Active Physics and NGSS
Arthur Eisenkraft
What are our goals as physics teachers?

- Higher student achievement
- Engaged students
- Appreciation (love?) of physics in the world
- Critical thinking

- Five years later: what is physics?
How do we reach these goals?

• Good, strong content
• Labs
• Demonstrations
• Connections of physics to students’ lives
  – Physics of sports
  – Physics in music
  – Physics and technology
• And we do our best in each of these domains
  – The question is, “How can our text support us?”
Active Physics

• Your grade book will look the same
• All content will be covered (or “uncovered”)
• Students will be actively involved
• Students will have higher achievement
• AND your text/program will support your efforts
  – Inquiry, relevance, interest, labs in context
  – Student creativity and 21st century skills
  – to merge the three dimensions of the Framework and NGSS
    • Scientific and Engineering Practices
    • Crosscutting Concepts
    • Disciplinary Core Ideas
Active Physics

“This is the best science course ever.”
What is a Sport?

• Attributes of a sport
Is Science Everywhere

• Choose a sport.
• Describe where we find science in the sport.
Can the science be entertaining?

- Voice overdub of your sport and science for PBS.
What do we value in Active Physics?

• How People Learn research
• Instructional models
• Inquiry
• What engages students intellectually
• Equity issues
• Problem based learning models
• National Science Education Standards
  – Framework and NGSS
• The teacher as a primary resource
• IT’S ALL IN THERE – inquiry. content, math, assessment, the 7E instructional model
A Framework for K-12 Science Education – National Academy of Sciences

The Three Dimensions of the Framework

1. Scientific and Engineering Practices

2. Crosscutting Concepts

3. Disciplinary Core Ideas
Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematic and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information
Crosscutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quality
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change
A core idea for K-12 science instruction is a scientific idea that:

• Has **broad importance** across multiple science or engineering disciplines or is a **key organizing concept** of a single discipline

• Provides a **key tool** for understanding or investigating more complex ideas and solving problems

• Relates to the **interests and life experiences of students** or can be connected to **societal or personal concerns** that require scientific or technical knowledge

• Is **teachable and learnable** over multiple grades at increasing levels of depth and sophistication
Disciplinary Core Ideas

Physical Sciences

PS 1: Matter and its interactions
PS 2: Motion and stability – Forces and interactions
PS 3: Energy
PS 4: Waves and their applications in technologies for information transfer
Disciplinary Core Ideas

**Life Sciences**

LS 1: From molecules to organisms: Structures and processes
LS 2: Ecosystems: Interactions, energy, and dynamics
LS 3: Heredity – Inheritance and variation of traits
LS 4: Biological evolution – Unity and diversity
Disciplinary Core Ideas

Earth and Space Sciences
  ESS 1: Earth’s place in the universe
  ESS 2: Earth’s systems
  ESS 3: Earth and human activity

Engineering, Technology, and the Applications of Science
  ETS 1: Engineering design
  ETS 2: Links among engineering, technology, science and society
How do they do it?

• Challenge on 1\textsuperscript{st} day
• Rubric on the 1\textsuperscript{st} day
Physics in Action

Scenario
Have you ever imagined being a TV sports analyst and having millions of people listen to you describe a football or baseball game? Perhaps you would like to provide the commentary for a sport in the Summer Olympics or an analysis of a figure-skating performance on television?

What qualifications are needed to have a career in sportscasting? Should you major in communication in college or be a retired professional athlete to do this job? Could a physics course be a key to becoming a sports analyst? Perhaps a student with physics knowledge can bring to the TV viewer a different perspective that might provide a new outlook on sporting events.

Your Challenge
A public broadcasting service has decided that it wants to televise a variety of sporting events and wants these programs to be educational as well as entertaining. To test out this idea, you are to provide the voice-over narration for a sports video. The narration will need to explain the physics of the action appearing on the screen. You will do a "science commentary" on a short (two to three minutes) sports video or a series of sports videos that add up to two to three minutes.

The public broadcasting service wants people to understand that the laws of physics deal not only with the things that happen in the laboratory, but also with everyday events in the real world. Your task is not to give a play-by-play description of the sporting event or give the rules of the game, but rather to go a step beyond.
You are to educate the audience by describing to them the rules of nature that govern the event. This approach will give the viewer (and you) a different perspective on both sports and physics.

You can think of this narration as a tryout for a broadcasting job. In this tryout, a traditional sports broadcaster will give the play-by-play and then turn the microphone over to you to give the physics of sports overview. You can provide the narration live, dub it onto the video soundtrack, or record an audio version. You will also need to submit a written script of the narration.

Criteria for Success

What criteria should be used to evaluate a voice-over narration or script of a sporting event? Since the intention is to provide an interesting analysis of the physics of sports, the voice-over should include the use of physics terms and physics principles. However, remember that physics principles are not enough. Your voice-over narration will also need to be entertaining.

Work with your class to develop a set of criteria for a successful voice-over narration. When you have decided what is required, compare your list with the list on the following page.
The Grading Rubric

- List criteria
  - Entertaining
  - Use a set amount of physics terminology
  - Follow instructions – 2 -3 minutes
  - Delivery
  - Creativity
**Standard for Excellence**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The use of physics terms and principles in the narration</td>
<td>50</td>
</tr>
<tr>
<td>- number of physics principles used</td>
<td></td>
</tr>
<tr>
<td>- physics concepts from the chapter integrated in the appropriate places</td>
<td></td>
</tr>
<tr>
<td>- physics terminology and equations used where appropriate</td>
<td></td>
</tr>
<tr>
<td>- correct estimates of the magnitude of physical quantities used</td>
<td></td>
</tr>
<tr>
<td>- additional research, beyond the basic concepts presented in the chapter</td>
<td></td>
</tr>
<tr>
<td>2. The quality of the oral narration</td>
<td>25</td>
</tr>
<tr>
<td>- knowledge of the sport</td>
<td></td>
</tr>
<tr>
<td>- entertainment value with respect to humor, excitement, and/or drama</td>
<td></td>
</tr>
<tr>
<td>- ease of following and understanding</td>
<td></td>
</tr>
<tr>
<td>- appropriate amount of narration</td>
<td></td>
</tr>
<tr>
<td>- duration of narration between two and three minutes</td>
<td></td>
</tr>
<tr>
<td>3. The quality of the written script of the narration</td>
<td>20</td>
</tr>
<tr>
<td>- use of correct science vocabulary</td>
<td></td>
</tr>
<tr>
<td>- consistent sentence structure</td>
<td></td>
</tr>
<tr>
<td>- correct spelling, punctuation, and grammar</td>
<td></td>
</tr>
<tr>
<td>- appropriate use of science symbols for units of measurement</td>
<td></td>
</tr>
<tr>
<td>4. Challenge completed on time</td>
<td>5</td>
</tr>
</tbody>
</table>

**Engineering Design Cycle**

The *Chapter Challenge* is to create an educational and entertaining sports voice-over. Now that you have read all of the criteria, you will use a simplified *Engineering Design Cycle* to help your group complete this design challenge. Clearly defining the *Goal* is the first step in the *Engineering Design Cycle*.

Although many people may be in the broadcast booth, a voice-over narration becomes the product of one person—the commentator or the scriptwriter. Although you will be working in cooperative groups during the chapter, each person will be responsible for a part of the voice-over or script for a sporting event. As a team you may share different aspects of the job, but the output of work per person should be the same.
Engineering Design

• 1\textsuperscript{st} exposure
  – Goal
  – Input
  – Process
  – Outputs
  – Feedback
Section 1  Newton's First Law: A Running Start

What Do You See?

Learning Outcomes
In this section you will:
- Describe Galileo's law of inertia.
- Apply Newton's first law of motion.
- Recognize inertial mass as a physical property of matter.
- Provide examples demonstrating that speed is always relative to some other object.
- Explain that the speed of an object depends on the reference frame from which it is being observed.

What Do You Think?
Every sport includes moving objects or people or both. That is what makes sports entertaining.
- How do figure skaters keep moving across the ice at high speeds for long times while seeming to expend no effort?
- Why does a soccer ball continue to roll across the field after it has been kicked?

Record your ideas about these questions in your Active Physics log. Be prepared to discuss your responses with your group and the class.

Investigate
In this Investigate, you will use a track and a ball to explore the question, “When a ball is released to roll down a track and up the opposite side of the track, how does the vertical height that the ball reaches on the opposite side of the track relate to the vertical height from which the ball is released?”

1. Make a track that has the same slope on both sides, as shown in the diagram on the next page. Your teacher will suggest how high the ends of the track sections should be.
The slope should be quite steep. For a 1-m track, the ends should be elevated 30 cm.

Mark your prediction on the recovered-height section of the track and explain your thoughts about this prediction in your log.

3. Now try it for real. Mark on the track where the ball reaches its highest point.
   a) How close was your prediction to the actual outcome? Why do you think your prediction was “close” or “way off”?
   b) Measure the vertical height where the ball stopped. Write a sentence that fully describes the movement of the ball in terms of its starting and recovered vertical heights.

4. Repeat Steps 2 and 3 when the recovered-height section of the track has an even less steep slope.
   a) First record your prediction.
   b) Compare your prediction with the actual outcome.

5. Imagine what would happen if you changed the right-hand section of the track so that it would be horizontal (zero slope), as shown below.

   a) No matter how far along the horizontal track the ball rolls, would it ever recover its starting height?
   b) How far do you think the ball would roll?
   c) What would keep the ball rolling on a horizontal track, like the one shown in the diagram above?
**NEWTON'S FIRST LAW OF MOTION**

**Galileo's Law of Inertia**

In the investigation, you observed, measured, and compared the release height of a ball on one side of the track to the recovered height on the other side of the track. You found that they were not exactly equal, but they were close to being equal.

Galileo Galilei (1564–1642) was an Italian physicist, mathematician, astronomer, and philosopher. Galileo is sometimes called the father of modern science. He introduced experimental science to the world. Galileo performed an experiment similar to the one you just completed. He observed that a ball that rolled down one ramp seemed to seek the same height when it rolled up another ramp.

Galileo also did a "thought experiment" in which he imagined a ball made of extremely hard material set into motion on a horizontal, smooth surface, similar to the final track in your investigation. He concluded that the ball would continue its motion on the horizontal surface with constant speed along a straight line "to the horizon" (forever).

From this, and from his observation that an object at rest remains at rest unless something causes it to move, Galileo formed the law of inertia: Inertia is the natural tendency of an object to remain at rest or to remain moving with constant speed in a straight line.

Galileo changed the way in which people viewed motion. Early on, people thought that all moving objects would stop. After Galileo, people thought about how moving objects might continue to move forever unless a force, a push or a pull, stopped them. That idea is not easy to understand. Any time you have pushed an object to move it, you have seen it stop. Nobody ever observes an object moving forever. Even when the surface is very, very smooth, the sliding or rolling objects eventually stop. However, Galileo realized that objects do not stop "on their own" but stop because there is a frictional force working that you cannot see and that is the force that stops the object.

**Newton's First Law of Motion**

Like Galileo, Isaac Newton was a great thinker. He was born in England in 1642, the year of Galileo's death. Newton's achievements brought him a great deal of recognition. Poems were written that honored Newton. Science, government, and philosophy all changed because of Newton's insights about the physics of the world.

Newton used Galileo's law of inertia as the basis for developing his (Newton's) first law of motion: In the absence of an unbalanced force, an object at rest remains at rest, and an object already in motion remains in motion with constant speed in a straight-line path.
Newton also explained that an object's mass is a measure of its inertia, or tendency to resist a change in motion. Given different masses moving at the same speed, the one with the greatest mass has the greatest inertia. The tendency of an object at rest to remain at rest appears to be common sense and few people think otherwise. The tendency of an object that is moving to continue moving (forever) unless acted upon by an unbalanced force is very different from what common sense would tell you. The evidence from the investigation you conducted should help to convince you that objects in motion stay in motion unless a force acts upon them. You will have to remind yourself of this many, many times since most people's intuition is that moving objects do not remain in motion, but tend to stop.

Here is an example of how Newton's first law of motion works: An empty grocery cart has a mass of 10 kg and a cart full of groceries has a mass of 30 kg. The cart with the greater mass has greater inertia.

To test your understanding of Newton's first law of motion, decide which of the following carts has the greatest inertia:

- a) 1 kg moving at 5 m/s
- b) 2 kg moving at 3 m/s
- c) 3 kg moving at 1 m/s
- d) 4 kg moving at 1 m/s

The correct response is d) because the 4-kg cart has the most inertia. The speed is not important in determining inertia.

**SI System: The Kilogram**

In this section, you read that inertia is related to mass. The kilogram is the base unit of mass. This particular base unit is a bit unusual. It is the only base unit that has a prefix. The prefix, kilo (k) placed in front of gram (g) stands for one thousand (10^3). The kilogram is equal to one thousand grams (1 kg = 1000 g).

It might be useful for you to relate the SI units that you will be using in Active Physics to the units that you use every day. A two-pound brick has a mass of about one kilogram.

In one of the most important science books of all time, *Principia*, Isaac Newton wrote his first law of motion. It is interesting both historically and in terms of understanding physics to read Newton's first law in his own words:
Part A: Calculating Velocity for Different Frames of References

You read that when describing speed or velocity it is important to give a frame of reference. You can calculate the velocity relative to a particular frame of reference mathematically using positive and negative numbers.

Strategy: Before determining a velocity, it is important to check the frame of reference. The rock's velocity with respect to the boat is different from the velocity with respect to the shore. The direction the rock is thrown also affects the final answer. Let the direction east be a positive value. Use a negative sign to indicate the direction west.

Given:
\[ v_b \text{ (velocity of the boat)} = 8.0 \text{ m/s east} \]
\[ v_r \text{ (velocity of the rock)} = 6.0 \text{ m/s} \]
(directon varies)

Solution:

a) With respect to the boat, the rock's velocity is 0 m/s. The rock is moving at the same speed as the boat, but you would not notice this velocity if you were in the boat's frame of reference.

b) With respect to the shore, the rock's velocity is 8.0 m/s east. The rock is on the boat, which is traveling at 8.0 m/s east. Relative to the shore, the boat and everything on it act as a single unit traveling at the same velocity.

c) The relative velocity is the sum of the velocity values. Since each is directed east, the value of each velocity is positive.
\[
\begin{align*}
v &= v_b + v_r \\
v &= 8.0 \text{ m/s east} + 6.0 \text{ m/s east} \\
v &= 8.0 \text{ m/s} + 6.0 \text{ m/s} \\
v &= 14.0 \text{ m/s east}
\end{align*}
\]
To answer these questions, look at a diagram of the setup above. You can use the right-hand slope and the height of the track to form a right-angled triangle. The hypotenuse of the right-angled triangle is the distance up the ramp the ball rolls ($d$) and the opposite side is the height of the ball when it stops rolling ($h$). If you know the angle and you know the height at which the ball was released, you can find the distance along the ramp using a scale diagram. Try this for the three angles given.

You can also use trigonometry to solve this problem by using the value of the sine of the angle of the ramp. The sine of the angle of the right-hand ramp is equal to $h/d$ (opposite/hypotenuse).

The value of the sine of the angle can be found using the “sin” button on your calculator (make sure your calculator is in “degree mode”). Then you may use that value in $h/d$ and solve for $d$.

2. Use a calculator to check the accuracy of the values of $d$ obtained using scale diagrams.

3. Use a calculator to find how far up the right-hand slope (measured along the slope) the ball will roll if the angle of the right-hand slope is:
   a) $10^\circ$
   b) $1^\circ$
   c) $0.1^\circ$
   d) $0.01^\circ$

4. How in a “perfect frictionless world” would the calculations you did above help you explain Newton’s first law of motion?

What Do You Think Now?

At the beginning of this section, you were asked the following:

- How do figure skaters keep moving across the ice at high speeds for long times while seeming to expend no effort?

- Why does a soccer ball continue to roll across the field after it has been kicked?

The ice skater effortlessly gliding across the ice at high speed and the soccer ball moving across the field are like the ball rolling along the horizontal portion of your track. What determines their horizontal speed and why do they keep moving without someone doing anything to keep them moving?
Physics

Essential Questions

What does it mean?
Even the greatest thinkers may not know why objects have inertia, but your investigations show that they do have inertia. Observation is the basis for all physical concepts. What does it mean when you say that an object with mass has inertia whether it is moving or stationary?

How do you know?
How do you know that the rolling ball you examined in your experiment would keep rolling forever unless some force acted on it? Why is the steady, straight-line motion of an object not "explained" but is simply stated as the way the world works in Newton's first law of motion?

Why do you believe?

<table>
<thead>
<tr>
<th>Connects with Other Physics Content</th>
<th>Fits with Big Ideas in Science</th>
<th>Meets Physics Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force and motion</td>
<td>Change and constancy</td>
<td>* Experimental evidence is consistent with models and theories</td>
</tr>
</tbody>
</table>

* In physics, ideal situations are often used to illustrate concepts. Nobody has ever arranged for a rolling ball to roll forever, so why do you believe that it would? Provide examples in which an object might keep moving in a straight line with a constant speed even longer than a rolling ball might.

Why should you care?
In your sports voice-over, you will want to use Newton's first law. Give an example in a sport where an object in motion remains in motion, or where an object at rest remains at rest.

Reflecting on the Section and the Challenge

"Immovable objects," such as defensive linemen in football, illustrate the tendency of highly massive objects to remain at rest and can be observed in many sports. Running starts can also be observed in many sports. Many observers may not realize the important role that inertia plays in preserving the speed already established when an athlete engages in activities such as jumping, throwing, or skating from a running start. For the challenge, you should have no problem finding a great variety of video segments that illustrate Newton's first law.

The segment that you select for your challenge might illustrate:

- That "an object at rest remains at rest."
- That the more massive an object, the more difficult it is to get it to start moving or to stop moving.
• How an object will tend to stay in motion until an external force stops it.
• How relative motion depends on the speeds of the player and the ball and the reference frame in which it is measured.

**Physics to Go**

1. You push a ball to start it rolling along a "perfectly frictionless" surface.
   a) How far will the ball roll?
   b) Explain your answer for a) using Newton's first law of motion.

2. A ball is released from a vertical height of 20 cm. It rolls down a "perfectly frictionless" ramp and up a similar ramp. What vertical height on the second ramp will the ball reach before it starts to roll back down?

3. Do you think it is possible to arrange conditions in the "real world" to have an object move, unassisted, in a straight line at constant speed forever? Explain why or why not.

4. Use what you have learned in this section to describe the motion of a hockey puck between the instant the puck leaves a player's stick and the instant it hits something. (No "slap shot" allowed; the puck must remain in contact with the ice.)

5. You are riding your bike and steadily pulling your little brother in his red wagon while someone standing still watches you and your little brother go by. He has a ball, and he throws the ball forward at a velocity of 2.5 m/s relative to his body while you are pulling the wagon at a velocity of 4.5 m/s. At what speed does the person who is standing nearby see the ball go by?

6. A track and field athlete is running forward with a javelin at a velocity of 4.2 m/s. If he throws the javelin at a velocity relative to him of 10.3 m/s, what is the velocity of the javelin relative to the ground?

7. You are riding in a train. Since the train car is almost empty, you and your friend are pushing a low-friction cart back and forth between the front and rear of the car. The train is moving at a speed of 5.6 m/s. Suppose you push the cart toward each other at 2.4 m/s.
   a) What is the velocity of the cart relative to the ground when the cart is moving toward the front of the car?
   b) What is the velocity of the cart relative to the tracks when it is moving toward the rear of the car?
   c) What if you and your friend push the cart perpendicular to the aisle as the train moves forward? This is a more complicated situation. What is the cart's velocity relative to the ground?
8. While riding a horse, a competitor shoots an arrow horizontally toward a target. The speed of the arrow relative to the ground as it reaches the target is 85 m/s. If the horse was traveling at 18 m/s, at what speed did the arrow leave the bow? (Assume the horse and arrow are traveling in the same direction.)

9. A ball is released on a ramp at a vertical height of 15 cm. Calculate how far up a second ramp (measured along the slope) the ball will roll if the angle of the second ramp is:
   a) 45°  b) 20°  c) 15°  d) 5°

10. Preparing for the Chapter Challenge
   a) Provide three examples of Newton's first law in sporting events. Describe the sporting event and which object when at rest stays at rest, or when in motion stays in motion.
   b) Describe these same three examples in the manner of a sportscaster.

Inquiring Further
1. Curling and Newton's first law
   Find out about a sport called curling. It is an Olympic competition that involves some of the oldest Olympians. How can this sport be used to illustrate Newton's first law of motion?

2. Sliding into base
   Why do baseball players often slide into second base and third base, but they almost never slide into first base after hitting the ball? (Hint: The answer depends on both the rules of baseball and the laws of physics.)
Section 2

Constant Speed and Acceleration: Measuring Motion

Learning Outcomes

- Give examples of distance, time, speed, and acceleration.
- Differentiate between instantaneous speed and average speed.
- Recognize when motion is accelerated.
- Calculate average speed and acceleration.

What Do You Think?

Some major-league pitchers can throw a baseball 100 mi/h, about 45 m/s. The ball reaches home plate in less than half a second. In that time, the batter must decide whether or not to swing at the pitch. If the batter decides to swing, he then must be able to react quickly enough to the pitch. It is no surprise that so few athletes are capable of competing in the major leagues.

- In your own words, explain the meaning of 100 mi/h and 45 m/s.

Record your response in your Active Physics log. Be prepared to discuss your response with your group and the class.

Investigate

In this Investigate, you will use a measuring device called a ticker timer to explore the concepts of constant speed and acceleration.

1. A ticker timer makes a dot on a paper tape every \( \frac{1}{50} \) of a second. As you pull the tape through the ticker timer, a dot will be made on the tape every \( \frac{1}{50} \) of a second. You can use the ticker timer to determine how fast something is moving.
Section 3

Newton's Second Law: Push or Pull

What Do You See?

Learning Outcomes

In this section you will
• Identify the forces acting on an object.
• Determine when the forces on an object are either balanced or unbalanced.
• Compare amounts of acceleration semi-quantitatively.
• Apply Newton's second law of motion.
• Apply the definition of the newton as a unit of force.
• Describe weight as the force due to gravity on an object.

What Do You Think?

Venus Williams is a record holder for one of the fastest serves in the world by a female tennis player. The speed of the serve was almost 208 km/h (129 mi/h). To serve a tennis ball at that speed requires skill, timing, and force.

• What is a force?
• How will the same amount of force affect a tennis ball and a bowling ball differently?

Record your ideas about these questions in your Active Physics log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this Investigate, you will use a flexible ruler to continuously push a cart (or a can or plastic bottle) across a table, floor, or open space.

1. Hold one end of the ruler against the table. Push on the other end of the ruler with your finger. Notice that a small force produces a small bend in the ruler and that a large force produces a large bend. You have created a force meter (an instrument that you can use to measure force).
2. Use the ruler to push the cart continuously with only a slight bend in the ruler (a small force) as shown above. Make sure you do not push the cart in spurts. The push (force) must be applied as a continuous motion so the ruler keeps the same amount of bend. You will need to keep up with the cart as it moves and to keep the same amount of bend in the ruler. It may be useful to have another member of your group watch to make sure the ruler keeps the same amount of bend throughout the duration of the push. You may need to practice a few times to be able to do this.

   a) Describe the motion of the cart.

3. This time, push the cart continuously with a large amount of bend in the ruler (a large force) as shown above. Remember, you need to keep up with the cart as you continually push it to keep the large amount of bend in the ruler.

   a) Describe the motion of the cart.

4. Select an object that has a smaller mass than the cart, can, or bottle. Use the ruler to push the object with a large, steady force (a large bend in the ruler).

   a) Record a description of the object (especially its mass) and the motion of the object.

5. Now use the same large amount of force to push objects of greater and greater mass.

   a) Record the results for each object in a data table in your log.

   b) Complete the statement below that describes the relationship of the mass of an object and its acceleration and write the entire completed statement in your log: “When equal amounts of a constant force are used to push objects having different masses, the more massive object...”
6. You conducted two different experiments. You first varied the amount of force on a single object. You then used the same force to push on objects of different mass. By conducting two different experiments, you were able to analyze the effects of changing either the mass or the force.

a) If you had conducted only one experiment in which you pushed on a large object with a small force and then pushed on a small object with a large force, what conclusions would you have drawn?

7. You noticed earlier that a small bend of the ruler corresponded to a small force and a large bend to a large force.

You can now check this relationship more precisely. Carefully clamp the flexible ruler to the end of a table.

8. Place one coin on the top surface of the ruler near the outside end. Observe what happens to the ruler.

a) Record your observations.

9. Repeat by placing two, three, and four coins on the ruler.

a) What happens to the ruler each time you add a coin?

b) How many pennies represent a small force? How many pennies represent a large force?

c) What force is causing the ruler to bend?

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**Qualitative and Quantitative Observations**

An observation is information that you get through your senses. When you describe the qualities of objects, events, or processes, the observations are qualitative. If you say that something smells spicy, tastes sweet, or feels sticky, you are making qualitative observations.

Observations that are based on measurements or counting are quantitative, because they deal with quantities. The temperature of a sauce cooking on the stove is a quantitative measurement.

In this investigation, you made semi-quantitative observations. The first measurements that you made of the bend of the ruler were small and large. These are semi-quantitative observations. You then calibrated the bend and compared the bend to the number of pennies required to make the ruler bend. The number of pennies that correspond to a small force and a large force are quantitative measurements.
Section 5

The Range of Projectiles: The Shot Put

Learning Outcomes

- Measure the acceleration due to gravity.
- Calculate the speed attained by an object that has fallen freely from rest.
- Understand the relationship between the average speed of an object that has fallen freely from rest and the final speed attained by the object.
- Know how to calculate the distance traveled by an object that has fallen freely from rest.
- Use mathematical models of free fall and uniform speed to construct a physical model of the trajectory of a projectile.
- Use the motion of a real projectile to test a physical model of projectile motion.
- Use a physical model of projectile motion to infer the effects of launch speed and launch angle on the range of a projectile.

What Do You Think?

A world record in the men's shot put of 23.12 m was set by Randy Barnes of the United States in 1990. In the women's javelin throw, Olafedys Menendez of Cuba broke the world record at 71.70 m in 2005.

- Describe the trajectories of projectiles launched from the ground at various angles.
- Describe how a greater launch speed of a projectile might change the range when the launch angle is the same.

Record your ideas in your Active Physics log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this Investigate, you will measure the acceleration due to gravity. You will then use a mathematical model to construct a physical model of the trajectory of a projectile. Finally, you will use a real projectile to test the physical model.

1. Your teacher will provide you with a method of measuring the acceleration caused by Earth's gravity for objects in a condition of free fall.
Your challenge for this chapter is to create a sports voice-over for the public broadcast service that will engage viewers and introduce physics concepts. Your commentary should be two or three minutes of engaging information that will educate the viewer on the laws of nature governing the sport they are watching.

For your initial design you will need the following:

- A sport that contains physics concepts you have studied
- The physics concepts you have studied linked to the sport
- Appropriate use of physics equations and terminology
- Proper units and approximate values for the magnitude of concepts relating to the sport
- Two to three minutes of live voice-over or recorded voice-over
- A written script of the narration

You still have more to learn before you can complete the challenge but this is a good time to give the Chapter Challenge a first try. It will give you a good sense of what the challenge entails and how you and other teams are going to approach your “broadcasting job.” Your Mini-Challenge for this chapter is to develop and present a one-minute voice-over narration to explain the physics behind the sport that you will be broadcasting. At this point you have a handful of physics topics to choose from and the entire world of sports to apply them to.

Go back and quickly review the Goal you established at the start of your chapter. This Mini-Challenge offers a unique opportunity because it allows you to complete a full trial-run of the Chapter Challenge with the physics information you have learned so far. As you learn additional physics information in the remaining sections you can add that to your Mini-Challenge voice-over or you could create an entire second voice-over, even choosing a different sport if you want to.

In the Engineering Design Cycle, you are adding a critical Input by choosing the sport and the specific sports action that you will be describing. You also have the new physics knowledge you have gained from Sections 1-5 in this chapter which you should review to help you compose your sports voice-over.

Section 1: You investigated Galileo’s principle of inertia and learned about the mass of an object and how mass is related to the concept of inertia. You also read about Newton’s first law and reference frames for measuring the speed of an object.

Section 2: You measured speed by making speed vs. time graphs using a ticker timer for objects with constant speeds and objects with changing speeds. You also explored the concept of acceleration, or the rate that speed is increasing or decreasing.
The Mini-Challenge

• Halfway through the chapter
• Practice
• Feedback
• Remove some of the mystery
• Engineering/Tech Design
  – Goal, inputs, process, outputs, feedback
  – 2\textsuperscript{nd} of 3 exposures of engineering design in each chapter
Section 6

Newton’s Third Law: Run and Jump

Learning Outcomes

In this section, you will
- Provide evidence that forces come in pairs, with each force acting on a different object.
- Use Newton’s third law to analyze physical situations.
- Describe how Newton’s third law explains much of the motion in your everyday life.

What Do You Think?

The high-jump record is 2.45 m (about 8 ft) for men and 2.09 m (about 6 ft) for women.

- Pretend that you have just met somebody who has never jumped before. What instructions could you provide to get the person to jump up (that is, which way do you apply the force when you push with your feet)?

Record your ideas about this question in your Active Physics log. Be prepared to discuss your responses with your small group and the class.

Investigate

In Part A of this Investigate, you will observe what happens when an object pushes or pulls on another object. In Part B, you will observe how a meter stick applies an upward force on a mass.

Part A: Push, Push Back and Pull, Pull Back

1. Carefully stand or sit on a skateboard or sit on a wheeled chair near a wall. (Your teacher may have one person demonstrate this part of the activity for safety reasons.) By touching only the wall, not the floor, cause yourself to move away from the wall to “coast” across the floor.
Part B: Observing a Meter Stick
Push Back

1. When you hold up a book, you apply an upward force and gravity applies a downward force of equal strength. As a result, the book has no acceleration. A free-body diagram (a diagram showing the forces acting on an object) to illustrate this is shown below. When a book sits on a table, gravity applies a downward force and the table supplies an upward force of equal strength. The free-body diagram illustrating the force of gravity on a book lying on a table is similar to the one of the hand holding up a book.

Walls, tables, and floors are extremely stiff, making it difficult to understand how they can produce forces. In this part of the Investigate, you will use something much less stiff, like a meter stick, to uncover how inanimate objects produce forces.

2. Set up a meter stick with a few books for support as shown.
3. Place a washer or coin in the center of the meter stick.
   a) In your log, record what happens.
4. Remove the washer and replace it with a 100-g mass (weight of 100-g mass = 1.0 N). Continue to place a few more 1.0 N weights on the center of the meter stick. Note what happens as you place each weight on the stick.
   a) Measure the deflection of the meter stick for each 1.0 N of weight and record the values for these deflections.

   b) How does the deflection of the meter stick compare to the weight it is supporting? In your log, sketch a graph to show this relationship.
   c) Remove the weights one at a time, noticing the change in deflection. Once all the weights have been removed, place the washer or coin back in the center of the meter stick. Do you think that the meter stick is deflecting? Write a concluding statement concerning the washer and the deflection of the meter stick.
   d) Draw the forces acting on the 100-g mass when it is at rest on the meter stick. (This is a free-body diagram.)
Section 7

Frictional Forces: The Mu of the Shoe

Learning Outcomes

- Apply the definition of the coefficient of sliding friction, \( \mu \).
- Measure the coefficient of sliding friction between the soles of athletic shoes and a variety of surfaces.
- Calculate the effects of frictional forces on the motion of objects.

What Do You See?

What Do You Think?

A shoe store may sell as many as 100 different kinds of sport shoes.

- Why do some sports require special shoes?
- Why would different features of a shoe be useful for different sports?

Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will examine how difficult it is to pull a shoe across a surface.

1. Take an athletic shoe. Use a spring scale to measure the weight of the shoe, in newtons.
   - a) Record a description of the shoe (such as its brand) and the shoe's weight, in your log.
   - b) List some things (which scientists call "variables") that may affect the force required to pull the shoe.
total force due to them was zero. Note that you actually measured the pulling force but used its value as the value for the frictional force. This is perfectly fine, since the two forces are equal in strength.

In the investigate, the shoe did not move in the vertical direction. Newton's second law informs you that the vertical forces on the shoe must add up to zero. The downward force of gravity on the shoe (weight) must be equal to the upward force applied to the shoe by the surface. Since this force is directed perpendicularly to the surface, it is often called the normal force, since the word "normal" sometimes means "perpendicular to." This force is equal in strength and in the opposite direction to the shoe's weight. Note that you measured the weight of the shoe, but used its value as the value for the normal force. Again, this is perfectly fine, since the two forces are equal in strength.

A free-body diagram can help you see the relationships among the four forces when the shoe moves with a constant speed.

![Free-body diagram of a shoe with forces labeled](image)

**Coefficient of Sliding Friction, \( \mu \)**

The coefficient of sliding friction, symbolized by \( \mu \), is defined as the ratio of two forces:

\[
\mu = \frac{\text{force of friction}}{\text{perpendicular force exerted by the surface on the object (normal force)}} = \frac{F_f}{F_n}
\]

The force of friction is the force required to slide the object on the surface with a constant speed.
Static Friction

As you worked on this Investigate, you might have noticed that it takes a larger force to get an object sliding across a surface than to keep it sliding once it has started to move. In that section, only sliding friction is discussed. When the object is not sliding, friction still acts between the surface and the object, but the force of friction now assumes the appropriate value between zero and a maximum so that the object remains at rest.

Imagine the athletic shoe at rest and you are not pulling on it. Now start to pull very gently. You are clearly applying a force to the shoe, but since the shoe is still at rest, the force of static friction must be equal and opposite to the force you are applying. Now pull on it a bit harder. If the shoe does not move, then the frictional force has also increased, so it is still equal and opposite to the force you are applying. Notice that the static frictional force can take on various values. This is unlike the sliding frictional force that always has a definite value for a given situation. If you keep increasing your pull on the shoe, the static frictional force also keeps increasing, until it reaches its maximum value given by $F_s = \mu_s F_n$. As soon as the forces you are applying is greater than the maximum static frictional force possible, the shoe breaks loose and accelerates. Because this force is greater than the sliding frictional force ($\mu_s > \mu$), you have to decrease the force you exert on the shoe in order for it to slide with a constant velocity. This is something that you may have noticed.

1. A block sitting on an incline makes an angle of 30° with the horizontal. The block has a mass of 1.5 kg.

a) Sketch the block. Draw three arrows representing the forces on the block (weight pointing downward, perpendicular force [also known as the normal force] of the incline on the block, and the force of static friction pointing parallel to the incline opposite to the direction the block may slide).

b) Draw a set of axes with one axis parallel to the incline and one axis perpendicular to the incline. Notice that two of the forces fall along these axes.

c) Draw the two components of the weight along these axes. Use a scale diagram or trigonometry (sines and cosines) to find the values of these components.

d) Because the block is at rest (not accelerating), all the forces must add up to zero. Use this fact to find the normal force and the force of static friction.
Essential Questions

What does it mean?
An athlete may complain that the field is slippery. How can you describe the same situation using the terms friction, coefficient of sliding friction, forces, and the symbol $\mu$?

How do you know?
A running shoe is pulled along the ground at a constant speed. How do you know that a frictional force was equal to the pulling force?

Why do you believe?

<table>
<thead>
<tr>
<th>Connects with Other Physics Content</th>
<th>Fits with Big Ideas in Science</th>
<th>Meets Physics Requirements</th>
</tr>
</thead>
</table>
| Force and motion                   | Change and constancy          | *Experimental evidence is consistent with models and theories

* Physicists often believe in invisible forces. Friction is invisible; it happens without you seeing it. A sliding object slows down and stops. If you did not believe in friction, could Newton’s first and second laws explain this motion?

Why should you care?
Friction, or the lack of enough friction, is critical to sports. Describe two parts of your sport where friction is critical and what you are going to say about it in your voice-over.

Reflecting on the Section and the Challenge
Many athletes seem more concerned about their shoes than other items of equipment, and for good reason. Small differences in the shoes (or skates or skis) can affect performance. Athletic shoes have become a major industry because people in all “walks” of life have discovered that athletic shoes are great just about anywhere. Now that you have studied friction, you know about a major aspect of what makes shoes function well. You are prepared to do physics commentary on athletic footwear and other effects of friction in sports when the need exists to be “sure-footed.” Your sports commentary may discuss the $\mu$ of the shoe, the change in friction when a playing surface gets wet, and the need for friction when running. You may also wish to discuss the use of cleats on certain surfaces or the friction of tires on the road in stock car races. No matter which sport you choose, friction will play an important role.
How do they do it?

• Challenge on 1\textsuperscript{st} day  (< 1 period)
• Rubric on 1\textsuperscript{st} day  (< 1 period)
• Sections/labs  (5 weeks)
  – WDYS?; WDYT; Investigate; Physics talk; Active Physics Plus; WDYT now
  – Essential Questions
  – Reflecting on the Activity and the Challenge
  – Physics to Go; Inquiring Further
• Challenge  (2-3 periods)
The Active Learning Challenge

• Learning takes place during the transfer from activity to challenge *(How People Learn)*

• Review the content multiple times in different contexts *(How People Learn)*

• Motivation *(What engages students intellectually)*

• Expertness *(What engages students intellectually)*

• Their interest, their culture *(Equity)*

• *It frames instruction without compromising content*
You will now be completing a second cycle of the Engineering Design Cycle as you prepare for the Chapter Challenge. The goals and criteria remain unchanged. However, your list of Inputs has grown.

You also have the additional Input of your own personal experience with sports as well as the feedback you received following your Mini-Challenge presentation.

**Section 1** You investigated Galileo’s law of inertia and learned how it relates to the mass of an object. You read about Newton’s first law and learned about reference frames for measuring the speed of an object.

**Section 2** You measured speed by making speed vs. time graphs using a ticker timer for objects with constant speeds and changing speeds. You also explored the concept of acceleration, or the rate at which speed increases or decreases.

**Section 3** You investigated the relationship between forces on an object and the acceleration and change in velocity that they produce. You also read about Newton’s second law, which helps to calculate the unbalanced force, mass, or acceleration of an object.

**Section 4** You used models to learn about the horizontal and vertical motion of a projectile. You also explored how the horizontal speed and total height of a projectile affects the horizontal distance that it travels.

**Section 5** You measured constant acceleration due to gravity and discovered how it causes all objects to speed up as they fall toward Earth. You also used calculations and models to describe the trajectory, or path, of a projectile.

**Section 6** You studied examples of force pairs and considered Newton’s third law as an explanation for the forces caused by inanimate objects. You also learned to use force diagrams to clearly represent forces on objects.

**Section 7** You measured the force of sliding friction between a sports shoe and various surfaces and calculated the coefficient of sliding friction for the different combinations. You also studied the impact of friction on the movement of objects.
Engineering Design

• 3rd exposure
  – Goal
  – Input
  – Process
  – Outputs
  – Feedback

• 3 Exposures to Engineering Design in each chapter
A. Dean Bell

Writer/Director, New York, NY

A. Dean Bell is an award-winning filmmaker, television writer, director, and producer. He wrote and directed the highly acclaimed show *SportsFigures* that aired on ESPN for 12 years.

*SportsFigures* is an educational television series designed to teach the principles of physics and mathematics through sports. Bell, having never even taken physics in high school while growing up in Rochester, New York, said he was not worried that he lacked a physics background when it came to writing and directing the show. “I was learning physics from the show’s advisors and I felt that my discovery process could be translated into the show,” he said.

*SportsFigures* won four Clarion Awards for best children’s television program, and a number of Parents’ Choice Awards. Bell knew that when *SportsFigures* was awarded these crowning achievements, his aim to combine education and entertainment had been achieved.

*SportsFigures* may have taped its last season, but it is still shown in reruns on Cable In The Classroom. “It is also used and available in school libraries across the country,” said Bell.

Bell is also an assistant professor at SUNY Purchase, New York, his alma mater, where he has been teaching directing and screenwriting since 1995. “I tell my college students that as writers, don’t hesitate to take that science course. You just might need to do something like write and direct a television series that teaches physics someday.”

Rick Angelo

Producer, ESPN, Fairfield, CT

Rick Angelo began his career in sports television in 1995. Today, Angelo produces games for all college sports for ESPN.

Angelo believes physics plays a phenomenal role in his job. “Everything with sports has something to do with physics,” he said. Producers use graphics and animation of the players to show a viewer the athleticism of the athlete. “We will use graphics to show the speed of a ball and what makes it the perfect pitch, to show the viewer what phenomenal athletes they are watching,” said Angelo. “Physics enhances our stories about the athletes.”

Sandra Giddins

Community Center Director and former Professional Athlete & Coach, Queens, NY

Sandra Giddins grew up in Yonkers, New York and started playing basketball at the age of nine. She played Division I basketball at Cheney University in Pennsylvania on a four-year scholarship.

Her athletic career lasted less than two years after suffering a knee injury while playing in Brazil. “I went up for a rebound and came down and my whole knee just twisted,” recalled Giddins. Giddins stated that physics and athletics go hand-in-hand. For example, many female basketball players often injure their knees while jumping, due to their low center of gravity. To avert injury, female athletes need to pay attention to their body’s center of mass.
### Physics Concepts

<table>
<thead>
<tr>
<th>Physics Concepts</th>
<th>Is There an Equation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>When an object is moving, it will continue to move at constant speed in a straight line unless there is an unbalanced force to change its motion. If the object is at rest, it stays at rest unless there is an unbalanced force. This is known as Newton’s first law.</td>
<td></td>
</tr>
<tr>
<td>The tendency of an object to resist changing its motion is called inertia. Inertia is measured in the same units as mass.</td>
<td></td>
</tr>
<tr>
<td>A frame of reference is the specific point of view from which a particular measurement is made. Different frames of reference yield different measurements.</td>
<td></td>
</tr>
</tbody>
</table>
| The acceleration is defined as the change in velocity with respect to time. | \[ a = \frac{\Delta v}{\Delta t} \]
| A force is measured in the SI unit newtons. | |
| The acceleration of an object \((a)\) is directly proportional to the net force applied \((F_{\text{net}})\), and inversely proportional to the object’s mass \((m)\). This is known as Newton’s second law. | \[ a = \frac{F_{\text{net}}}{m} \]
| The weight \((F_g)\) of an object is equal to an object’s mass \((m)\) multiplied by the strength of Earth’s gravitational field \((g)\). Weight is the force of Earth’s gravity acting on an object. | \[ F_g = mg \]
| Using significant figures ensures that any calculations made do not indicate a level of precision greater than the measurements. | |
| The net force \((F_{\text{net}})\) on an object in equilibrium is zero. When an object is in equilibrium (either at rest or traveling with constant velocity) the vector sum of all the forces acting on the object equals zero. | \[ F_{\text{net}} = 0 \]
| When forces act at right angles on the same body, the net force is determined by using the Pythagorean theorem. | \[ F_{\text{net}} = \sqrt{F_1^2 + F_2^2} \]
| The shape of a projectile’s path is a parabola if there is no air resistance. | |
| The vertical velocity and the horizontal velocity of an object are independent of one another, and can be used separately to determine aspects of a projectile’s flight. The total velocity can be calculated from the horizontal and vertical components using the Pythagorean theorem. | \[ v = \sqrt{v_x^2 + v_y^2} \]
| The horizontal distance traveled by a projectile \((d_{\text{hori}})\) equals the projectile’s horizontal speed \((v_{\text{horiz}})\) multiplied by the time of flight. The vertical distance covered by a projectile \((d_{\text{vert}})\) depends upon the acceleration due to gravity \((g)\) and the time the object is in flight \((t)\) squared. The horizontal and vertical motions of a projectile are independent of each other. | \[ d_{\text{horiz}} = v_{\text{horiz}} t \]
\[ d_{\text{vert}} = \frac{1}{2}gt^2 \]
The maximum range of a projectile returning to the same height as the launch point occurs when it is launched at 45° degrees to the horizontal.

When an object is projected at an angle to the horizontal, the motion may be analyzed after the velocity is broken into vertical and horizontal components.

Forces come in pairs. Whenever a force is exerted on a mass \( b \) \( (F_{\text{exerted}}) \), the mass \( b \) exerts an equal force in the opposite direction on the mass \( a \) \( (-F_{\text{on a}}) \). This is known as **Newton's third law**.

\[
F_{\text{on a}} = -F_{\text{on b}}
\]

The normal force is a force that acts perpendicular to a surface.

A **free-body diagram** is a sketch of all the forces acting on an object.

The force of friction \( (f) \) equals the coefficient of friction \( (\mu) \) multiplied by the normal force \( (F_n) \). Friction is a force acting between two bodies in contact that resists the relative motion of those bodies. It always acts parallel to the surfaces in contact.

\[
f = \mu F_n
\]

The coefficient of friction \( (\mu) \) is a dimensionless constant.

The coefficient of static friction \( (\mu_s) \) on an inclined plane equals the tangent of the angle the plane makes with the horizontal \( \tan \theta \).

\[
\mu_s = \tan \theta
\]

An object’s kinetic energy \( (KE) \) is proportional to the object’s mass \( (m) \) multiplied by its velocity squared \( (v^2) \). Kinetic energy is an object’s energy of motion.

\[
KE = \frac{1}{2} mv^2
\]

**Gravitational potential energy** \( (GPE) \) is proportional to an object’s mass \( (m) \) multiplied by its vertical height above Earth \( (\Delta h) \) and the acceleration due to gravity \( (g) \). Gravitational potential energy is energy due to an object’s vertical position above Earth’s surface.

\[
GPE = mgh
\]

**Elastic potential energy** \( (EPE) \) is proportional to the spring constant of the material \( (k) \) multiplied by the material’s change in length \( (\Delta x) \) squared. Elastic potential energy is energy stored in a material due to its compression or stretch.

\[
EPE = \frac{1}{2} kx^2
\]

Work \( (W) \) done on an object can increase its kinetic energy \( (\Delta KE) \). When work is done on an object moving on a horizontal surface, the kinetic energy of the object increases.

\[
W = \Delta KE = \left( \frac{1}{2} mv_f^2 - \frac{1}{2} mv_i^2 \right)
\]

Work \( (W) \) is the product of the force exerted on an object \( (F) \), and the displacement in the direction of the force \( (d) \). Work done on an object increases its energy and may change an object’s kinetic or potential energy.

\[
W = Fd
\]

The law of **conservation of energy** states that energy may change its forms, but not its amount. The total amount of energy remains the same during any changes in form.
Here are some examples of how the concepts you studied in this chapter relate to other sciences.

**Newton's First Law — Inertia**

*Biology* Animals with large body mass are generally unable to change direction quickly when in motion. Smaller animals can often elude their larger predators by making sharp turns while moving quickly.

*Chemistry* Massive molecules diffuse more slowly than less massive ones, allowing chemists to separate molecules and atoms by mass.

*Earth Science* When tectonic plates collide, the inertia of their combined mass can cause mountain ranges to rise at the point of intersection.

**Newton's Second Law**

*Biology* A flea is able to exert tremendous force for its size, allowing it to accelerate its body into huge jumps, up to 13 in. (33 cm), or 200 times the length of their bodies.

*Chemistry* The electric force of attraction between water molecules causes them to accelerate and join, forming water droplets.

*Earth Science* The force of gravity causes water to accelerate as it passes over a waterfall, increasing the erosive power of the water at the bottom of the fall.

**Newton's Third Law**

*Biology* An octopus propels itself through water by shooting out a forceful stream of water similar to jet exhaust. The reaction force of the ejected water on the octopus may cause an acceleration of up to 30 m/s².

*Chemistry* When an atom of gas in a balloon strikes the inner surface of the balloon, the force the balloon wall exerts on the atom to change its direction is equal to the force the atom exerts on the balloon. It is this combined force of countless atoms that keeps the balloon inflated.

*Earth Science* When a hurricane strikes land, the wind exerts tremendous force on topographical features and objects on the land. The reaction force of these objects on the moving air causes it to slow down, which is why hurricanes eventually dissipate as they move over land.

**Projectile Motion**

*Biology* Seagulls will often drop clams shells onto rocks to break them open, demonstrating a natural understanding of projectiles.

*Chemistry* The force of gravity causes settling of insoluble particles in a mixture with water. This is enhanced by spinning of a centrifuge.

*Earth Science* Volcanic eruptions often blast large rocks into the air. These rocks behave as projectiles, and their landing place may be accurately predicted.

**Friction**

*Biology* Air friction limits the speed at which a bird can fly. Friction, exerted as drag, pushes against the outstretched skin of a flying squirrel, allowing it to land safely after jumping from a high tree.

*Chemistry* Frictional forces provide the activation energy required to begin many chemical processes, such as the lighting of a match.

*Earth Science* The force of friction between tectonic plates holds them in place as they attempt to slide past each other. When this friction is eventually overcome, earthquakes often result from the sudden, rapid movement of the plates.

**Conservation of Energy**

*Biology* The chemical energy in the food a frog eats is converted into potential energy in its leg muscles. When the frog jumps, this energy is transformed into kinetic energy.

*Chemistry* When two atoms bond together, their electric potential energy decreases and their kinetic energy increases by the same amount.

*Earth Science* Earth continually receives energy from the Sun and radiates energy back out to the universe at the same rate. But the usefulness, or quality, of energy received from the Sun and that radiated by Earth, is greater. This is important for the continuance of events on Earth, which are characterized by energy conversions to forms that are less useful, or of lower quality. The higher quality energy received from the Sun compensates for the loss of energy quality in energy conversions on Earth.
Content Review

1. A cart is rolling along a frictionless, horizontal surface. Which of the following describes the motion of the cart as it continues to roll along the surface?
   a) The cart will slow down as it runs out of the forward force.
   b) The cart will continue to roll with constant speed.
   c) The cart will continue to roll with constant speed only if it is rolling downhill.
   d) The cart will slow down as it uses up its speed.

2. Which object has the most inertia?
   a) A 0.001-kg bumblebee traveling at 2 m/s
   b) A 0.1-kg baseball traveling at 20 m/s
   c) A 5-kg bowling ball traveling at 3 m/s
   d) A 10-kg tricycle at rest

3. An athlete walks with a piece of ticker tape attached to herself with the tape timer running, and produces the tape shown below.

   [Diagram of ticker tape with markings]

   According to the tape, she was traveling with
   a) constant velocity.
   b) positive acceleration.
   c) negative acceleration.
   d) constant velocity, then negative acceleration.

4. A track coach with a meter stick and a stopwatch is trying to determine if a student is walking with constant speed. He should
   a) measure the walker's speed at regular intervals to see if it is always the same.
   b) measure the total distance the student travels and the total time to get the average speed.
   c) measure the beginning and ending times only to see if they are the same.
   d) use the meter stick to measure the student's stride length and time how long it takes to take one step.

5. If a cart is traveling with uniform negative acceleration, what conclusions can be drawn about the forces acting on the cart?
   a) The cart must be frictionless.
   b) The cart must be rolling downhill.
   c) The cart must have a net unbalanced force acting on it.
   d) No force is needed, the cart will naturally slow down.

6. A student wants to set up an experiment to determine the effect of a net force on an object's acceleration. To do this, she should
   a) vary the force acting on the object and the mass of the object at the same time.
   b) vary the force acting on the object, but not the object's mass.
   c) vary the mass of the object, but not the force acting on the object.
   d) keep both the force acting on the object and the mass of the object constant as it rolls along a horizontal surface.

7. A 2-kg block is dropped from the roof of a tall building at the same time a 5-kg ball is thrown horizontally from the same height. Which statement best describes the motion of the block and the motion of the ball? (Disregard air resistance.)
   a) The 2-kg block hits the ground first because it has no horizontal velocity.
   b) The 6-kg ball hits the ground first because it has more mass.
   c) The 6-kg ball hits the ground first because it is reeled.
   d) The block and the ball hit the ground at the same time because they have the same vertical acceleration.
8. A pitching machine launches a baseball horizontally with no spin. Which of the following statements correctly describes the ball's motion in the air as the launch speed is increased?
   a) The ball's acceleration increases, and the distance it falls in one second decreases.
   b) The ball's acceleration remains the same, and the distance the ball falls in one second decreases.
   c) The ball's acceleration remains the same, and the distance the ball falls in one second increases.
   d) The ball's acceleration remains the same, and the distance the ball falls in one second remains the same.

9. A punter on a football team can kick the ball at an angle of either 30° or 80°. If he wants to maximize both the amount of time the ball spends in the air and the distance the ball travels, at which angle should he kick the ball?
   a) the 30° angle because the ball goes further
   b) the 80° angle because the ball goes further
   c) the 30° angle because the ball spends more time in the air
   d) the 80° angle because the ball spends more time in the air

10. A student is holding a book that has a weight of 20 N in his hand while sitting in a chair. The man claims that the book must be attracting Earth with a force of 20 N. His claim must be
    a) false because books do not attract objects.
    b) false because Earth is much larger than the book.
    c) true because the book has more inertia than Earth.
    d) true due to Newton's third law of action-reaction.

11. Which diagram of a 5-kg mass resting on a table correctly represents the force of the table on the mass?

   ![Diagram of forces](image)
   a) ![Diagram a]
   b) ![Diagram b]
   c) ![Diagram c]
   d) ![Diagram d]

12. Two students have a “tag-of-war” on a smooth gym floor. One student has a mass of 70 kg and is wearing socks, but no athletic shoes. The other student has a mass of 60 kg and is wearing athletic shoes. The student most likely to win will be
    a) the 60-kg student because he can pull harder on the 70-kg student.
    b) the 70-kg student because he can pull harder on the 60-kg student.
    c) the 60-kg student because he experiences a greater frictional force with the floor.
    d) the 70-kg student because he experiences a greater frictional force with the floor.

13. Automobiles with front-wheel drive that have the engine located over the drive wheels have better traction in snow than automobiles with rear-wheel drive. This is most likely because
    a) the tires on front-wheel drive automobiles have a higher coefficient of friction than rear-wheel drive automobiles.
    b) the front tires encounter the snow first.
    c) the front tires have a higher normal force than the rear-wheel tires because the engine is heavier than the rear of the automobile.
    d) the front wheels are used for steering.

14. A student whose mass is 60 kg and a bicycle with a mass of 20 kg are at rest on a horizontal road. The student exerts a force of 120 N to accelerate the bike over a distance of 48 meters. What is the velocity of the bicycle and rider at the end of the 48 meters?
    a) 3 m/s
    b) 6 m/s
    c) 8 m/s
    d) 12 m/s

15. A basketball player is able to jump to a vertical height of 1.25 m. A student calculates that the player must have left the floor with a velocity of 5 m/s. The student can prove this claim by using
    a) conservation of energy.
    b) the principle of friction.
    c) Newton's third law of motion.
    d) the principle of inertia.
16. Design an experiment to measure the coefficient of friction between a steel block and the surface of your classroom lab table.
   a) What measuring tools will you need?
   b) What measurements will you take to determine the coefficient of friction?
   c) Show how you will use this data to calculate the coefficient of friction.

17. When you sit on a park bench, the bench exerts an upward force on you.
   a) Compare the force exerted by the park bench on you to your weight.
   b) Explain how the bench is able to provide the force required.

18. During an activity to measure how high a student can jump, the following measurements were made by the student's lab partners:
   - Mass = 65 kg
   - Increase in height of the student's center of mass during jump from the crouched down (ready) position = 0.60 m
   - Change in height from the ready position to the exact point where the student's feet leave the ground = 0.35 m
   a) How much gravitational potential energy did the student have at the peak of the jump?
   b) How much spring potential energy did the student's legs have as he was crouched in the ready position?
   c) Explain why the kinetic energy the student had as he left the ground was less than the spring potential energy when in the crouched down, ready position.

19. A ball is kicked horizontally off a tall building as shown.
   a) Draw a sketch of the ball's positions at 0.1 s intervals for the first 0.4 s as the ball falls to the ground.
   b) Draw arrows to represent the ball's horizontal velocity at positions described in a).
   c) Draw arrows to represent the ball's acceleration for the positions described in a).
   d) Draw arrows to represent the ball's vertical velocity in the positions described in a).

20. Before leaving Earth, the mass of an astronaut is measured to be 60 kg. The astronaut lands on the Moon and measures the acceleration of gravity to be 1.6 m/s².
   a) What would the astronaut's weight be on Earth?
   b) What would the astronaut's weight be on the Moon?
   c) What would be the astronaut's mass be on the Moon?
   d) Explain your answers to a) and b) using Newton's second law.

21. Four forces act on a 10-kg mass as shown in the diagram. What would be the acceleration of the mass be?

22. A soccer ball is kicked so that at the peak of its trajectory, it has a horizontal speed of 15 m/s, and is 5 m above the ground. How far away from the kicker does the soccer ball land?

23. A motorcycle rider starts out on top of a ramp 10 m high, and then rides down and jumps the motorcycle as shown. The rider is at the peak of his jump at 5 m. How fast is the motorcycle going horizontally at this point?
Active Physics

“This is the best science course ever.”
Active Physics

- Challenge
- Activity level
  - What do you think?
  - For you to do
  - For you to read (This is your traditional program)
  - Physics Talk (This is your traditional program)
  - Reflecting on the Activity and the Challenge
  - Physics to Go (This is your traditional program)
  - Stretching exercise
- Mini challenge – engineering design
- Challenge Project – Problem Based Learning
- IT’S ALL IN THERE – inquiry, content, math, assessment, the 7E instructional model
ABC as part of the 7E instructional model

- Engage
- Elicit
- Explore
- Explain
- Elaborate
- Extend

Evaluate

- Enhancing the 5E model:
  *The Science Teacher* (9/03)
  Available at www.cosmic.umb.edu
A Framework for K-12 Science Education – National Academy of Sciences

The Three Dimensions of the Framework

1. Scientific and Engineering Practices

2. Crosscutting Concepts

3. Disciplinary Core Ideas
Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematic and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information
Crosscutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quality
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change
Disciplinary Core Ideas

Physical Sciences

PS 1: Matter and its interactions
PS 2: Motion and stability – Forces and interactions
PS 3: Energy
PS 4: Waves and their applications in technologies for information transfer
Disciplinary Core Ideas

Life Sciences

LS 1: From molecules to organisms: Structures and processes
LS 2: Ecosystems: Interactions, energy, and dynamics
LS 3: Heredity – Inheritance and variation of traits
LS 4: Biological evolution – Unity and diversity
Disciplinary Core Ideas

**Earth and Space Sciences**
- ESS 1: Earth’s place in the universe
- ESS 2: Earth’s systems
- ESS 3: Earth and human activity

**Engineering, Technology, and the Applications of Science**
- ETS 1: Engineering design
- ETS 2: Links among engineering, technology, science and society
Integrating the Three Dimensions of the Framework
Can it be done?

Active Physics and the NRC Framework
Active Physics and the NRC Framework

Active Physics Components

Science and Engineering Practices

1. Investigations for every concept
2. Elicit prior understandings for every concept
3. Engagement of students for every concept
4. What do you think Now (argument from evidence) for every concept
5. Engineering Design Cycle
   a. Chapter introduction
   b. Mini-challenge
   c. End of chapter challenge
6. Essential Question #2: “How do we know?” for every concept
8. Physics at Work
Active Physics and the NRC Framework

Active Physics Components

Crosscutting Concepts

1. Connections to other disciplines
   a. Chemistry and Physics
   b. Life Science and Physics
   c. Earth Science and Physics
2. Essential Question #3: “Why do we believe?” articulating the Nature of Science for every concept.
Active Physics and the NRC Framework

Disciplinary Core Ideas

Active Physics Components

1. Physics Talk for every concept
   a. With links to investigations (science and eng practices)
2. Essential Question 1: “What Does It Mean?” for every concept
3. Physics Learned and “Is there an question?”
# Active Physics and the NRC Framework (Section Level)

<table>
<thead>
<tr>
<th>What Do You See?</th>
<th>Science and Engineering Practices</th>
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<tr>
<td>What Do You Think?</td>
<td>Science and Engineering Practices</td>
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<tr>
<td>Investigation</td>
<td>Science and Engineering Practices</td>
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<tr>
<td>Physics Talk</td>
<td>Disciplinary Core Ideas</td>
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<tr>
<td>Active Physics Plus</td>
<td>Disciplinary Core Ideas</td>
</tr>
<tr>
<td>What Do You Think Now</td>
<td>Science and Engineering Practices</td>
</tr>
</tbody>
</table>

## Four Essential Questions

1. What does it mean?
2. How do we know?
3. Why do we believe?
4. Why should I care?

1. Disciplinary Core Ideas
2. Science and Engineering Practices
4. Disciplinary Core Ideas

<table>
<thead>
<tr>
<th>Reflecting on the Activity and the Challenge</th>
<th>Disciplinary Core Ideas</th>
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<tr>
<td>Physics to Go</td>
<td>Disciplinary Core Ideas</td>
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<tr>
<td>Science and Engineering Practices</td>
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<tr>
<td>Inquiring Further</td>
<td>Disciplinary Core Ideas</td>
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<tr>
<td>Science and Engineering Practices</td>
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</tbody>
</table>
## Active Physics and the NRC Framework (Chapter Level)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Disciplinary Core Ideas</th>
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<tr>
<td>Challenge</td>
<td>Disciplinary Core Ideas</td>
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<tr>
<td>Criteria for Success</td>
<td>Science and Engineering Practices</td>
</tr>
<tr>
<td>Engineering Design Cycle</td>
<td>Science and Engineering Practices</td>
</tr>
<tr>
<td>1. Introduction</td>
<td></td>
</tr>
<tr>
<td>2. Mini-challenge</td>
<td></td>
</tr>
<tr>
<td>3. Chapter Challenge</td>
<td></td>
</tr>
<tr>
<td>Physics Corner</td>
<td>Disciplinary Core Ideas</td>
</tr>
<tr>
<td>Physics You Learned</td>
<td>Disciplinary Core Ideas</td>
</tr>
<tr>
<td>Connections to Other Sciences</td>
<td>Crosscutting Concepts</td>
</tr>
<tr>
<td>Physics at Work</td>
<td>Disciplinary Core Ideas</td>
</tr>
<tr>
<td>Science and Engineering Practices</td>
<td></td>
</tr>
<tr>
<td>Practice Test</td>
<td>Disciplinary Core Ideas</td>
</tr>
</tbody>
</table>
Meeting the needs of all Students

This section is designed to help teachers to help struggling students.

Information in a table identifies learning issues, places their location within each activity, and recommends instructional and management strategies for helping students compensate for problems teaching the skills.

Compensation techniques have been labeled Accommodations and teaching skills has been labeled Augmentation.
Augmentation and Accommodation

To understand how augmentation and accommodation can be used as tools by teachers to help struggling students access each activity:

Assume some students in the class cannot follow complex multi-step directions.

What will these students learn about conduction, convection and radiation if they cannot read the text or follow the specific directions embedded in it?

Their confusion quickly results in either a cessation of their learning or distraction of others. To prevent this, a teacher can either accommodate the students by providing them with directions they can understand (accommodation) or he can teach them direction following skills (augmentation).
English Language Learners (TE)

- Linked to each and every activity
- One full page
- Instructional model of 7E and ABC works well with ELL.

- Teachers do not have to read a book or attend a workshop on ELL and then figure out how to transfer those lessons to the classroom.
- Every teacher using this resource will be a better teacher for ELL students (and all students) and gain expertise throughout the year.
Our next steps

• To implement the vision of the Framework, we will all need professional development

• What will people need?
  – Science and Engineering Practices
  – Crosscutting Concepts
  – Disciplinary Core Ideas
Similar Issues with *Active Physics*

- Problem based learning
- Teachers who had weak content background
- Inquiry lab experiments
- Engineering design
- Crosscutting concepts
- New assessment models
Our Solution

• Online Just-in-time PD
  – Asynchronous access
  – PD aligned with the curriculum used in class
  – PD accessed while you are teaching

• The Professional Development model
  – Prepare
  – Share
  – Compare
Prepare – Share - Compare

Activity 2: Push or Pull--Adding Vectors

Activity 2 Pre-Quiz
The teacher should take this quiz prior to preparing for the activity. The quiz will help teachers focus on the essential understandings and crucial physics of each section.

Please take a few moments to take the quiz and submit your answers. You should not study. You can be confident that your results will not be shared with others in any way in which you could be identified.

Prepare Activity 2
Activity overview, demonstration video, Arthur’s crucial physics video, animations, student misconceptions, lesson plans, and more!

Share Activity 2
Share your problems and successes with fellow teachers.

Activity 2 Post-Quiz
The teacher should take this quiz prior to giving it to students. The quiz will help teachers focus on the essential understandings and crucial physics of each section.

Please take a few moments to take the quiz and submit your answers. You should not study. You can be confident that your results will not be shared with others in any way in which you could be identified.

Compare Activity 2
Compare your post-quiz results with those of other teachers.

Download Activity 2 Resources
Get quiz handouts, answer keys and illustrations for use in class.
Prepare

• Each chapter has 10 sections
• Each section
  – Content review
  – Crucial content
  – Videos
    • Crucial Content
    • How to perform related investigation
  – Lesson Plans
  – Student Misconceptions
Prepare: Video of Master Teacher

Activity 3: Sounds from Vibrating Air

Try the Activity

- Watch the Active Physics video where a teacher talks about the activity and shows you the equipment to use.
- Try the experiment yourself with your equipment and while following the directions in the Student Text.
## Prepare: Misconceptions

### Activity 2: Push or Pull, Adding Vectors

#### Misconceptions

<table>
<thead>
<tr>
<th>WHAT SOME STUDENTS SAY</th>
<th>HOW AN EXPERT WOULD RESPOND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force is needed for constant speed</td>
<td>Force is needed for changes in speed.</td>
</tr>
<tr>
<td>Inanimate objects (like a table top) cannot produce forces.</td>
<td>A table top does apply a force to an object on the table that prevents it from moving down to the ground.</td>
</tr>
<tr>
<td>In an object is at rest, no forces are acting on the object.</td>
<td>There may be forces on the object, but the forces are balanced so that there is no net force on the object.</td>
</tr>
<tr>
<td>Force is a property of an object. An object has force and when it runs out of force, it stops moving.</td>
<td>A force is applied to the object by something external to the object. Once the force is no longer applied, the object no longer.</td>
</tr>
<tr>
<td>The motion of an object is always in the direction of the net force applied to the object.</td>
<td>A force can be applied in the opposite direction to the object's motion.</td>
</tr>
<tr>
<td>Gravity is not a force.</td>
<td>Gravity is a force and acts in the same way that other forces act.</td>
</tr>
<tr>
<td>Gravity can not exist without air.</td>
<td>Gravity is a force between any two masses. It is most easily noticeable for objects near very large masses, like the Earth or moon. Although the moon does not have air, there is a force of gravity.</td>
</tr>
</tbody>
</table>
Prepare: Lesson Plan

Lesson 1

Lesson Plan 1

1. Begin with sports blooper (should require only 2 minutes) - a way to engage students
2. Journal/Notebook
   a. Remind the students to begin a new page in their journal. The heading of the page should be Activity 2: Push or Pull - Adding Vectors
3. What Do You See
   a. Ask the students to comment on what they see in the cartoon.
   b. Ask the students what they think will happen if the girl continues to add coins to the ruler. Ask the students what they think will happen to the boy's round object if the ruler is not restricted by the floor.
   c. REMINDER: Do not try to get the "correct" answer. You are asking these questions to find out about students' prior understandings. Listen intently to student responses and respond with comments such as, "interesting", "yes", "I understand what you mean."
   d. (3 minutes)
4. What Do You Think?
   a. Ask the students the two What Do You Think questions.
   b. Have each student write a quick response in their journal (30 seconds - 1 minute)
   c. Direct the students, "See if you wrote the same answer as the students next to you." This is a better approach than "Share your answer with the student next to you."
   d. Ask for a few student ideas and write these on the board
   e. (4 minutes)
5. For You to Do
   a. It is worthwhile to provide students with specific time frames to complete each part of the For You to Do and/or to provide time frames for each stop. This time frame guidance should never extend beyond 15 minutes. If you give students 1/2 hour, many will squander the first 10 minutes with little work accomplished.
   b. Show the apparatus to the students and briefly describe the experiment. There are two distinct parts to this investigation. In the first part, students find out how much a ruler bends as different weights (coins) are placed on it. In the second part, the students use a bent ruler to push objects with different masses.
   c. Discuss safety (danger) issues that could occur as the ruler is fixed to the table with the C-clamp, as the pennies are added to the ruler and when the ruler is used to push a ball or can across the table or floor. By asking the students what might go wrong, the safety discussion is more meaningful.
   d. Have students complete Steps 1-4 of the investigation
      i. You have 10 minutes to complete steps 1-2
      ii. Creating a force meter can take 5 minutes or 5 hours depending on the precision that you require. We want students to recognize that more bend in the ruler corresponds to a greater force of the ruler on the coins. We also want students to know that we can build instruments that can measure force and that all measuring devices do not have to be "store bought."
   e. You can decide how much precision you want and may even suggest that some students pursue this as an Active Physics Plus if they finish their other requirements early.
   f. Have students complete Steps 5 - 8 of the investigation
      i. You have 10 minutes to complete steps 5-8
      ii. You can have the students push a tennis ball or a can or a small cart. You will find that some students will hit the ball - one hit from the ruler. This is incorrect. You want them to push on the ball continuously while keeping the ruler in contact with ball and keeping the same bend in the ruler. This will require practice. As you go around the room, encourage all students in each group to try this.
      iii. As you walk about the room, ask each group of students, "Why is it so hard to keep the force constant (or the ruler bent)?" If any of the students respond, "Because the object keeps moving faster and faster" congratulate them on this astounding discovery. This is Newton's 2nd law. A constant force makes something move faster and faster. This is the essence of the investigation.
   f. Additional notes:
      i. Students can be expected to need practice to exert constant amounts of force on moving objects.
      ii. Remind them that they are not hitting the object with a single impact but continuously pushing on the object.
      iii. Remind them also that they will do better to grab the ruler with their whole hand, not with a thumb and finger like some illustrations would have them believe.
Share

• Each chapter has 10 sections
• Each section has a “share” opportunity
  – Content questions
  – Equipment questions
  – Student questions
  – Pacing questions
  – What went wrong
  – What went right
Share: Threaded Discussions

These folders open a communication area for each activity of Physics In Action. This is where we can talk about the nature of the resources available to enhance our teaching, ask questions about content; make inquiries of each other commenting about how something went in our classroom (or maybe it did not go too well) and wonder about how other students comprehended something.

Goal: you get the gist of it. Just go ahead and share what’s happening in your classroom as you teach Physics in Action. ALL comments are welcome! There are no wrong or stupid questions! Open those windows, please.

The COMPARE folder is a great place for us to discuss the Post-quizzes that we give to our students. Which question seemed troublesome to them? Which was a breeze? In general, how did the quizzes go?

- Share Activity 1 (Conditional) (33 Messages / 33 New)
- Share Activity 2 (Conditional) (27 Messages / 27 New)
- Share Activity 3 (Hidden) (0 Messages)
- Share Activity 4 (Conditional) (0 Messages / 9 New)
- Share Activity 5 (Conditional) (9 Messages / 9 New)
- Share Activity 6 (Conditional) (2 Messages / 2 New)
- Share Activity 7 (Conditional) (14 Messages / 14 New)
- Share Activity 8 (Conditional) (5 Messages / 5 New)
- Share Activity 9 (Hidden) (1 Message / 1 New)
- Share Activity - Chapter Challenge (14 Messages / 14 New)

- Compare Activity 1 (Conditional) (7 Messages / 2 New)
- Compare Activity 2 (Conditional) (11 Messages / 11 New)
- Compare Activity 4 (Conditional) (1 Message / 1 New)
- Compare Activity 5 (Conditional) (13 Messages / 13 New)
- Compare Activity 6 (Conditional) (5 Messages / 5 New)
- Compare Activity 7 (Conditional) (2 Messages / 2 New)
- Compare your post-quiz results with those of other teachers.
Compare

• Each chapter has 10 sections
• Each section has a “compare” opportunity
  – Quiz administered to students
    • Avoiding a ceiling effect
  – Questions related to quiz
  – Use of student data to inform instruction
Compare: Threaded Discussions

The COMPARE folder is a great place for us to discuss the Post-quizzes that we give to our students. Which question seemed troublesome to them? Which was a breeze? In general, how did the quizzes go?

- **Compare Activity 1**: Share your post-quiz results with those of other teachers.
- **Compare Activity 2**: Share your post-quiz results with those of other teachers.
- **Compare Activity 3**: Share your post-quiz results with those of other teachers.
- **Compare Activity 4**: Share your post-quiz results with those of other teachers.
- **Compare Activity 5**: Share your post-quiz results with those of other teachers.
- **Compare Activity 6**: Share your post-quiz results with those of other teachers.
- **Compare Activity 7**: Share your post-quiz results with those of other teachers.
How to Sign Up for Haiku

Email Ben Rasa at brasa@iat.com with your name,
the curriculum you are using (Active Chemistry or Active Physics),
and your school or district email address.
What are our goals as physics teachers?

• Higher student achievement
• Engaged students
• Appreciation (love?) of physics in the world
• Critical thinking

• Five years later: what is physics?
Active Physics

“This is the best science course ever.”
"I wish my physics course had been like that."
Have a great school year.