Standard

CT - 8.1 – Forces and Motion

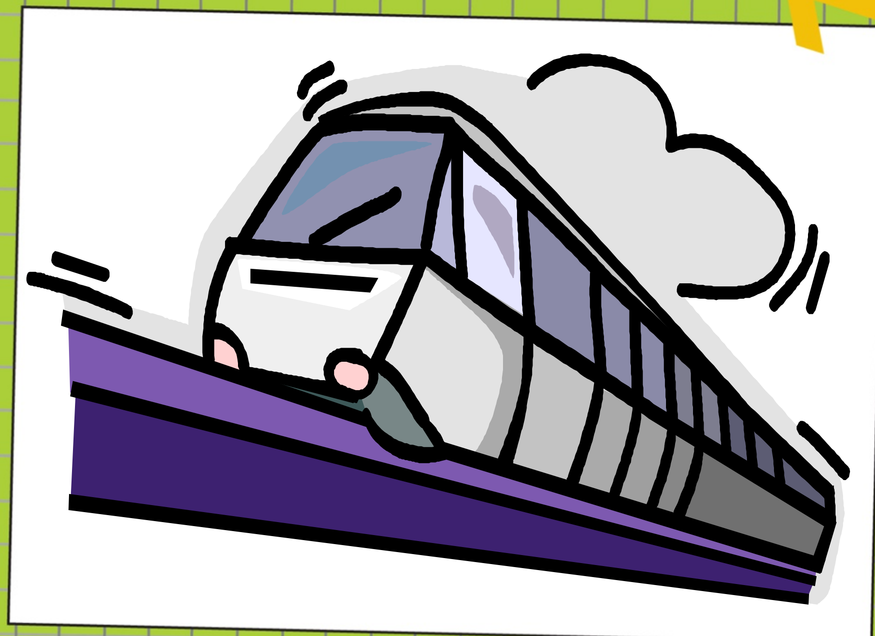
MA - Physical Gr. 6-8 #11 and #13

GET A MOVE ON

Connecticut

Science

Center



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Connecticut Science Center

Table of Contents

Summary

What makes an object move as it does? This package not only helps students to answer that question, it also engages students in investigations that will allow them to make connections to force & motion in their everyday experiences. During your visit, students will be able to program a robot, watch items fall through the eyes of a high- speed camera, predict the actions of a skateboard and rider and wonder how the train moves along the Mag-Lev track without any visible means of support while visiting the **Forces in Motion** and **The Picture of Health** galleries. While participating in the Science Center classroom activity; Trebuchets, students will experience force translated into motion. They will explore and test simple changes that will affect the output of the apparatus. The pre and post activities are designed to enhance your classroom visit and to extend the learning of your students.

This program has been developed as a unit to complement some of the core themes, content standards and expected performances of the CT Core Science Frameworks, as well as the National Science Education Standards. It is a supplemental series of "hands-on" investigations that are inquiry-based and designed to engage students as well as to enhance and build upon their prior content knowledge. It may be integrated with other subjects or it may be taught in its entirety within the science classroom.

The complete CT Core Science Curriculum Frameworks is available at the website http://www.sde.ct.gov/sde/cwp/view.asp?a=2618&q=320890. See also: American Association for the Advancement of Science, *Atlas of Science Literacy*, Project 2061. In addition, Grade Level Expectations (GLEs) were released in Spring, 2009, to "unpack" the science content. Content standard 8.1 is designed to allow students to explore how forces act upon objects to create the resulting motion and how a study of an object's motion can help to determine the forces on it.

Following are the specific sections from the CT Core Science Curriculum Framework that are addressed in this unit. The C INQ information reflects the process skills intended for grades 6-8 specifically representing the content standards of scientific inquiry, literacy, and numeracy.

Inquiry Standards

Grades 6-8 Core Scientific Inquiry, Literacy and Numeracy	
Content Standards	Expected Performances
SCIENTIFIC INQUIRY ♦ Scientific inquiry is a thoughtful and coordinated attempt to search out, describe, explain and predict natural phenomena. ♦ Scientific inquiry progresses through a continuous process of questioning, data collection, analysis and interpretation. ♦ Scientific inquiry requires the sharing of findings and ideas for critical review by colleagues and other scientists. SCIENTIFIC LITERACY ♦ Scientific literacy includes speaking, listening, presenting, interpreting, reading and writing about science. ♦ Scientific literacy also includes the ability to search for and assess the relevance and credibility of scientific information found in various print and electronic media. SCIENTIFIC NUMERACY ♦ Scientific numeracy includes the ability to use mathematical operations and procedures to calculate, analyze and present scientific data and ideas.	C INQ.1 Identify questions that can be answered through scientific investigation. C INQ.2 Read, interpret and examine the credibility of scientific claims in different sources of information. C INQ.3 Design and conduct appropriate types of scientific investigations to answer different questions. C INQ.4 Identify independent and dependent variables, and those variables that are kept constant, when designing an experiment. C INQ.5 Use appropriate tools and techniques to make observations and gather data. C INQ.6 Use mathematical operations to analyze and interpret data. C INQ.7 Identify and present relationships between variables in appropriate graphs. C INQ.8 Draw conclusions and identify sources of error. C INQ.9 Provide explanations to investigated problems or questions. C INQ.10 Communicate about science in different formats, using relevant science vocabulary, supporting evidence and clear logic.

CT Science Standards, Grade Level Concepts & Expectations, & CMT Correlation

Force and Motion – What makes objects move the way they do? GRADE 8			
8.1 — An object's inertia causes it to continue to moving the way it is moving unless it is acted upon by a force.			
Core Science Curriculum Framework	Underlying Concepts *Students should understand that…*	Grade-Level Expectations *Students should be able to…*	CMT Expected Performances
8.1.a The motion of an object can be described by its position, direction of motion and speed. 8.1.b An unbalanced force acting on an object changes its speed and/or direction of motion. 8.1.c Objects moving in circles must experience force acting toward the center.	GRADE-LEVEL CONCEPT 8.1.a 1. An object is said to be in motion when its position changes in relation to a point of reference. An object's motion can be described and represented graphically according to its position, direction of motion, and speed. 2. Speed describes the change in an object's position over a period of time, and is measured in units such as meters per second or miles per hour. 3. Average speed takes into account the different speeds at which an object moves over a period of time. Average speed is calculated by dividing the total distance traveled by the change in time, regardless of any changes in motion or direction during its travel. 4. Motion of objects can be represented on a distance vs. time line graph, with distance traveled as the vertical ("y") axis and time as the horizontal ("x") axis. The steepness and slant of the motion line vary depending on the speed and direction of the moving objects. A straight horizontal line indicates an object at rest. GRADE-LEVEL CONCEPT 8.1.b 1. In order for an object to change its motion, a push/pull (force) must be applied over a distance. 2. Forces can act between objects that are in direct contact, or they can act over a distance. There are forces of attraction, such as gravity or magnetism, and forces of resistance, such as friction and drag (air resistance). Forces are measured in Newtons or pounds using scales.	1. Demonstrate how forces, including friction, act upon an object to change its position over time in relation to a fixed point of reference. 2. Calculate the average speed of an object and distinguish between instantaneous speed and average speed of an object. 3. Create and interpret distance-time graphs for objects moving at constant and nonconstant speeds. 4. Predict the motion of an object given the magnitude and direction of forces acting upon it (net force). 5. Investigate and demonstrate how unbalanced forces cause acceleration (change in speed and/or direction of an object's motion). 6. Assess in writing the relationship	C22. Calculate the average speed of a moving object and illustrate the motion of objects in graphs of distance over time. C23. Describe the qualitative relationships among force, mass and changes in motion. C24. Describe the forces acting on an object moving in a circular path.

	3. Forces can act simultaneously on an object from all directions with different strengths (magnitudes). When the magnitude and direction of all the forces acting on an object are combined, or added together, the total force (net force) determines the object's motion. Forces in opposite directions are subtracted; forces in the same direction are added. 4. If the strength of all the forces acting on an object from one direction is equivalent to the strength of the forces from the opposite direction, then the forces cancel each other out, and are said to be balanced. Balanced forces keep an object moving with the same speed and direction, including keeping it at rest. 5. If the net force acting on an object is not zero, then the forces are said to be unbalanced, and the object's speed or direction will change, changing its motion (acceleration). Acceleration is any change in motion, and occurs when something speeds up, slows down or changes direction. On a position time graph, this would be indicated by a change in the steepness of the motion line, or by a curved line. 6. The greater the unbalanced force on an object, the greater its change in motion (acceleration). The greater the mass of an object, the greater the force needed to change its acceleration. Given the same amount of force, an object with a greater mass will change acceleration less. The total net force acting on an object can be determined by measuring its mass and change in motion (acceleration). GRADE-LEVEL CONCEPT 8.1.c 1. Some objects continuously change direction without changing speed, causing them to move in a circular path. Circular motion is caused by a constant unbalanced force that is constantly changing direction and pulling towards the center. If there were no force pulling the object toward the center, it would continue to move in a straight line in the direction it was moving before the force was removed. SCIENTIFIC LITERACY TERMINOLOGY: Motion, point of reference, speed, constant speed, average speed, position-time graph, slope, force, friction, gravity, inertia, mass, acceleration, balanced/unbalanced forces, net force, circular motion	between an object's mass and its inertia when at rest and in motion. 7. Express mathematically how the mass of an object and the force acting on it affect its acceleration. 8. Design and conduct an experiment to determine how gravity and friction (air resistance) affect a falling object. 9. Illustrate how the circular motion of an object is caused by a center seeking force (centripetal force) resulting in the object's constant acceleration.	

CT Science Standard 8.1 – Force and Motion
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Massachusetts Learning Standards

Physical Science
Grades 6-8
Standard #11

Explain and give examples of how the motion of an object can be described by its position, direction of motion, and speed.

Physical Science
Grades 6-8
Standard #13

Differentiate between potential and kinetic energy. Identify situations where kinetic energy is transformed into potential energy and vice versa.

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Safety Standards

1. Review expectations for appropriate behavior, handling of materials, and cooperative group procedures to be sure those activities are accessible and safe for all students prior to beginning these investigations.
2. Make any necessary student modifications.
3. Monitor students to be sure they are acting appropriately, handling materials accordingly, and working cooperatively especially when working with moving objects.
4. For more comprehensive information on science safety, consult the following guidelines from the CT State Department of Education: http://www.sde.ct.gov/sde/lib/sde/pdf/curriculum/science/safety/middleschool_sciencesafety.pdf

CT Science Standard 8.1 – Force and Motion

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Misconceptions and Facts

Misconception	Fact
Gravity is a force that attracts objects to the surface of the earth.	Gravity pulls objects toward the center of the earth. Ex: People/objects fall into holes. Cars roll down hills. Objects sink in water.
Weight and mass are the same thing.	The mass of an object does not change, but changes in gravity will change the weight of the object.
Friction only occurs between solids.	Friction occurs between solids, liquids and gasses. Ex: Wind burnt face (solid/gas friction); Sailing, swimming, belly flop, (solid/liquid friction); High pressure washing (liquid/solid friction).
Constant speed needs constant force.	Once in motion, an object will stay in motion without additional force, unless acted upon by a force. Ex: Once a large snowball starts to roll down a hill, it will continue to roll until it comes to a stop.
Heavier objects fall faster.	In the absence of air resistance, all objects, regardless of mass, will fall at the same rate.
Acceleration indicates that a moving object has increased its speed.	Acceleration is a change in speed or direction. The object may increase or decrease speed or change its direction.
An object, moving in a circular path, will continue to move in a circular path once the force is released.	An object will move in a straight path from the point of release. Ex: An object attached to a cord that is spun in a circle will move out in a straight line once released.
Objects in space need a continuous force to keep them in motion.	There is no friction in space to affect motion. Once in motion, a space vehicle will continue to move in a straight line and at constant speed.

Other student misconceptions may be found at: http://www.eskimo.com/~billb/miscon/opphys.html
See also: American Association for the Advancement of Science, *Atlas of Science* Literacy, Project 2061.

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Pre-Visit Activity

The following highlighted GLE's and GLC's are covered in this section:

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ACTIVITY SUMMARY

A visit to the CT Science Center begins in your classroom with the pre-visit activities. Please consider these activities as a prerequisite that prepare your students for the actual visit. We encourage all teachers who bring their students to the CT Science Center to plan to do these pre and post activities and to plan on providing follow-up assessment and activities which integrate your visit into a meaningful unit of study.

Introduction

Motion is all around us, just take a look. People are moving about and objects are in use. Acting on the motion of all objects are visible and invisible forces alike. Students have experienced motion and forces for their entire life, yet many have not thought about how force can increase, decrease or change the direction of motion. After a visit to the CT Science Center, students will think about force and motion in a whole new way.

In this activity, students examine the motion of objects. They design an investigation that explores the effect of friction on motion and use mathematics to calculate and compare the speed of objects as they move down a ramp. As the students work with variables, such as, height of the ramp, and mass of the moving object, they begin to develop knowledge of the relationship between the variables. This activity should take one 50-60 minute class periods.

Purpose

Students will be able to:

- Design investigations that include objects of different masses, friction, force and ramps at various heights, angles, or lengths.
- Calculate and graph speed.
- Explore the relationship between force, mass and speed.

Activity Summary

Students will explore how height and mass affect the speed of a car. Once the initial engaging activities are completed, the students will have the opportunity to select a question of their choice to investigate. In a group of 3 or 4, the students will design, perform and report the findings of their investigation.

Materials

- Cars
- Ramps *(approx. 100 cm. in length)*
- Blocks *(or books)*
- Assorted Masses
- Stop Watches
- Measuring Tapes
- Calculators
- Protractors

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Engaging Activity

1. Divide students into groups and assign each group to one of the two stations. There may be multiples of Station A and Station B

    TASK CARD: Station A – Determine the relationship between the slope of the ramp and the speed of the car? Students will record the time it takes the car to travel down the ramp. Students will adjust the height of the ramp using blocks or books. The height of the ramp, the distance traveled by the car, the time it took the car to travel that distance, and other observations and questions should be written in the students' science notebook.
    TASK CARD: Station B – How does mass affect the speed of the car? Students will record the time it takes the car to travel down the ramp. Students will place various masses on the car as cargo. The mass of the car, the mass of the cargo, the distance traveled by the car, the time it took the car to travel that distance, and other observations and questions should be recorded.

Students will use these investigations as a basis for predicting what will happen and be able to explain their prediction.

2. Allow students to explore the question at the station for about 20 minutes. Students should predict what will happen. Students should do three trials of three different heights (Station A) and three different masses (Station B) and record their findings. Students write" I Notice" (Observe) and "I Wonder" (Question) statements regarding the investigation in their notebooks. Students should be able to explain their predictions.
3. Have the students switch stations and conduct the experiment at the second station. The students will proceed as in the first station to collect data.
4. Once the students have had 20 minutes at each station, students can put the materials away. Create a graph of their findings to share with the class.
5. Teacher synthesis and wrap up.

TASK CARD A

Determine the relationship between the slope of the ramp and the speed of the car.

TASK CARD B

How does the mass affect the speed of the car?

Discovery Center Activity

The following highlighted GLE's and GLC's are covered in this section:

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Design a Roller Coaster

Activity Preparation

In this activity the students will use pipe insulation to design a roller coaster. In preparation, the teacher needs to purchase ½" pipe insulation from a home improvement store. The pipe insulation needs to be cut down exactly down the center to make two "C" shaped pieces. A knife or scissors work best but care needs to be taken when cutting to make sure it is cut in the center.

Materials (For Each of the 10 Stations)

- ½" Pipe Insulation (Cut in half, the long way)
- Medium Diameter Marble
- Masking Tape
- Skewers, Styrofoam, paper towel or bathroom tissue roles to support the roller coaster

Introduction

When you ride a roller coaster, there are many forces at work. Sometimes it can be difficult to break them down in order to identify what is pushing and pulling on what. In this activity the students will have the opportunity to design their own roller coaster from pipe insulation, masking tape and wooden supports. The "cars" are going to be marbles. This is a somewhat flexible activity, you can develop rules or goals for the students to achieve, such as the fastest time down the track or they need to have a certain amount of loops, etc.

1. Students should be divided into groups of 2-4.
2. Give them any instructions that you feel they need to focus on, such as number of loops, fastest time, etc.
3. Before they receive their materials they need to develop a written plan showing the forces (as simple as arrows in the direction of the forces) that they think will be acting on the marble as it rolls through the track.
4. After facilitator approval, each group will receive 3 lengths of cut pipe insulation, with a role of masking tape, supports and a marble. If desired provide a stop watch as well.
5. Students should get about 20 minutes to build and test their coaster. After each test, the students should record what they observed happening and any questions they may have. Mention that they should keep a journal to keep track of any changes and thoughts they have on the coaster.
6. After the 20 minutes, go around the room and with the whole class paying attention test each of the coasters. Record the data on the board. Alternatively, have the students record their time, and if desired average speed down the roller coaster.

Wrap-Up:

After all the coasters have been tested, pull the class together and with a focus to the different forces, discuss what some of the challenges were, also what and why they made changes to their coasters in order to get them to do what they wanted. Also, what are some of the questions that they have regarding the forces that influenced their marble? Briefly discuss Newton's of Motion focusing on his First (Inertia – An object stays in motion or at rest until acted upon by an outside force) and Second Laws (Force = Mass x Acceleration).

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Trail Guides

We have created a set of "Trail Guides" for use by you and your students. The first section consists of the trail guides with teacher notes; the second section has the exact same Trail Guides without the teacher notes. You may copy these directly as handouts.

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	and forces of resistance, such as friction and drag (air resistance). Forces are measured in Newtons or pounds using scales. 3. Forces can act simultaneously on an object from all directions with different strengths (magnitudes). When the magnitude and direction of all the forces acting on an object are combined, or added together, the total force (net force) determines the object's motion. Forces in opposite directions are subtracted; forces in the same direction are added. 4. If the strength of all the forces acting on an object from one direction is equivalent to the strength of the forces from the opposite direction, then the forces cancel each other out, and are said to be balanced. Balanced forces keep an object moving with the same speed and direction, including keeping it at rest. 5. If the net force acting on an object is not zero, then the forces are said to be unbalanced, and the object's speed or direction will change, changing its motion (acceleration). Acceleration is any change in motion, and occurs when something speeds up, slows down or changes direction. On a position time graph, this would be indicated by a change in the steepness of the motion line, or by a curved line. 6. The greater the unbalanced force on an object, the greater its change in motion (acceleration). The greater the mass of an object, the greater the force needed to change its acceleration. Given the same amount of force, an object with a greater mass will change acceleration less. The total net force acting on an object can be determined by measuring its mass and change in motion (acceleration). GRADE-LEVEL CONCEPT 8.1.c 2. Some objects continuously change direction without changing speed, causing them to move in a circular path. Circular motion is caused by a constant unbalanced force that is constantly changing direction and pulling towards the center. If there were no force pulling the object toward the center, it would continue to move in a straight line in the direction it was moving before the force was removed. SCIENTIFIC LITERACY TERMINOLOGY: Motion, point of reference, speed, constant speed, average speed, position-time graph, slope, force, friction, gravity, inertia, mass, acceleration, balanced/unbalanced forces, net force, circular motion	unbalanced forces cause acceleration (change in speed and/or direction of an object's motion). 6. Assess in writing the relationship between an object's mass and its inertia when at rest and in motion. 7. Express mathematically how the mass of an object and the force acting on it affect its acceleration. 8. Design and conduct an experiment to determine how gravity and friction (air resistance) affect a falling object. 9. Illustrate how the circular motion of an object is caused by a center seeking force (centripetal force) resulting in the object's constant acceleration.	

Teacher Trail Guides

Trail Guide *First Robotics Exhibit*: 8.1 Forces and Motion

Visit the **Forces and Motion Gallery - 4th Floor North**

Robot Throw

What are 3 forces that act upon the ball as it leaves the robot's arm?

What could you do to get a perfect shot if the target were twice the distance?

Draw the path of the ball as it leaves the robotic arm.

Does the ball travel in a straight line? Why or why not?

Talk with a partner and then write your thoughts down in your science notebook.

Teacher Notes:
Gravity, air resistance (or friction), and thrust (from the arm) are all acting on the ball. The flight of the ball is affected by the energy of the ball as it leaves the robot and the mass of the ball. If you change the distance you need to change the speed of the throw, alter the trajectory of release, or change the mass of the projectile.
Standard 8.1 GLC #1b, 2b, 3b;
GLE #4

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Trail Guide *Test a Car*: 8.1 Forces and Motion

Visit the **Forces and Motion Gallery - 4th Floor North**

Test a Car (Mag-Lev Test Bed)

What are the forces working on the maglev train? Draw the track and vehicle. Label the forces that are at work.

How would you design a vehicle that would be more efficient, allowing it to travel faster?

Send a train down the track and record the time. What was the average speed of your train? (Record the color of your train also) Hint: the maglev track is 442 cm long.

Compare your ideas and results with a partner and then write your thoughts down in your science notebook

Write your reasoning in your science notebook. Discuss it with a partner.

Teachers Notes:
Magnetic levitation transport or maglev is a form of transportation that suspends guides or propels vehicles by electromagnetic force. There is no rolling friction between the track and the train. Excluding the effects of gravity; air resistance is the only force working against the forward motion of the train, allowing it to move quickly.
Students can use their imagination. Focus on more aerodynamic features of the train, the use of various materials or different track designs.

Forces at work include air resistance on the nose of the train, magnetic force between the track and the train, and inertia.
Standard 8.1 GLC #1a, 2a, 3a, 2b, 3b; GLE #2

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Trail Guide *Gravity Race*: 8.1 Forces and Motion

Visit the **Forces and Motion Gallery - 4th Floor North**

Square Wheel Cars

Find a partner and send a car without any additional weight on it down the track. Record the time. What was the average speed?

Add 4 weights to the car and position them so the weight is evenly distributed. Send the car down the track, record the time and find the average speed. Did the speed change? Why?

What forces are acting on the car?

Now build a car that you think will go fastest down the track. What variables are you taking into account? Record the time and find the average speed of your car. (The track is 356 cm long.)

Discuss your results with your partner and use your science notebooks to write down your thoughts.

Teachers note:
Gravity will slow down the car. Air resistance or drag, will also affect the motion of the car. Friction is also a factor. In the classroom you might want to put the whole class data together and see if there were any trends.
Standard 8.1 GLC #1a, 2a, 3a, 2b, 3b; GLE #1, 2, 5

Trail Guide *Helmet Crash Test*: 8.1 Forces and Motion

Visit the **Sports Gallery – 5th Floor South**

Helmet Crash Test

With a partner design an investigation that shows how the height of the hammer affects force.

Make a prediction and give a reason why you think this.

Show your data to prove or disprove your prediction.

What did you use as a control in this investigation?

Teachers Notes:
The investigation should have a testable question, a procedure and a data table. A prediction should be based on observation and be directly related to the testable question. An example of a control could be a trail without a helmet.
Standard 8.1 GLC # 2b

Trail Guide *Sporting Equipment*: 8.1 Forces and Motion

Visit the **Sports Gallery – 5th Floor South**

Sporting Equipment

Look at all the sporting equipment on the walls. Choose one sport and describe how the equipment is used to maximize or minimize the forces required to play the sport.

For example: *The kayak is streamlined so friction force is minimized as it goes through the water. The paddle has a large surface area so that it maximizes friction with the water allowing you to move. The life jacket adds buoyancy to your body making it easier for you to float on top of the water*

Discuss your ideas with a partner.

Teachers note:
All sports rely on friction, whether it be with the air, water, ground, or ice. Minimizing or maximizing the roll of friction in sports helps us perform better.
Standard 8.1 GLC #1b, 2b

CT Science Standard 8.1 – Force and Motion
An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Trail Guide *Sail into the Wind*: 8.1 Forces and Motion

Visit the **Forces and Motion Gallery – 4th Floor North**

Sail into the Wind

Experiment with the position of the sails. What position makes it go faster going towards and away from you? Calculate the average speed. (The track is 384 cm long.)

What forces are acting on the sail boat? Would this change if it were in water?

If you are sailing downwind (with the wind) how would you want to position your sails? Why?

Why do sailboats have a keel?

Discuss your ideas with a partner

Teachers notes:
The forces acting on a sailboat are drag, lift and gravity. The boats in the exhibit travel on a cushion of air so there is no buoyancy force present. When you are traveling downwind you want the sails to be out all the way because you are no longer relying on lift to move you through the water but just on the power of the wind. When traveling downwind you can only travel as fast as the wind is blowing, but then you are traveling upwind you can go faster than the wind. Sail boats have a keel to provide force to keep the boat moving straight in the water and from keeping the wind from knocking it down. Without a keel the boat would move sideways.
Standard 8.1 GLC #1a, 2a, 3a, 1b, 2b, 3b, 5b; GLE #2

Trail Guide *Heliflyers*: 8.1 Forces and Motion

Visit the **Forces and Motion Gallery – 4th Floor North**

Heliflyers

Construct a basic helicopter and put it over the fans. What forces are acting on the helicopter? Does it make a difference that the air is moving instead of the helicopter moving through the air?

Now design and test a helicopter that will either go the highest, stay in flight the longest, or carry the most weight. What were your findings? What factors did you have to think about when making your helicopter? Keep in mind that you might have to make a few helicopters before you achieve the results you're looking for.

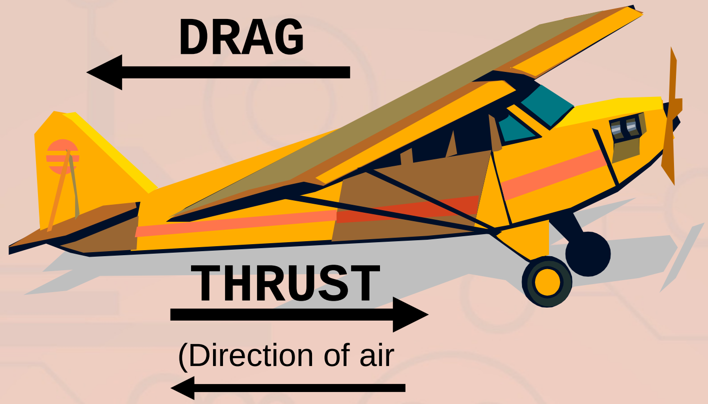
Compare your design with that of a partner, how were they the same, how were they different?

Teachers notes:
The main forces are lift, drag and gravity. When making the helicopters the students can change the length of the body, the length of the blades and many other factors. As an extension in the classroom see what forces the students tried to minimize or maximize to make their helicopters work the best.
Standard 8.1 GLC #1b, 2b, 3b, 5b; GLE #4, 8

5th Floor!

Gallery Science: 8.1 Wind Tunnel Science*

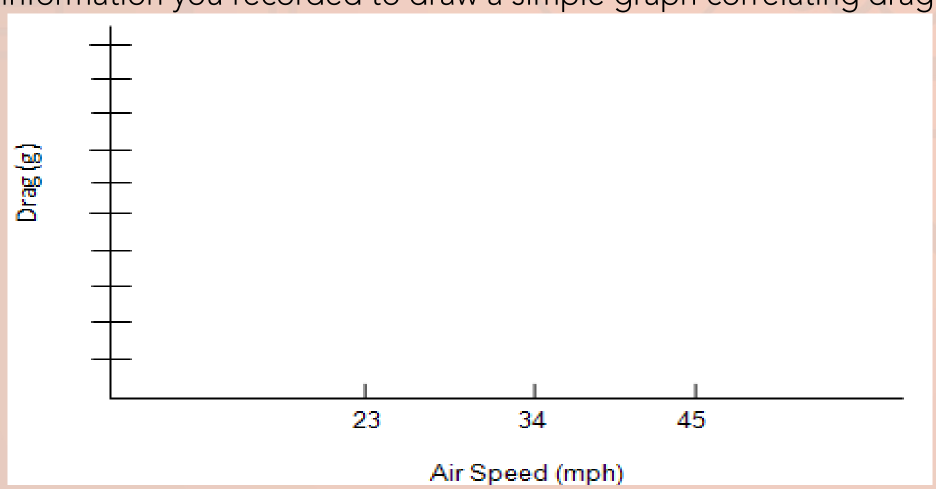
Find the Gallery Scientist
In the
Invention Dimension
Gallery!



Make a **paper plane** and bring it to the Gallery Scientist to test it in the wind tunnel!
Test the airplane and measure its drag at air speeds of 23 miles per hour, 34 miles per hour, and 45 miles per hour. Record the drag measurements below.

23 mph: ______ 34 mph: ______ 45 mph: ______

Now use the information you recorded to draw a simple graph correlating drag to air speed.



What would you modify about your plane to achieve lower drag measurements?

**If you wish for your students to take advantage of this Gallery Science program, you must make arrangements with a Gallery Scientist 30 days prior to your visit. For more information please contact TJ McKenna at tmckenna@ctsciencecenter.org.*

Student Trail Guides

Trail Guide *First Robotics Exhibit*: 8.1 Forces and Motion

Visit the **Forces and Motion Gallery - 4th Floor North**

First Robotics

What are 3 forces that act upon the ball as it leaves the robot's arm?

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Does the ball travel in a straight line? Why or why not?

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Trail Guide *Gravity Race*: 8.1 Forces and Motion

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What forces are acting on the car?

Now build a car that you think will go fastest down the track. What variables are you taking into account? Record the time and find the average speed of your car. (The track is 356 cm long.)

Discuss your results with your partner and use your science notebooks to write

Trail Guide *Helmet Crash Test*: 8.1 Forces and Motion

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Trail Guide *Sail into the Wind*: 8.1 Forces and Motion

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5th Floor!

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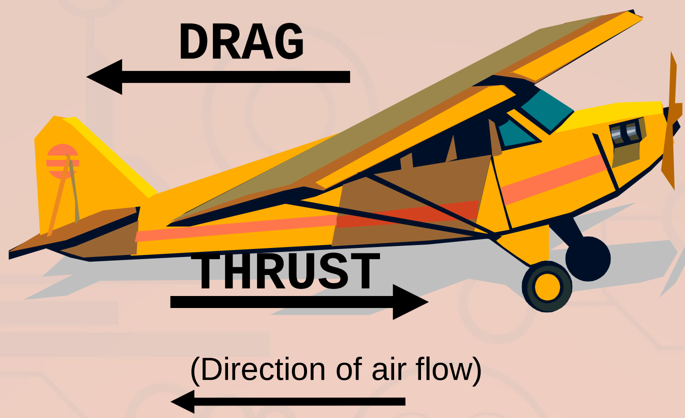

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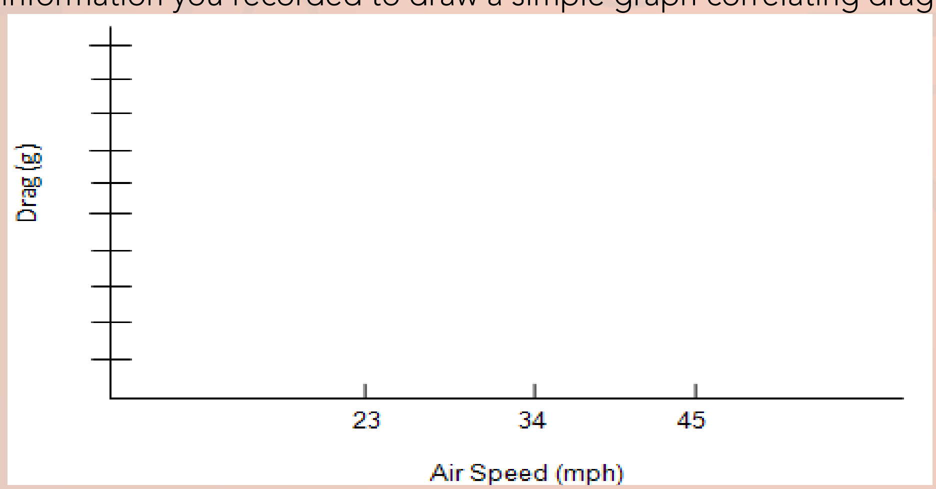


What would you modify about your plane to achieve lower drag measurements?

____

____

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Post Visit Activities

The following highlighted GLE's and GLC's are covered in this section:

Force and Motion – What makes objects move the way they do? GRADE 8			
8.1 — An object's inertia causes it to continue to moving the way it is moving unless it is acted upon by a force.			
Core Science Curriculum Framework	Underlying Concepts *Students should understand that…*	Grade-Level Expectations *Students should be able to…*	CMT Expected Performances
8.1.a The motion of an object can be described by its position, direction of motion and speed. 8.1.b An unbalanced force acting on an object changes its speed and/or direction of motion. 8.1.c Objects moving in circles must experience force acting toward the center.	GRADE-LEVEL CONCEPT 8.1.a 1. An object is said to be in motion when its position changes in relation to a point of reference. An object's motion can be described and represented graphically according to its position, direction of motion, and speed. 2. Speed describes the change in an object's position over a period of time, and is measured in units such as meters per second or miles per hour. 3. Average speed takes into account the different speeds at which an object moves over a period of time. Average speed is calculated by dividing the total distance traveled by the change in time, regardless of any changes in motion or direction during its travel. 4. Motion of objects can be represented on a distance vs. time line graph, with distance traveled as the vertical ("y") axis and time as the horizontal ("x") axis. The steepness and slant of the motion line vary depending on the speed and direction of the moving objects. A straight horizontal line indicates an object at rest. GRADE-LEVEL CONCEPT 8.1.b 1. In order for an object to change its motion, a push/pull (force) must be applied over a distance. 2. Forces can act between objects that are in direct contact, or they can act over a distance. There are forces of attraction, such as gravity or magnetism, and forces of resistance, such as friction and drag (air resistance). Forces are measured in Newtons or pounds using scales. 3. Forces can act simultaneously on an object from all directions with different strengths (magnitudes). When the magnitude and direction of all the forces acting on	1. Demonstrate how forces, including friction, act upon an object to change its position over time in relation to a fixed point of reference. 2. Calculate the average speed of an object and distinguish between instantaneous speed and average speed of an object. 3. Create and interpret distance-time graphs for objects moving at constant and nonconstant speeds. 4. Predict the motion of an object given the magnitude and direction of forces acting upon it (net force). 5. Investigate and demonstrate how unbalanced forces cause acceleration (change in speed and/or direction	**C22.** Calculate the average speed of a moving object and illustrate the motion of objects in graphs of distance over time. **C23.** Describe the qualitative relationships among force, mass and changes in motion. **C24.** Describe the forces acting on an object moving in a circular path.

	an object are combined, or added together, the total force (net force) determines the object's motion. Forces in opposite directions are subtracted; forces in the same direction are added. 4. If the strength of all the forces acting on an object from one direction is equivalent to the strength of the forces from the opposite direction, then the forces cancel each other out, and are said to be balanced. Balanced forces keep an object moving with the same speed and direction, including keeping it at rest. 5. If the net force acting on an object is not zero, then the forces are said to be unbalanced, and the object's speed or direction will change, changing its motion (acceleration). Acceleration is any change in motion, and occurs when something speeds up, slows down or changes direction. On a position time graph, this would be indicated by a change in the steepness of the motion line, or by a curved line. 6. The greater the unbalanced force on an object, the greater its change in motion (acceleration). The greater the mass of an object, the greater the force needed to change its acceleration. Given the same amount of force, an object with a greater mass will change acceleration less. The total net force acting on an object can be determined by measuring its mass and change in motion (acceleration). GRADE-LEVEL CONCEPT 8.1.c 1. Some objects continuously change direction without changing speed, causing them to move in a circular path. Circular motion is caused by a constant unbalanced force that is constantly changing direction and pulling towards the center. If there were no force pulling the object toward the center, it would continue to move in a straight line in the direction it was moving before the force was removed. SCIENTIFIC LITERACY TERMINOLOGY: Motion, point of reference, speed, constant speed, average speed, position-time graph, slope, force, friction, gravity, inertia, mass, acceleration, balanced/unbalanced forces, net force, circular motion	of an object's motion). 6. Assess in writing the relationship between an object's mass and its inertia when at rest and in motion. 7. Express mathematically how the mass of an object and the force acting on it affect its acceleration. 8. Design and conduct an experiment to determine how gravity and friction (air resistance) affect a falling object. 9. Illustrate how the circular motion of an object is caused by a center seeking force (centripetal force) resulting in the object's constant acceleration.	

CT Science Standard 8.1 – Force and Motion
An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Activity Preparation

The instructor will demonstrate the safe use of the trebuchets, the areas designated in the room for use and the direction of aim for the trebuchets. A clay ball will be used as a projectile and given to each of the groups. <u>No other projectile will be allowed.</u> Though the Trebuchets are less than 2 feet tall, they can throw a projectile a considerable distance, therefore safety measures must be taken when working with them. The instructor will demonstrate the apparatus and show the various positions of the arm. The students will be divided into groups of 3 and assigned one of two different activities to test the trebuchet. In one activity the students are changing the mass of the counter-weight. The second activity has them varying the position of the counter-weight. During both activities the students will record their observations and questions in their notebooks, as well as any other findings.

For best results the students should have <u>approximately 10 to 15 feet of free space</u> towards which to launch their clay projectiles. Though the clay should not cause any serious damage, it is always wise to avoid having the trebuchets aimed at any people, windows, doors, or anything else that might be damaged by the clay. Furthermore, if space is a concern, be sure to establish a safe procedure for firing the trebuchets and measuring the results.

Materials (For Each Of The 10 Stations)

- Trebuchet
- Clay Projectile *(approximately ½ inch in diameter)*
- Masses *(washers)*

Introduction

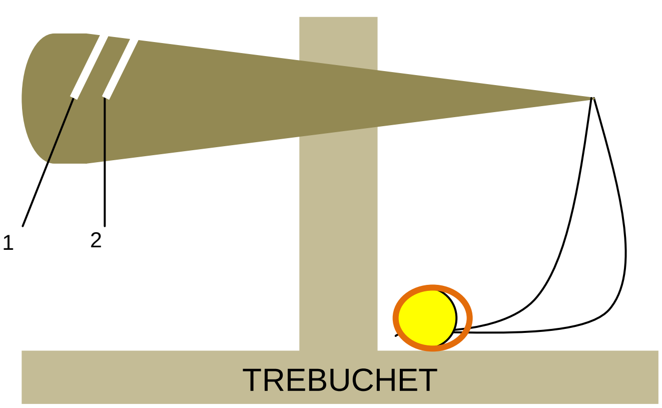
The instructor will start the class with an introduction of the concept of inertia and forces. The students will be shown the differences between a trebuchet and a catapult. In a catapult there is an elastic force pulling and holding the throwing arm in place. With a trebuchet the force is provided by gravity pulling down on the counterweight.

The instructor will explain that the students will be testing the position of the counterweight or the mass of the counterweight. For an interdisciplinary touch the teacher can provide the students with a history of the trebuchet as a weapon.

7. Students will be divided into groups of 3 and assigned to one of the trebuchet stations.
8. The stations will be divided so that ½ the groups are working on Activity A, while the other half work on Activity B
9. Students will be reminded before they begin their investigation that they must conduct a fair test.
10. Students will also be instructed on safely firing the trebuchets and measuring the results.

ACTIVITY A – ADJUSTING THE MASS OF THE COUNTER-WEIGHT

11. In activity A the students will vary the mass of the counter-weight.
12. Students at each station will be told to leave the



counter-weight at a set location.

13. Students have been provided with extra masses to add to the counter-weight.
14. Students will test the trebuchet with different masses attached to the counter-weight.
15. Students will compare the distance the projectile is thrown with the different masses on the counter-weight.
16. What conclusions can students draw from this experiment?
17. What explanation can you give for your results?

ACTIVITY B – ADJUSTING THE LOCATION OF THE COUNTER-WEIGHT

18. In activity B the students will vary the location of the counter-weight on the arm.
19. Students will be told not to adjust the amount of mass on the counter-weight.
20. Students will have two slits in the arm where they can place the counter-weight *(Marked 1, and 2)*
21. Students will test the trebuchet with the counter weight in each of the different locations.
22. Students will compare the distance the projectile is thrown with the weight in each of the locations.
23. What conclusions can you draw from this experiment?
24. What explanations can you give for your results?

CLOSURE:

To conclude the lesson and draw the different concepts together, the instructor will assess the students understanding of inertia and forces, as well as addressing the concepts of mechanical advantage and leverage. The teacher may provide the students with the following examples, pressing a nail into a board with your hand compared to using a hammer. Holding the hammer near the head compared to holding the hammer at the end of the handle. Holding a baseball bat near the top compared to holding near the bottom. All of these examples reinforce the concepts of leverage and gravity and how they can play an important role on the forces that affect our lives every day.

ACTIVITY A

COMPARING THE MASS OF THE COUNTER-WEIGHT

- Always keep the counter-weight of the trebuchet at the same location.
- You have been provided with extra masses to add to the counter-weight.
- Test the trebuchet with different masses attached to the counter-weight; including the mass you were provided.
- For the best results, test each mass several times.
- You can add or remove mass as you feel is appropriate.
- Record your results after each test of the trebuchet.
- Compare the distance the projectile is thrown with the different masses on the counter-weight.
- What conclusions can you draw from this experiment?
- What explanation can you give for your results?

ACTIVITY B

COMPARING THE LOCATION OF THE COUNTER-WEIGHT

- Always keep the same mass on the counter-weight.
- The trebuchet has two slots in the arm where you can place the counter weight.
- Test the trebuchet with the counter weight in each of the different locations.
- For the best results, test each position several times.
- Record your results after each test of the trebuchet.
- What conclusions can you draw from this experiment?
- What explanation can you give for your results?

Post-Visit Activity Two
Parachutes

The study of force and motion, coupled with the experiences of the pre-visit activities, the CSC classroom activity, and the visit to the galleries in the Science Center that also pertain to force and motion can now be discussed in total.

Post Visit Assessment

Students will work in small groups to construct square parachutes of various sizes. Students will take turns dropping the parachutes, observing the drops, and timing and recording their observations on a data sheet. The students use the data obtained to create a bar graph so that comparisons can be made.

Objective:

Students will:

- Work in small groups to construct parachutes
- Measure sides of a square in centimeters
- Predict how long it will take the parachutes to descend to the ground
- Work cooperatively to obtain and record data
- Complete a bar graph using collected data
- Use data to draw conclusions about the relationship of parachute size to the time of descent

Materials:

- Pencils
- Scissors
- String
- Tape
- Glue Stick
- Ruler
- White plastic garbage bag (24" x 28")
- Permanent Markers – optional for decorating parachute
- Timer/Stop watch
- Data Sheet

Each Parachute requires:

- 1 square piece of plastic bag
- 122 cm (48") of string cut into 4 equal lengths
- Tape for string
- Metal Washers (as weights)

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Activity:

1. Organize students in groups of 2 or 3 and have them decide on which task they will perform
2. Distribute the necessary materials to each group. Measure four separate squares on the plastic bag and label 25 cm, 28 cm, 30cm, and 33cm on the corresponding parachute.
3. Review any safety instructions. Take turns to drop the parachutes so that there are no accidents.
4. Construct the parachutes. Follow the directions and create each parachute the same way.
   a. Cut the long string into four equal pieces by folding it in half, then in half again. Cut on the folded ends.
   b. Lay the plastic square flat and attach one string to each corner with a small piece of tape.
   c. Gather the four loose ends of string and tie them onto 2 or 3 metal washers. Use the same amount of washers for each trial.
5. When everyone has made their parachutes review the technique for dropping parachutes. If you are in a classroom, a simple technique is to pinch the top of the parachute gently, hold at arm's length above your head, and drop.
6. Next step is to practice how to time your drop with timer/stop watch.
7. Review the datasheet together and assign a recorder for each group.
8. Each student should record their predictions about the duration of the fall.
9. Students take turns dropping parachutes while the recorder gathers the information for the group. After each drop other group members can fill in their individual data sheets.
10. When all groups are done, each group should complete a bar graph with their findings.
11. Come together and allow each group to share their findings.

Note: Students should conclude the larger parachute; the slower it will drop because it catches more air, creating more drag: therefore slowing the rate of descent.

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

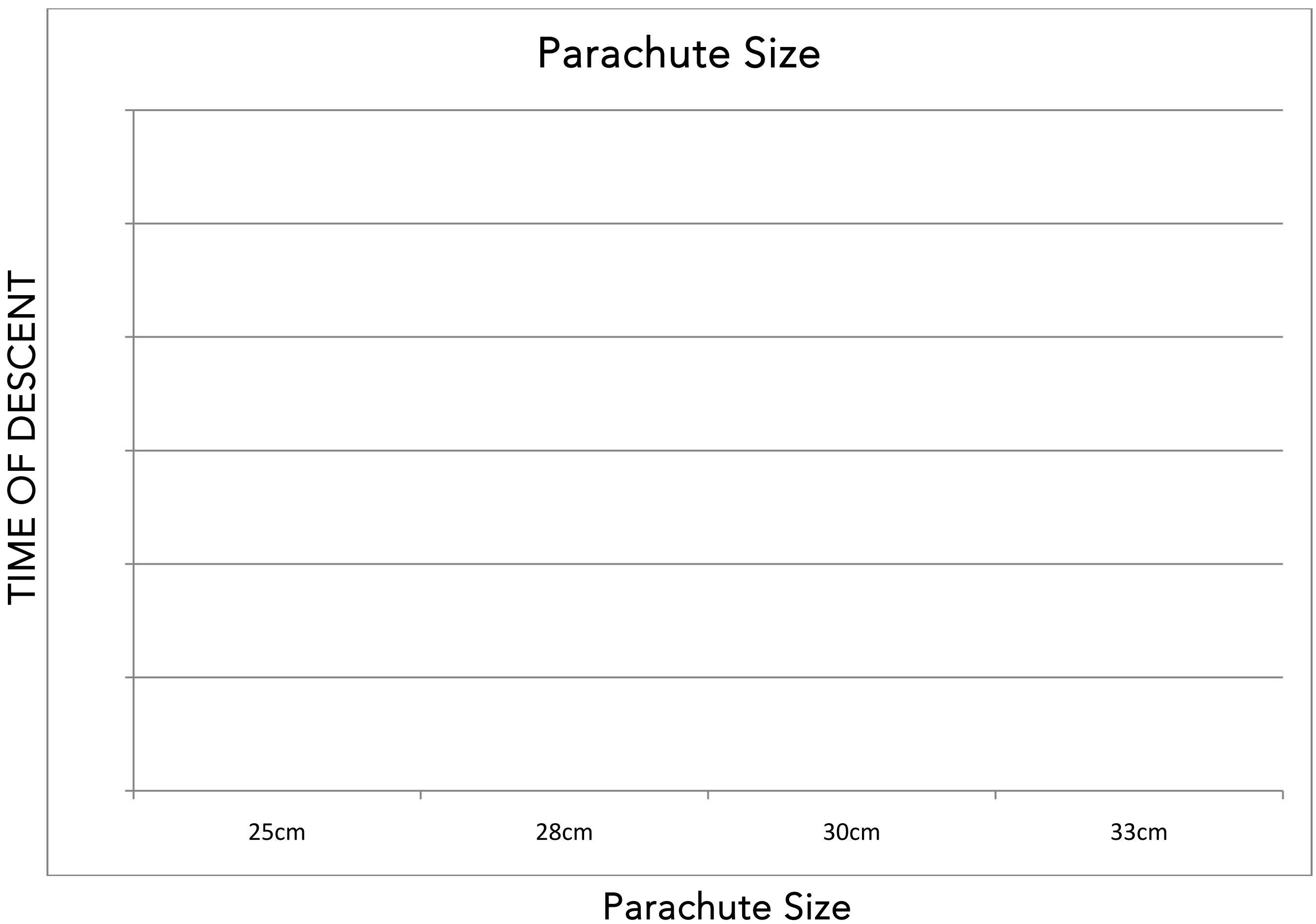
Parachute Drop Data Sheet

Name:

Predictions and Observations:

Parachute	Trial 1 (seconds)	Trial 2 (seconds)	Difference (seconds)
25cm			
28cm			
30cm			
33cm			

Use the data from the Actual Time column to fill in the bar graph below:



Performance Task

Using the experiences from the Science Center and from unit work, encourage the students to design and/or construct a skateboard or amusement park. This activity can be done with pencil and paper or with a computer program. Students can also build a miniature skateboard park or amusement park using cardboard and 'found' items. Students should be able to label where force and motion are demonstrated on their models.

Curriculum Embedded Performance Task

Middle School Science

Content Standard 8.1

Shipping and Sliding

Teacher Manual

Connecticut State Department of Education
Bureau of Curriculum and Instruction

Acknowledgements

The Connecticut State Department of Education is grateful to the many dedicated science educators who contributed to the development of the elementary, middle and high school curriculum-embedded performance tasks and teacher manuals. Beginning with the initial ideas for tasks, through the classroom field testing, to the guidelines for classroom implementation, these inquiry teaching and learning activities are the result of the creativity, experiences and insights of Connecticut's finest science educators. We thank all of you, too numerous to list, who gave your time and energy so generously to this project.

Overview of the Elementary and Middle School Curriculum-Embedded Performance Task Model

The Connecticut State Board of Education approved the Core Science Curriculum Framework in October of 2004. The framework promotes a balanced approach to PK-12 science education that develops student understanding of science content and investigative processes.

WHAT IS A CURRICULUM-EMBEDDED PERFORMANCE TASK?

Curriculum-embedded performance tasks are examples of teaching and learning activities that engage students in using inquiry process skills to deepen their understanding of concepts described in the science framework. Developed by teachers working with the Connecticut State Department of Education, the performance tasks are intended to influence a constructivist approach to teaching and learning science throughout the school year. They will also provide a context for CMT questions assessing students' ability to do scientific inquiry.

The three elementary performance tasks are conceptually related to Content Standards in Grades 3 to 5 and the three middle school performance tasks are related to Content Standards in Grades 6 to 8. The elementary performance tasks provide opportunities for students to use the Inquiry Expected Performances for Grades 3 to 5 (see Science Framework B.INQ 1-10 skills) to understand science concepts. The middle school performance tasks provide opportunities for students to use the Inquiry Expected Performances for Grades 6 to 8 (see Science Framework C.INQ 1-10 skills) to understand science concepts. **Teachers are encouraged to use the state-developed curriculum-embedded performance tasks in conjunction with numerous other learning activities that incorporate similar inquiry process skills to deepen understanding of science concepts.** Students who regularly practice and receive feedback on problem-solving and critical thinking skills will steadily gain proficiency.

HOW ARE THE PERFORMANCE TASKS STRUCTURED?

Each performance task includes two investigations; one that provides some structure and direction for students, and a second that allows students more opportunity to operate independently. The goal is to gradually increase students' independent questioning, planning and data analysis skills. The elementary performance tasks introduce students to understanding and conducting "fair tests". The middle school performance tasks focus on designing investigations that test cause/effect relationships by manipulating variables.

Mathematics provides a useful "language" for quantifying scientific observations, displaying data and analyzing findings. Each curriculum-embedded performance task offers opportunities for students to apply mathematics processes such as measuring, weighing, averaging or graphing, to answer scientific questions.

Not all science knowledge can be derived from the performance of a hands-on task. Therefore, each curriculum-embedded task gives students opportunities to expand their understanding of concepts through reading, writing, speaking and listening components. These elements foster student collaboration, classroom discourse, and the establishment of a science learning community.

A useful structure for inquiry-based learning units follows a LEARNING CYCLE model. One such model, the "5-E Model", engages students in experiences that allow them to observe, question and make tentative explanations before formal instruction and terminology is introduced. Generally, there are five stages in an inquiry learning unit:

- **Engagement:** stimulate students' interest, curiosity and preconceptions;
- **Exploration**: first-hand experiences with concepts without direct instruction;
- **Explanation:** students' explanations followed by introduction of formal terms and clarifications;
- **Elaboration:** applying knowledge to solve a problem. Students frequently develop and complete their own well-designed investigations;
- **Evaluation:** students and teachers reflect on change in conceptual understanding and identify ideas still "under development".

The performance tasks follow the "5-E" learning cycle described above. However, the teacher can decide the role the performance task will play within the larger context of the entire learning unit. Early in a learning unit, the performance task can be used for engagement and exploration; later in a learning unit, the performance task might be used as a formative assessment of specific skills.

HOW ARE PERFORMANCE TASKS USED WITH YOUR CLASS?

Curriculum-embedded performance tasks are designed to be used as part of a learning unit related to a Framework Content Standard. For example, while teaching a unit about human body systems (Content Standard 7.2,) the teacher decides the appropriate time to incorporate the "Feel The Beat" performance task to investigate factors affecting pulse rate. In this way, the natural flow of the planned curriculum is not disrupted by the sudden introduction of an activity sequence unrelated to what students are studying.

The performance tasks are NOT intended to be administered as summative tests. Students are not expected to be able to complete all components of the tasks independently. Teachers play an important role in providing guidance and feedback as students work toward a greater level of independence. Performance tasks provide many opportunities for "teachable moments" during which teachers can provide lessons on the skills necessary for students to proceed independently.

There is no single "correct" answer for any of the performance tasks. Students' conclusions, however, should be logical, or "valid" interpretations of data collected in a systematic or "reliable" way. Variations in students' procedures, data and conclusions provide opportunities for fruitful class discussions about designing "fair tests" and controlling variables. In the scientific community, scientists present their methods, findings and conclusions to their peers for critical review. Similarly, in the science classroom, students' critical thinking skills are developed when they participate in a learning community in which students critique their own work and the work of their peers.

Performance tasks should be *differentiated* to accommodate students' learning needs and prior experiences. The main goal is to give <u>all</u> students opportunities to become curious, pose questions, collect and analyze data, and communicate conclusions. For different learners, these same actions will require different levels of "scaffolding" as they move toward greater levels of independence. For example, if students have had experiences creating their own data tables, the teacher may decide to delete part or all of the data table included in the performance task. Other possible adjustments include (but are not limited to):

- Text readability;
- Allowing students to control all or some of the variables;

- Whether the experimental procedure is provided or student-created;
- Graph labels and scales provided or student-created;
- Expectations for communication of results; or
- Opportunities for student-initiated follow-up investigations.

There are many science investigations that are currently used in schools that provide inquiry learning opportunities similar to those illustrated in the performance tasks. Students need a variety of classroom experiences to deepen their understanding of a science concept and to become proficient in using scientific processes, analysis and communication. **Teachers are encouraged to use the state-developed curriculum-embedded performance tasks in conjunction with numerous other learning activities that incorporate similar inquiry processes and critical thinking skills.**

HOW ARE THE PERFORMANCE TASKS RELATED TO THE CMT?

The new Science CMT for Grades 5 and 8 will assess students' understanding of inquiry and the nature of science through questions framed within the CONTEXT of the curriculum-embedded performance tasks. Students are not expected to recall the SPECIFIC DETAILS OR THE "RIGHT" ANSWER to any performance task. The questions, similar to the examples shown below, will assess students' general understandings of scientific observations, investigable questions, designing "fair tests", making evidence-based conclusions and judging experimental quality.

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Here is an example of the type of multiple-choice question that might appear on the Grade 5 Science CMT. The question is related to the "Soggy Paper" performance task:

> Some students did an experiment to find out which type of paper holds the most water. They followed these steps:
>
> 1. Fill a container with 25 milliliters of water.
> 2. Dip pieces of paper towel into the water until all the water is absorbed.
> 3. Count how many pieces of paper towel were used to absorb all the water.
> 4. Repeat with tissues and napkins.
>
> If another group of students wanted to repeat this experiment, which information would be most important for them to know?
>
> a. The size of the water container
> b. The size of the paper pieces *
> c. When the experiment was done
> d. How many students were in the group

Here is an example of the type of constructed-response question that might appear on the Grade 8 Science CMT. The question is related to the "Feel The Beat" performance task:

> Imagine that you want to do a pulse rate experiment to enter in the school science fair. You've decided to investigate whether listening to different kinds of music affects people's pulse rate.
>
> Write a step-by-step procedure you could use to collect reliable data related to your question. Include enough detail so that someone else could conduct the same experiment and get similar results.

NOTE THAT THE CMT QUESTIONS DO NOT ASSESS A CORRECT "OUTCOME" OF A PERFORMANCE TASK OR STUDENTS' RECOLLECTION OF THE DETAILS OF THE PERFORMANCE TASK. Students who have had numerous opportunities to make observations, design experiments, collect data and form evidence-based conclusions are likely to be able to answer the task-related CMT questions correctly, even if they have not done the state-developed performance tasks. However, familiarity with the context referred to in the test question may make it easier for students to answer the question correctly.

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Introduction to "Slipping and Sliding"

In this performance task, students will explore variables that affect the friction between two surfaces. First, they will conduct a guided inquiry to find out how the properties of surface materials affect friction. Then they will design their own experiment to explore an independent variable that they choose.

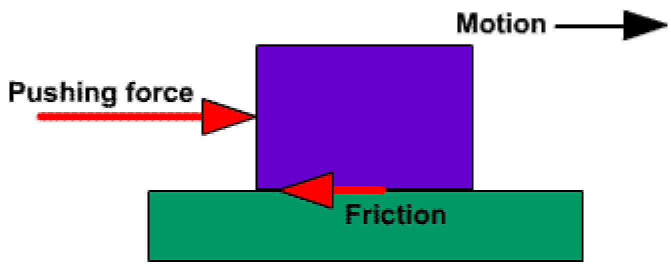
SAFETY NOTES:

- Review expectations for appropriate behavior, handling of materials and cooperative group procedures prior to beginning this investigation.
- For more comprehensive information on science safety, consult the following guideline from Council of State Science Supervisors - http://www.csss-science.org/downloads/scisaf_cal.pdf

BACKGROUND:

Friction is a force that resists motion. It is present whenever two surfaces slide against each other. Although surfaces might look smooth, viewed under a microscope they are actually rough and jagged. When the surfaces are pushed or pulled against each other, their tiny jagged points get caught, making movement difficult.

The physical properties of different surfaces affect the amount of friction that results when they contact each other. The greater the friction force between the two surfaces, the greater the force needed to cause motion.



FRAMEWORK CONTENT STANDARD:

Shipping and Sliding is related conceptually to the following learning unit - An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

UNDERLYING SCIENCE CONCEPTS (KEY IDEAS):

- Friction is a force that resists motion and is present whenever two surfaces are in contact with each other.
- The amount of friction can vary depending upon the properties of the two surfaces in contact and the amount of force between the two objects.

KEY INQUIRY SKILLS:

- Pose investigable questions based on observations
- Identify dependent and independent variables and constants
- Present data in an organized format
- Interpret data to form conclusions
- Apply experimental results to solve problems

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

MATERIALS NEEDED:

Listed below are all the materials needed to complete the two experiments in Shipping and Sliding. Some materials are supplied in starter kits provided by the Connecticut State Department of Education. These materials are marked with an asterisk (*). The remaining materials are supplied by the school district:

20 small washers	2 plastic cups to hold washers
20 large washers (or 25g, 50g, 100g, 200g weights)	Ruler
1 wooden block (approx. 10cm x 6cm x 3cm) *	Masking tape
1 Masonite test surface *	String (1 m)
2 or 3 jumbo paper clips	Access to a balance or scale
A plastic cylinder (a pen, for example)	Graph paper
Various surface materials for testing	

- If these materials are not available, substitutions can be made. The plastic cylinder can be replaced with a smooth wooden dowel and the wood block can be replaced with any rectangular object (e.g., a Jell-O box, package of index cards, etc.)
- Note: students might need more than 20 small washers for certain trials depending on variables altered.

ADVANCE PREPARATION FOR THE TEACHER:

1. Carefully read through all teacher and student materials. Modify the Student Materials based on the needs of your students. Then print and photocopy Student Materials.
2. Read the ENGAGE scenario aloud with students several days before beginning the actual experiments. Ask students to bring in samples of different surface materials whose friction properties they are interested in testing.
3. Gather all materials prior to the first day to ensure an orderly and efficient distribution. Suggestions include a "cafeteria line" in which supplies are laid out on the counter and students proceed through to take necessary amounts or a "packaged set" approach where appropriate supplies are already organized in separate containers and students obtain one container per group.
4. Determine laboratory groups to ease confusion at the introduction to the experiment.

ESTIMATED COMPLETION TIME AND PACING SUGGESTIONS:

Timing varies depending on the length of the class period. The **minimum** suggested classroom time is 110 minutes with some activities, such as the graph and the conclusions, completed at home. Listed below are two possible options that may be used for pacing:

- Option 1 (40-45 minute periods)

  Day 1: Teacher introduction of first task and lab partner discussion of experimental design. (This can be completed for HW) Students should complete up through step five before the next class period.

  Day 2: Teacher approval of design and performance of first task. Students will complete this at varying time lengths and should work on completing steps seven through eleven. If not complete, this should be finished for HW.

Day 3: Teacher introduction of second task and group discussion of experimental design. Due to familiarity with the procedure, this will require less time and after teacher approval, students may begin the second task.
Day 4: If necessary, students should finish the second task. Remaining time should be used for group discussion and completion of calculations and questions.

- Option 2 (90 minute periods)
  Day 1: Teacher introduction of first task and development of experimental design. This is followed by teacher approval of design and performance of task. Students will complete this at varying time lengths and should work on completing steps seven through eleven to be finished for HW.
  Day 2: Teacher introduction of second task and group discussion of experimental design. Due to familiarity with the procedure, this will be accomplished with less time and after teacher approval, students may begin the second task. Remaining time should be used for group discussion and completion of calculations and questions.

PEDAGOGY:

Consult the teacher notes accompanying each step of the performance task for suggestions related to classroom implementation, differentiation, assessment and extension strategies. The ▲ symbol is used to indicate a differentiation opportunity. Each Teacher Note is followed by a reference to the Framework inquiry skill featured in that task component. For example, the notation "**C INQ.3**" indicates an inquiry skill related to designing or conducting a simple investigation.

Shipping and Sliding

A Guided Exploration of Factors Affecting Friction

ENGAGE

Many of the products we use are made or grown in other countries and sent here by plane, boat or truck. Some companies that make televisions, for example, put them in wood boxes that are carried here by cargo ships. When ocean waves cause the ship to tilt from side to side, the boxes sometimes slide across the cargo room floor and damage the televisions packed inside. Increasing the friction in the cargo room may solve the problem. The television manufacturer is willing to change the box materials and the shipping company is willing to change the floor materials. Imagine that you have been hired to conduct a friction study that will explore ways to increase the friction force and solve the problem of the sliding boxes.

Teacher notes:
Prompts can include:

- *"How can we cause the boxes not to slide?"*
- *Connection of friction with icy road conditions*
- *Discussion of friction with various shoe surfaces*
- *When is friction considered a "bad thing" vs. a "good thing?"*
- *How did friction help you get to school?*
- *Connection with sports – ex/ wax on skis, sneakers*

A quick demonstration of friction could be having the students quickly rub their hands together with varying speed and amounts of pressure.

EXPLORE

First, you and your partners will design and conduct experiments to find how friction is affected by different box and floor materials. Next, you will identify and explore another variable that may also affect friction. Then, you will analyze your experimental findings to make recommendations to the television manufacturer or the shipping company.

Get Ready

The first question you will explore in this investigation is the friction force created when different surface materials slide against each other. Gather a variety of different textured materials from home or school that you can test by attaching them to a model shipping box or cargo room floor. You may choose to experiment with **floor** materials (such as felt, carpet, sandpaper or tiles), or you may choose to test different **box** materials such as plastic, metal, wood or different papers.

Teacher notes:
Discuss possible materials for simulating different floor surfaces.

Bring these materials to class the day before you begin your friction experiments.

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Teacher notes: As a back-up, provide a variety of materials for testing. Simulated floor surfaces can include samples of felt, tile, carpet, wood, and foil. For students who are varying the box materials, provide a variety of materials that shipping containers could be made from.

In addition to your own collection of textured materials, your teacher will provide your group with the following supplies:

20 small washers	2 plastic cups to hold washers
20 large washers (or 25g, 50g, 100g, 200g weights)	Ruler
1 wooden block (approx. 10cm x 6cm x 3cm) *	Masking tape
1 Masonite test surface *	String (1 m)
2 or 3 jumbo paper clips	Access to a balance or scale
A plastic cylinder (a pen, for example)	Graph paper
Various surface materials for testing	

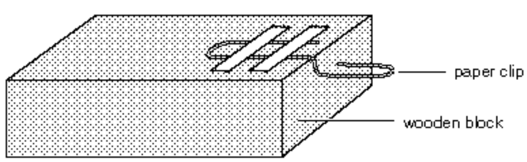
Experiment #1: Effect of Materials on Friction Force

In this investigation, you will explore which combinations of floor and box materials create more or less friction. A simple way to measure friction is described below:

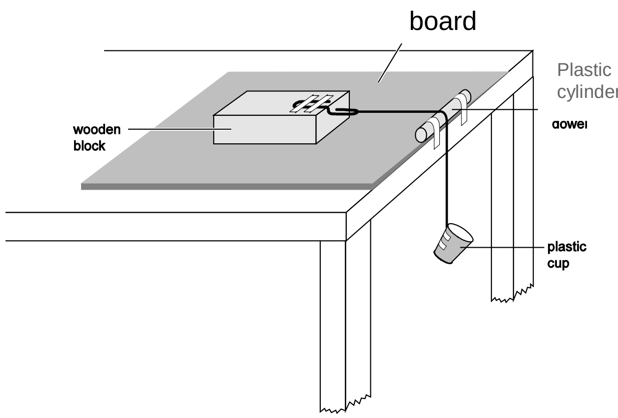
A Method for Testing Friction:

Teacher notes: You may find it helpful to demonstrate steps 1-5 as they are discussed.

1. Construct a model shipping box like the one in the diagram below. The paper clip will allow you to pull the box with a measured amount of force:



2. Use a piece of cardboard as a model of a cargo room floor.
3. Tape a plastic cylinder along the edge of your work table. Place the cardboard shipping floor on your work table near the plastic cylinder.
4. Tie a loop at one end of the string and attach the loop to the paper clip. Drape the string over the plastic cylinder and use tape to attach the plastic cup to the other end of the string (see diagram below).



5. By adding small washers to the plastic cup, you can measure the pulling force needed to start the box moving. The more force needed to start the box moving, the greater the friction between the floor and the box materials. You can keep track of the number of washers, or you can find the mass of a single washer and keep track of the total mass needed to start the box moving.

Conduct Your Experiment

1. Identify the **question** you will investigate.

Teacher notes: Students may choose to keep the floor material constant and explore the friction created by changing the box materials, or they may keep the box material constant and vary the floor materials. Students should be sure to include both an independent and dependent variable. C INQ.1

2. **Predict**, based on your experiences, which materials will have the greatest and least amount of friction.

Teacher notes: C INQ.1

3. Design a **procedure** to collect data to answer your research question. Identify the **independent** and **dependent** variables in your experiment. Think about the parts of your experiment that should be kept **constant** so you can collect consistent data.

Teacher notes: Students should be made aware that they need to quantify the amount of motion necessary. For example, they can require the block to move 10 cm. each time or if they state the block will hit the cylinder, they need to give the starting measurement of the block. This will allow the variable of movement to remain constant. In addition, multiple trials are necessary to increase validity of results. Remind students that their design should include enough detail so that it can be easily replicated. C INQ.3

4. Write your procedure in your science notebook. Include enough detail so that you or someone else could repeat your experiment.

Teacher notes: C INQ.3

5. Create a **data table** to record data related to your experiment.

Teacher notes: Depending on your students' experiences creating their own data tables, you may want to provide them with a blank table without any labels, or you might provide some of the column and row labels. C INQ.5

6. Do your experiment and **record** your findings in your data table.

Teacher notes: Students should be reminded to keep individual data because they will be completing the laboratory report individually. C INQ.5

7. Think about the data you have collected. Do the data for each trial seem reasonable? If not, do you need to repeat any trials to correct any **errors**?

Teacher notes: Encourage students to look do multiple trials, and to look for data that does not fit the pattern. C INQ.5

8. **Analyze** the data.

Teacher notes: Students may need guidance in how to calculate the pulling force needed to overcome the friction force. Remind students that appropriate units are necessary. C INQ.6

9. **Interpret** the data. Write your conclusions in your science notebook.

*Teacher notes: What **assumptions** can be made about friction and materials by interpreting the data from the experiment? Were there any surprises? What questions might require further testing?* C INQ.8

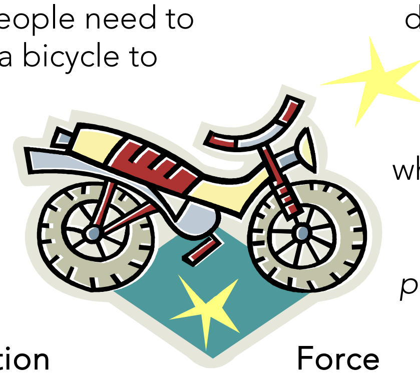
10. **Compare** your experimental design and results with others in your class.

Teacher notes: Facilitate a post-lab discussion to compare methods and results. C INQ.10

Prompts can include:

- *Are your data reliable? How confident are you in the accuracy of your measurements?*
- *What are some potential errors that might have occurred during your experiment?*
- *How can you improve this experiment if you were to repeat it?*
- *What other factors affect friction that you could have investigated?*

Sometimes, people need to increase friction in order to perform a task. For example, adding ridges to a bicycle tire gives it better traction. At other times, people need to decrease friction. For example, grease is applied to the wheels of a bicycle to reduce friction and let the wheels spin easily.



In addition to the properties of the surface materials, what other factors do you think might affect friction?

Teacher notes: Lead a class discussion during which possible factors are listed. C INQ.1

Experiment #2: Effect of Mass or Surface Area on Friction Force

Design and conduct an experiment to explore one of these factors. Keep a detailed and organized record of your experimental design, data collection and analysis in your science notebook.

Teacher notes: Students may also explore other factors that might affect friction.

1. What **ideas** do you have about the way in which mass or surface area might affect friction? Discuss your ideas and predictions with your partners.

Teacher notes: CINQ.1

2. Identify the **question** you will investigate and the results you **predict**.

Teacher notes: Check that students mention both an independent and a dependent variable (cause and effect). Students may change the mass of the block and leave the surface area constant or they may change the surface area and keep the mass of the block constant. CINQ.1

3. Design a **procedure** to collect data to answer your research question. Identify the **independent** and **dependent** variables in your experiment. Think about the parts of your experiment that should be kept **constant** so you can collect consistent data.

Teacher notes: Mass can be altered by adding washers to the top of the block. Surface area can be an altered by rotating the block. C INQ.4

4. Write your procedure in your science notebook. Include enough detail so that you or someone else could repeat your experiment.

Teacher notes: C INQ.3

5. Create a **data table** to record data related to your experiment.

Teacher notes: Students should draw on their previous experience in Experiment #1 to design a data table appropriate for their experiment. C INQ.5

6. Do your experiment and **record** your findings in your data table.

Teacher notes: C INQ.5

7. Think about the data you have collected. Do the data for each trial seem generally consistent? If not, do you need to repeat any trials to correct any **errors**?

Teacher notes: C INQ.8

8. **Analyze** the data. Show your calculations in your science notebook.

Teacher notes: If students varied the mass of the box, calculate the mass of washers on the box. If they varied the surface area, calculate the area of the box in contact with the floor. Then, average the number (or mass) of small washers needed to start the box moving in all of the trials. C INQ.6

9. **Graph** your analyzed data. Think about the most appropriate type of graph to show a relationship between two variables.

CT Science Standard 8.1 – Force and Motion

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Teacher notes: Students may need guidance in deciding the appropriate graph to represent the data. In addition, some students may require assistance in the construction of their graph. CINQ.7

10. **Interpret** the data. Based on your experiment, what conclusions can you make about the effect of surface area or mass on the friction between two surfaces?

Teacher notes: C INQ.8

11. Share and compare your results with others in your class. How were they alike? How were they different?

Teacher notes: C INQ.10

Communicate Your Findings

Use the findings from your friction experiments to solve the sliding box problem. Talk with your partners about what changes might be made to the shipping boxes, the way the TVs are packed in the boxes, or the cargo room floor to increase the friction and reduce the sliding.

Write a Report:

Write a report to the TV manufacturer or the shipping company describing your research and recommendations for reducing the sliding of the shipping boxes.

Your report should include:

- a clear statement of the problem you investigated;
- a description of the experiments you carried out;
- the results of your experiments (including data presented in the form of charts, tables or graphs);
- your conclusions from the experiments;
- comments about how experimental errors may have affected your results; and
- a recommendation to the company about changes that should be made to the shipping boxes or the cargo room floor to reduce the sliding box problem on the ship.

Teacher notes: C INQ.10

Curriculum Embedded Performance Task
Middle School Science
Content Standard 8.1

Shipping and Sliding

Student Materials

Connecticut State Department of Education
Bureau of Curriculum and Instruction

CT Science Standard 8.1 – Force and Motion

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Shipping and Sliding

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Bring these materials to class the day before you begin your friction experiments.

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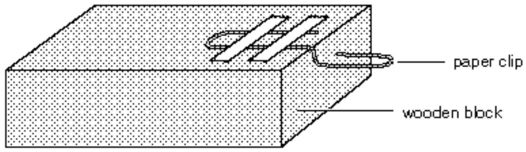
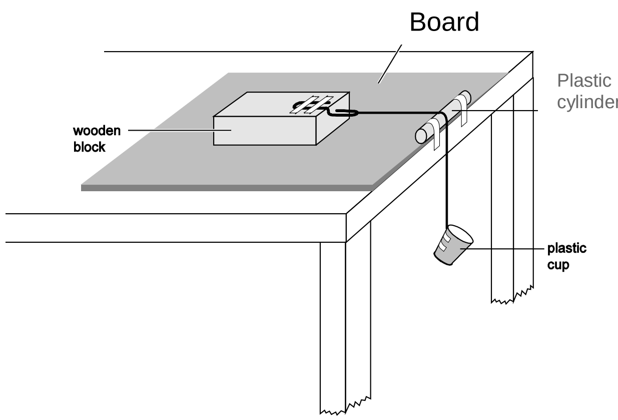
A Method for Testing Friction:

1. Construct a model shipping box like the one in the diagram below. The paper clip will allow you to pull the box with a measured amount of force:



2. Use a piece of cardboard as a model of a cargo room floor.
3. Tape a plastic cylinder along the edge of your work table. Place the cardboard shipping floor on your work table near the plastic cylinder.
4. Tie a loop at one end of the string and attach the loop to the paper clip. Drape the string over the plastic cylinder and use tape to attach the plastic cup to the other end of the string (see diagram below).

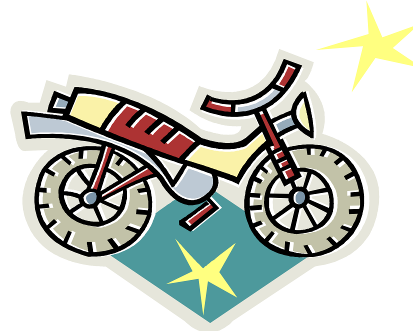


5. By adding small washers to the plastic cup, you can measure the pulling force needed to start the box moving. The more force needed to start the box moving, the greater the friction between the floor and the box materials. You can keep track of the number of washers, or you can find the mass of a single washer and keep track of the total mass needed to start the box moving.

Conduct Your Experiment

1. Identify the **question** you will investigate.
2. **Predict**, based on your experiences, which materials will have the greatest and least amount of friction.
3. Design a **procedure** to collect data to answer your research question. Identify the **independent** and **dependent** variables in your experiment. Think about the parts of your experiment that should be kept **constant** so you can collect consistent data.
4. Write your procedure in your science notebook. Include enough detail so that you or someone else could repeat your experiment.
5. Create a **data table** to record data related to your experiment.
6. Do your experiment and **record** your findings in your data table.
7. Think about the data you have collected. Do the data for each trial seem reasonable? If not, do you need to repeat any trials to correct any **errors**?
8. **Analyze** the data.
9. **Interpret** the data. Write your conclusions in your science notebook.

10. **Compare** your experimental design and results with others in your class.



Sometimes, people need to increase friction in order to perform a task. For example, adding ridges to a bicycle tire gives it better traction. At other times, people need to decrease friction. For example, grease is applied to the wheels of a bicycle to reduce friction and let the wheels spin easily.

In addition to the properties of the surface materials, what other factors do you think might affect friction?

Experiment #2: Effect of Mass or Surface Area on Friction Force

Design and conduct an experiment to explore one of these factors. Keep a detailed and organized record of your experimental design, data collection and analysis in your science notebook.

1. What **ideas** do you have about the way in which mass or surface area might affect friction? Discuss your ideas and predictions with your partners.
2. Identify the **question** you will investigate and the results you **predict**.
3. Design a **procedure** to collect data to answer your research question. Identify the **independent** and **dependent** variables in your experiment. Think about the parts of your experiment that should be kept **constant** so you can collect consistent data.
4. Write your procedure in your science notebook. Include enough detail so that you or someone else could repeat your experiment.
5. Create a **data table** to record data related to your experiment.
6. Do your experiment and **record** your findings in your data table.
7. Think about the data you have collected. Do the data for each trial seem generally consistent? If not, do you need to repeat any trials to correct any **errors**?
8. **Analyze** the data. Show your calculations in your science notebook.
9. **Graph** your analyzed data. Think about the most appropriate type of graph to show a relationship between two variables.
10. **Interpret** the data. Based on your experiment, what conclusions can you make about the effect of surface area or mass on the friction between two surfaces?
11. Share and compare your results with others in your class. How were they alike? How were they different?

Communicate Your Findings

Use the findings from your friction experiments to solve the sliding box problem. Talk with your partners about what changes might be made to the shipping boxes, the way the TVs are packed in the boxes, or the cargo room floor to increase the friction and reduce the sliding.

Write a Report:

Write a report to the TV manufacturer or the shipping company describing your research and recommendations for reducing the sliding of the shipping boxes.

Your report should include:

- a clear statement of the problem you investigated;
- a description of the experiments you carried out;
- the results of your experiments (including data presented in the form of charts, tables or graphs);
- your conclusions from the experiments;
- comments about how experimental errors may have affected your results; and
- a recommendation to the company about changes that should be made to the shipping boxes or the cargo room floor to reduce the sliding box problem on the ship.

Teacher Resources

Safety Disclaimer:

The content of this Teacher's Resource section is intended to serve as an educational resource for teachers and students.

Preparing for the safety of yourself and your students is a critical step in planning for any hands-on science- related activities. Prior to conducting any of the activities included in this resource section, please familiarize yourself and your students with any potential hazards, and take the necessary precautions appropriate for each specific activity.

Connecticut Science Center is not responsible for the contents of any books, videos, websites or other resources to which we provide a reference and does not necessarily endorse the opinions, activities, services, products or information expressed within them.

Background for the Teacher

Middle school students come to school thinking they know nothing about physics and the physical world around them. However, they know more than they think. Some of their knowledge comes from the media and from the movies, some of their knowledge comes from previous years spent in school and some of their knowledge is intuitive, based on personal experiences. Much of this physics knowledge rattling around in their heads is incorrect and full of misconceptions. Hopefully, some of this information will prove helpful in challenging your student's ideas of physics and how the world works.

Force & Motion

An object may be solid, liquid or gas; anything that has **mass. Plasma** is a form of matter separate from the traditional solid, liquid and gas. It is a collection of charged particles that take the form of gas-like clouds or ion beams. Plasma is frequently described as "ionized gas." **Motion** is the movement of an object from one place to another. To measure or describe motion, a **reference point**, or a starting point is needed. To put an object into motion or to change the motion of an object, a force must be applied; that force is either a **push** or a **pull**. A push and/or pull may start, stop, slow down, speed up or change the direction of an object in motion. If an object has two or more forces acting upon it with the same strength, the net force (total force) is considered to be a **balanced force**. The object does not move. An **unbalanced force** occurs when one of the forces is stronger than the other, hence moving the object in the direction of the greater force.

Distance is the change in position of the object. **Speed** is the average rate of movement over the distance. To calculate speed, divide distance by time (S = D/T). Speed is sometimes confused with velocity. Speed measures distance traveled per unit of time. **Velocity** also measures speed and includes the direction of the motion.

Acceleration is a change in speed or direction of an object. If an object's speed or velocity increases, positive acceleration occurs. If the speed or velocity of an object decreases, there is negative acceleration. If the speed or velocity of an object is constant, there is no acceleration.

Gravity

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Gravity is a universal force existing between all objects, dependent upon both the mass of the objects and the distance between them. Objects with larger masses exert more force than smaller masses. The Earth exerts a gravitational pull on objects toward the center of the mass of the planet. It is the mass of the Earth that determines the weight of an object on Earth. Gravity acts only as an attractive force or as a pull.

Examples: A baseball will travel through the air and eventually come down because of friction and gravity. A person weighing 75 k on Earth will weigh 12.5k on the Moon because the gravity on the moon is 1/6 of the gravity on Earth. (The person's mass remains the same.)

Friction is a force that opposes the motion between two surfaces. When one surface moves over another, frictional force acts to slow down and stop the motion. The amount of friction depends on several factors; the materials the objects are made from, the texture of the surfaces and the amount of force pressing the surfaces together. There are various types of friction:

- Rolling friction: Produced when one object rolls over another.
- Sliding or kinetic friction: Produced when surfaces slide over each other. Smooth surfaces decrease while rough surfaces increase the amount of friction. Lubricants, such as oil, wax or graphite, help to decrease friction.
- Starting or static friction: The difference in the force required to put an object into motion compared to the force necessary to keep the object in motion. (For example: To start a large object moving, such as a car, requires much force, but once the car is in motion, the force to keep it moving, becomes less.)
- Fluid or air friction: The motion of an object through air, water or other liquids. Friction in fluids or through air is also called drag or resistance. Objects that are streamlined move through air and/or fluids with less friction.

Friction is necessary for motion. A car would not be able to accelerate if wheels being moved by the engine could not push against the road because of the friction between the road and the tires. Reducing or increasing the effects of friction can affect motion. Mountain bikes have knobbed tires in order to increase traction (increase friction) on rocky surfaces. Smooth tires on pavement have increased friction caused by greater surface area in contact with each other.

Newton's 1st Law of Motion: Inertia

An object in motion will stay in motion and continue in a straight line unless acted upon by a force. An object at rest will stay at rest unless acted upon by a force.

Examples:

- Belts and air bags are installed in vehicles to prohibit passengers from moving forward through the windshield once a vehicle stops quickly.
- In space, once moving, a space ship will continue to travel in a straight line (the Earth's gravity moves it in a circular path) and at a constant rate, unless acted on by a force.
- A bicycle hits a curb, the bicycle will stop and the rider will continue to move forward. (the other force is the curb)

Circular Motion

Uniform circular motion is actually a specific type of motion. An object is undergoing uniform circular motion if it is traveling at a constant speed while moving in a circle. For example, if you drive a car around a circle while maintaining a constant speed, you are performing uniform circular motion. The main requirements for uniform circular motion are a constant speed and motion in a circle. As an object moves in a circle, it is constantly changing its direction because (according to Newton's first law of motion and object will move in a straight line unless acted upon by an external force). Therefore an object moving in a circle is accelerating because it is changing direction. The direction of the external force is toward the center of the circle, along the radius. Wherever the object is on the circle, the force required to keep it moving in a circle at a constant speed has to be directed from the object to the center of the circle it is traveling around. The direction of the acceleration is inwards. The example of the space ship orbiting the Earth is appropriate in that the space ship would fly off in a straight line if it were not for the gravitational force of the Earth pulling it inward--centripetal force. The arm of the Trebuchet travels in an arc, the projectile travels in a straight line after it is released.

Professional Development

Come be a student for a day! Prior to bringing your class to the CT Science Center, you are encouraged to spend time at the Center and explore the exhibits and programs available to you and your students by participating in our two day Field Trip Professional Development Workshop.

During these two days, you will have an opportunity to explore the **Forces in Motion Gallery,** and **Health Gallery** and other relevant galleries using our standards based Trail Guides. These guides will lead you and your students on the pathway toward enjoying the museum while maintaining focus on your grade level or content standard.

You will also have the opportunity to participate as a learner in the pre visit, visit and post visit activities provided by the CT Science Center. In addition, you will participate in an Embedded Task aligned with content standard 8.1. Afterward, you will process the various activities and discuss their applications in your classroom and in your students' learning.

Interdisciplinary Connections

History

The history of the Trebuchet is rich, reaching far back into ancient times. Not only did the ancients use Trebuchets to destroy castle walls, they also wanted to toss things over the walls to reach into the city. Students can trace the development of the Trebuchet from early times through their use today.

Mathematics

Motion and force lends itself to the use of mathematics.

- Calculation of speed can be graphed and plotted.
- Angles of release may also be measured and studied (What is the optimum release angle for longest toss and is this also related to the highest arc?)
- Ratios of the lever arm may also be calculated, to determine the mechanical advantage.

Websites

An actual floor friction experiment conducted at a seismic laboratory in California.
http://www.ce.berkeley.edu/~dakon/friction/

Animated friction experiments in a "cartoon" format.
http://www.bbc.co.uk/schools/scienceclips/ages/8_9/friction.shtml

The Physics Classroom - Newton's Laws: Force & Motion
A good source for physics information for the teacher and highly motivated students
http://www.glenbrook.k12.il.us/gbssci/phys/class/newtlaws/u2l1a.html

Physics Demonstrations: A Sourcebook for Teachers
A listing of physics demonstrations for teachers of all age groups. The activities are listed by category, not by grade level. Many are appropriate for middle school.
http://sprott.physics.wisc.edu/demobook/intro.htm

About.com
Teacher background site, not for most students
http://physics.about.com/od/physics101thebasics/p/PhysicsLaws.htm

National Science Teachers Association
A website for teacher and student use from NSTA. Easy to use.
http://www.scilinks.org

Connecticut State Department of Education
Here the links can be found to the State Science Standards, all the embedded tasks, the GLE's, professional development opportunities, web sites and other information pertinent to science education.
http://www.sde.ct.gov/sde/cwp/view.asp?a=2618&q=320890

CT Science Standard 8.1 – Force and Motion

An object's inertia causes it to continue moving the way it is moving unless it is acted upon by a force to change its motion.

Literature Links

Title	Author	Publisher	ISBN	Summary
A Crash Course in Forces and Motion with Max Axiom, Super Scientist	Emily Sohn	Graphic Library	0736878904	Super scientist, Max Axiom explains science in ways never seen before, making science accessible and super cool.
Awesome Experiments in Force and Motion	Michael DiSpezio	Sterling	1402723717	Over 70 experiments that demonstrate principals and encourage critical thinking.
Backyard Catapults: How to Build your Own.	Bill Wilson	Loompanics Unlimited	1559502460	Includes history, plans and information on ballistas and trebuchets.
Energy, Forces and Motion	Alastair Smith	Usborne Publishing	0746046308	An internet linked library of science. High interest.
Eyewitness: Force & Motion	Peter Lafferty	Eyewitness Series	0789448823	Force & Motion features standards such as gravity and friction. Topics are explored in full color photographs. Text is limited with short explanations for each topic.
Force and Motion: Stop Faking It!	William Robertson & Brian Diskin	NSTA	0873552091	One in the series, *Stop Faking It*, the rationale behind complicated concepts is explained.
Isaac Newton: Giants of Science	Kathleen Krull	Viking Juvenile	0670059218	The life and personality of the scientist is profiled, as well as several of his theories.
Janice VanCleave's Energy for Every Kid	Janice VanCleave	Jossey-Bass	047133099X	Presents entertaining, challenging experiments and activities to help you understand the different types of energy—including heat, sound, electricity, and light—and how they bring about change in the world around you.

Videos

A video segment from NOVA. A medieval throwing machine is recreated
http://www.teachersdomain.org/resources/hew06/sci/phys/maf/trebuchet/index.html

An interactive roller coaster illustrates the relationship between potential and kinetic energy.
http://www.teachersdomain.org/resources/hew06/sci/phys/maf/rollercoaster/index.html

An interactive simulation that explores the properties of projectile motion. A target can be hit by changing the variables, such as, direction, the projectile's mass and size and the presence of air resistance.
http://www.teachersdomain.org/resources/hew06/sci/phys/maf/projmotion/index.html

An interactive video that shows centripetal force in action
http://www.teachersdomain.org/resources/lsps07/sci/phys/maf/circmotion/index.html

Physicist and inventor, Dean Kamen, shares insights into the world of engineering and invention. Newton's Laws of Motion are key to the designs.
http://www.teachersdomain.org/resources/phy03/sci/phys/mfw/segway/index.html

Classroom Material Kits

SEPUP Mega-Modules: Issues and Physical Science: Force and Motion
http://www.sepup.com/catalog.php?item=IAPS-MM4-1032

Delta Education: Force and Motion
www.delta-edu.com/productdetail.aspx?Collection=Y&prodID=2011&menuID=53&topID=&subID

FOSS Force and Motion multimedia program
www.lawrencehallofscience.org/foss/scope/folio/html/ForceandMotion/3.html

Home and School Connections

Force and motion lends itself well to observations and investigations that can be performed at home. Some of these may include:

- Students keep a journal of their encounters with friction. Examples might be slipping on ice, opening a jar, riding a bicycle, writing on paper or walking.
- Students experiment with weight distribution in a backpack.
- Students can test various types of footwear for sliding or gripping ability.
- Skateboarders can try out various track surfaces for stability and ease of movement.
- Students can try to determine the best material to spread over icy surfaces; such as kitty litter, sand, and salt.
- Students can interview an engineer or mechanic to discuss the use of lubricants on machinery with moving parts.
- Students can search the internet for information regarding the types of tire treads and conditions for their use on racecars.
- Students can use what they learned at the CT Science Center about force and motion to practice accuracy while throwing baseballs or footballs.

Student Resources

Safety Disclaimer:

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Websites for Students

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Animated friction experiments in a "cartoon" format.
http://www.bbc.co.uk/schools/scienceclips/ages/8_9/friction.shtml