2).$$

With friction included, the predicted acceleration would be less that what was predicted previously. Notice that if friction could be ignored, the equation is the same as it was
before.

Activity Teaching Notes

APPLICATION: WHO HAS THE PULL AROUND HERE?

Lab setup	<u>easy</u>		moderate		difficult	
Calculations	easy		<u>moderate</u>		difficult	
Reliability	excellent		good		<u>fair</u>	
Interest	<u>excellent</u>		good		fair	
Lab time	-1 class		1 class		<u>+1 class</u>	
Process Skill	<u>A</u>	B	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
Reasoning	1	2	<u>3</u>	<u>4</u>	<u>5</u>	

Engaging Students With Phenomena

<u>Materials</u>

Low friction dynamics carts, three 20 N spring balances, meter stick, two stopwatches

<u>Teaching Strategies</u>

1. This activity or Who Pushed That Speeding Car? (or both) may be utilized as the application activity.
2. The data collection takes one class period. Another period is needed for calculations and discussion.
3. Ask students how motion will change if the force is increased to 80 N and the cart is allowed to coast to a stop. Students should recognize that friction is a force that opposes motion and is considered a negative number if the velocity direction is positive.
4. Station spotters should be placed at the 10 m line to reduce the possibilities of falls. Insist that the students maintain a constant force on the spring balances and resist temptations to pull harder at the starting line or give that extra push at the 10 m line.
5. If inline skates are used force increases need to be smaller and the 10 m line can be moved to 5 m.

<u>Sample Data/Calculations</u>

Procedure answers:

For a constant applied force ($Force_{applied}$) of 20.0 N

Pushing on Cart

1. Mass of student and cart = 67.0 kg
2. Time for acceleration ($t_{acceleration}$) = 9.89 s
3. Average velocity (v_{ave}) = +10 m / 9.89 s = +1.01 m/s
4. Initial velocity ($v_{initial}$) = 0 m/s
5. Final velocity (v_{final}) = (2)(v_{ave}) = +2.02 m/s
   $v_{ave} = (v_{initial}+v_{final})/2$ and $v_{initial} = 0$ so $v_{final} = 2v_{ave}$
6. Acceleration (a) = (v_{final} - v_{inital})/ $t_{acceleration}$ = (+2.02 m/s - 0)/(9.89 s) = +0.204m/s^2
7. Force$_{net\ (or\ accelerating)}$ = ma = (67.0 kg)(+0.204 m/s^2) = +13.7 N

Cart Coasting

1. Coasting time ($t_{coasting}$) = 20.5 s
2. Initial velocity ($v_{initial}$)= +2.02 m/s
3. Final velocity (v_{final}) = 0
4. Acceleration (a) = (v_{final} - v_{inital})/ $t_{coasting}$ = (0 - +2.02 m/s)/(20.5 s) = -.0985 m/s^2
5. Force$_{friction}$ = (67.0 kg)(-.0985 m/s^2) = -6.60 N

Developing and Using Scientific Ideas

1. What is the relationship between frictional force, accelerating force and the measured force on the spring for each trial?
   Ans. Measured force on the scale is approximately equal to the sum of the frictional force and the accelerating force (net force) or the accelerating force (net force) equals measured force on scales (applied force)minus frictional force.
2. Does it appear that frictional forces act during the first 10 m? Explain.
   Ans. Friction does act during the first 10 m because the product of mass and acceleration is only 13.7 N, not the 20 N as recorded on the spring balance.
3. Derive an equation that will predict acceleration if mass, accelerating force and frictional force are all known.
   Ans. Acceleration equals the accelerating force (net force) divided by the mass only if frictional forces are not considered part of the accelerating force. Considering friction, the equation becomes: $F_{net} = F_{applied} + F_{friction}$ so $a = F_{net}/m = (F_{applied} + F_{friction})/m$ Note that the value for friction is in the opposite direction to the applied force (scale reading) and will be negative. F_{net} is the vector sum of all forces on the skater.
4. If an average net force of 50 N delivered by a bicyclist produces an acceleration of 1.5 m/s^2, what acceleration would you predict for the same cyclist on the same bicycle if she applied a net force of 75 N?
   Ans. Since acceleration is directly related or proportional to the net force on the object, one could write $a_1/a_2 = F_1/F_2$. Then (1.5 m/s^2)/(a_2) = (50 N)/(75 N). And a_2 = (3/2)(1.5 m/s^2) or a_2 = 2.25 m/s^2

Extending the Activity

Observe various types of motion outside of class and return with descriptions of the events in terms of forces, velocities, changes in velocity, acceleration, and mass.

Example/Answer Suggest that they may also look at cases when the force is not along the same line with the velocity. Some examples might be collisions of cars at intersections, a football player gets pushed out of bounds while running down field, the motion of a baseball in flight toward center field, etc.

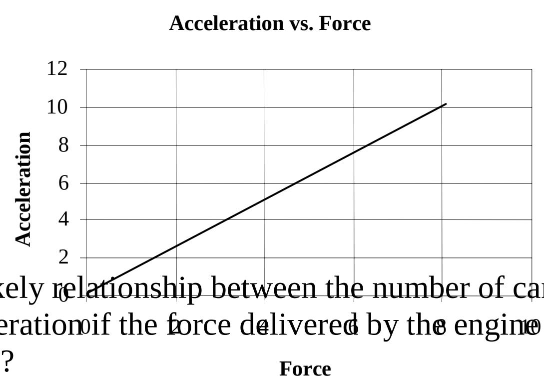
UNIT I: CONCEPTUAL PRACTICE – NEWTON'S 2ND LAW
Answer Key

1. Galaxy weight loss had a great off – lose 1/6 of your weight in two days. All you need do is live on the moon where gravity in 1/6 that of the earths. What is wrong with this idea?
   Ans. Although it true that you will weigh less on the moon than on earth, you would still have the same mass as on earth because your mass never changes. The acceleration of gravity as changed, not your mass. You, however, may expand in size because of the lower gravity. As a result, by going to the moon you may look like you have gained weight even though you haven't.

2. If an object is not accelerating, can you conclude that no forces are acting on it? Explain.
   Ans. No you cannot. Like a car moving at a constant velocity it has frictional forces and the engine force. There is no place in the universe where a force would not be acting on you because gravity will always be pulling on you.

3. If we say that one quantity is proportional to another quantity does this also mean they equal to each other. Explain using mass and weight in you example.
   Ans. Mass and weight are proportional to each other but they are not equal. Weight has a multiplier (a constant – the acceleration of gravity) on it so it's always larger.

4. With your knowledge of Newton's 2nd law sketch graphs for the following scenarios:
   a. John is comparing the force on his bicycle pedal with acceleration while his mass remains constant in Figure TG 8.13.



   b. What is the likely relationship between the number of cars and mass of a train and its acceleration if the force delivered by the engine remains constant in Figure TG 8.14?

Figure TG 8.13

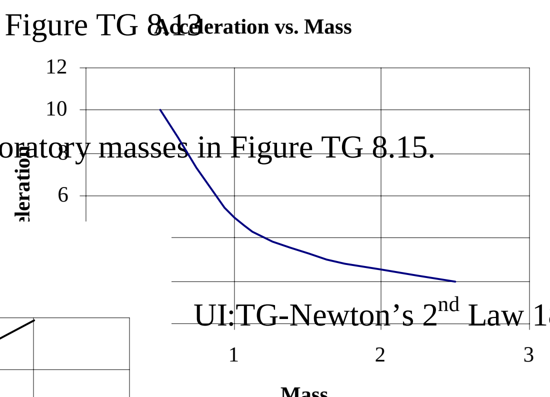
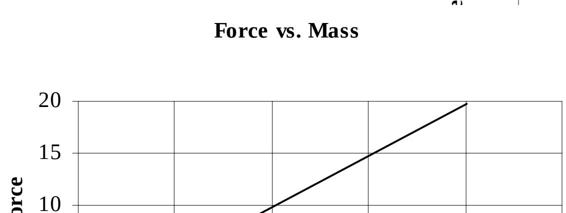


Figure TG 8.14

c. Heather compares the weights of laboratory masses in Figure TG 8.15.



Activity Teaching Notes

APPLICATION: WHO PUSHED THAT SPEEDING CAR

Lab setup	<u>easy</u>		moderate		difficult	
Calculations	easy		<u>moderate</u>		difficult	
Reliability	excellent		good		<u>fair</u>	
Interest	<u>excellent</u>		good		fair	
Lab time	-1 class		1 class		<u>+1 class</u>	
Process Skill	<u>A</u>	B	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
Reasoning	1	2	<u>3</u>	<u>4</u>	<u>5</u>	

<u>Materials</u>

Car, pickup truck or school van with operating horn and speedometer, two stopwatches, a level, smooth roadway or parking lot approximately one city block long

<u>Teaching Strategies</u>

1. This activity is designed to have the students relate the concepts of net force, applied force and friction to the motion of a car, perhaps the most common symbol of our prosperity. Students are confronted to associate the concept of net force to the measured acceleration of any object, including the car.
2. This activity is an alternative to Who Has The Pull Around Here? for the application activity. Because of students confusion with the concept of net force to the measured acceleration the instructor might consider doing both activities to increase students comprehension of the concept.
3. Indicate to the students that they will be pushing a car on a level surface and that they are to determine the average pushing force per student associated with the acquired acceleration. Give the students some time to individually think about a plan that would allow them to find this average applied force per student. Consider handing out the student activity a day in advance and having the students write out their plans as homework. After they have had time to think about a plausible procedure, divide the students into working groups and then have them discuss their individual plan and then decide on a group plan to solve the problem. Student groups could share their plan with the whole class, so that any nonproductive plans can be modified, based on your discretion.
4. Before the lab search for a level area with minimum traffic like the frontage road to the school the school parking lot or service drive. If you cannot find a level road, then a road with a constant, slight incline going uphill will work

very well. The only concession will be the calculated friction forces will be larger than the level road. In this situation a half city block will work fine.

5. The weight of the car or truck is typically given on the registration papers of the vehicle. If not, the vehicle can be weighed on a grain elevator scale or roadside weight scale.
6. One workable plan could be to measure the time it takes to increase the speed of the car from zero to 10 miles/hour. The acceleration can then be calculated. Knowing the mass of the vehicle now allows students to calculate the net force. Allow the students to ponder which force they have now calculated. They should recognize that a net force causes any calculated value of acceleration. The applied force is then the net force plus the force of friction on the car. If no clues are given, in terms of calculating force of friction, students may have some difficulty identifying the force of friction until you ask them about what causes the car to slow down and come to a stop.
7. Be sure to use the definition of "net" as the sum of all the components. Then $F_{net} = F_{applied} + F_{friction}$. Point out that the signs (+) or (-) are extremely important to the value of the forces. If the direction of the applied force is defined as (+), then the force of friction should be assigned (-) since it opposes motion. When the above equation is solved for $F_{applied}$ then the relationship becomes $F_{applied} = F_{net} - F_{friction}$.
   The applied force will be larger than the net force since a negative value for the force of friction will be used and then added to the net force.
8. In the second trial, load the car with additional passengers and instruct the students to attempt to push with the same constant force as in the previous trial. The purpose of this part is to show the effect of added mass and to compare frictional forces. In order to achieve good results it is crucial that the students push with equal force when the car is empty and when the car is loaded.
9. Draw attention to the accelerating force (net force) for the empty and loaded car, the frictional forces, and applied forces. This is an excellent example of the larger magnitude of force needed to accelerate a car when compared to the magnitude of the force needed to maintain the car at a constant velocity.

<u>Sample Data/Calculations</u>

Procedure answers:

1. In this activity you, with the help of other students, will physically push and accelerate a car on a level area. You are expected to determine the force that is required to produce the constant acceleration of the car. From the definition of net force,

$$F_{net} = F_{applied} + F_{friction}$$

   By pushing on the car, you can cause the car to accelerate and perhaps make measurements to calculate this acceleration. By knowing this acceleration and the mass of the car you can determine force. Which of the above forces would you be calculating? Explain your reasoning.

   <u>Ans</u>. F_{net} - The sum of all forces is the cause for any acceleration.

2. When you stop pushing on the car it will coast, slow down and come to a stop. Which force is causing this negative acceleration? How could you determine the value of this force?
   Ans. $F_{friction}$ – See data below.
3. How can you find the value of the third force in the above equation?
   Ans. $F_{applied} = F_{net} – (- F_{friction}) = F_{net} + F_{friction}$
5. What was the average F_{net} per person pushing the car?
   Ans. Total net force divided by the number of pushers.
6. What was the average $F_{applied}$ per person pushing the car?
   Ans. $F_{applied}$ ($F_{net} + F_{friction}$) divided by the number of pushers.
7. Does the value for the average $F_{applied}$ per person pushing the car seem reasonable? You might push on a bathroom scale on an appropriate wall space with the calculated force. Does it still seem reasonable?
   Ans. This force should be reasonable.
9. Predict how the accelerations will compare. What was the basis for your predictions?
   Ans. Acceleration should be less since mass is increased.
10. Predict how the forces will compare. What was the basis for your predictions?
   Ans. It should be the same if all pushers push with their greatest force in both trials. Generally students push harder when the car is loaded.
11. How did the accelerations compare? Discuss any differences from your predictions.
   Ans. Acceleration should be less for the loaded car than the unloaded car.

1. Weight of car & driver = 2050 lbs
2. Weight of passengers = 800 lbs
3. Total weight = 2850 lbs
4. Initial velocity ($v_{initial}$) = 0
5. Final velocity (v_{final}) = +5.00 mi/hr
6. Time for acceleration ($t_{acceleration}$) = 4.60 s
7. Time for deceleration ($t_{deceleration}$) = 19.2 s
8. Number of students pushing = 6
9. Total mass = (2850 lbs)(1 kg)/(2.205 lbs) = 1293 kg = 1290 kg
10. v_{final} = (+5 mi/hr)(.447 m/s)/(1 mi/hr) = +2.24 m/s
11. Acceleration (a_{push}) = (v_{final} - $v_{initial}$)/$t_{acceleration}$ = (+2.24 m/s)/(4.6 s) = +.487 m/s^2
12. $Force_{net} = ma_{push}$ = (1290 kg)(+.487 m/s^2) = +628 N or (628 N)(0.209 lb/N) = +141 lbs
13. Deceleration (a_{coast}) = (v_{final} - $v_{initial}$)/$t_{deceleration}$ = (0 - +2.24 m/s)/ 19.2 s = -.117 m/s^2

14. $Force_{friction} = ma_{coast}$ = (1290 kg)(-.117 m/s^2) = -151 N = (-151 N)(0.209 lb/N) = -34 lbs
15. $F_{applied} = F_{net} - F_{friction}$.
    $F_{applied}$ = +628 N – (-151 N) = +779 N or +175 lbs
16. Net Force /person = (+779 N)/(6) = +103 N = +29.2 lbs

Developing and Using Scientific Ideas

1. Compare and interpret the magnitude of the applied force with the net force.
   Ans. If there is friction in a system, then the applied force will always be greater than the net force (accelerating force). In fact the applied force equals the net force plus friction.
2. Under what conditions is the following statement true? "A constant force produces a constant velocity."
   Ans. This will be true only when the applied force is equal to the force of friction.
3. If an average net force of 50 N delivered by a bicyclist produces an acceleration of 1.5 m/s^2, what acceleration would you predict for the same cyclist on the same bicycle if she applied a net force of 75 N?
   Ans. Since acceleration is directly related or proportional to the net force on the object, one could write $a_1/a_2 = F_1/F_2$. Then (1.5 m/s^2)/(a_2) = (50 N)/(75 N). And a_2 = (3/2)(1.5 m/s^2) or a_2 = 2.25 m/s^2
4. Sally, with her roller blades, has a mass of 50 kg. If there is a frictional force on Sally of 15 N, what applied force must Sally exert to provide her with an acceleration of 0.60 m/s^2?
   Ans. In order to accelerate at 0.60 m/s^2, the required net force is
   F_{net} = ma = (50 kg)(2.25 m/s^2) = 112 N
   $F_{applied} = F_{net} - F_{friction}$ = 112 N – (-15 N) = 127 N

Extending the Activity

Observe various types of motion outside of class and return with descriptions of the events in terms of forces, velocities, and changes in velocity, acceleration, and mass.

Example/Answer Suggest that they may also look at cases when the force is not along the same line with the velocity. Some examples might be collisions of cars at intersections, a football player gets pushed out of bounds while running down field, the motion of a baseball in flight toward center field, etc.

Learning Cycle Teacher Notes
WRAPPING IT UP

Building a Case and Promoting Student Reflection

Have students think of various physical events including sporting events and have them identify the forces acting on the ball.

In volleyball, describe the force and motion of the ball

a) When the server makes contact with the ball,
b) When the ball is lofted back over the net, and
c) When the ball is hit and returned by a player.

In canoeing, describe the force and motion of the paddle and water on the boat.

Select various aspects of a football game and describe it in terms of force and motion.

It should be recognized that anytime there is a non-zero net force on an object, there is a change in velocity and an acceleration of that object. It should also be noted that the direction of the velocity of the object is independent from the direction of the change in velocity. The direction of the force is the same direction as the acceleration of the object.

Select some phenomena where the velocity of an object is constant and ask students to describe the forces and acceleration related to the object. You may select such events as riding a bike at constant velocity, car traveling at constant velocity, a book lying on a desk, etc.

Ask students to describe what experiences helped them to connect acceleration with force and why some people have the understanding that force is directly related to velocity instead of acceleration. Have the students give some additional examples from their experiences that show the relationship between acceleration, force and mass.

Extending Student Knowledge and Promoting Student Inquiry

Using sources of technological data on cars (e.g. Internet, <u>Car and Driver</u> magazine, etc.), ask students to determine if there is a correlation between the horsepower to weight ratio of a car and its "0 to 60" time. Ask them to predict what they think the relationship will be. Have them do their search and check their prediction. Which cars have a large horsepower to weight ratio? What safety concerns might exist for such cars? Sports cars in general will have large horsepower to weight ratios. This will make their "0 to 60 mph" times have little meaning since they have a great ability to accelerate.