National Aeronautics and
Space Administration

Langley Research Center
Hampton, VA 23681-2199

Educational Product

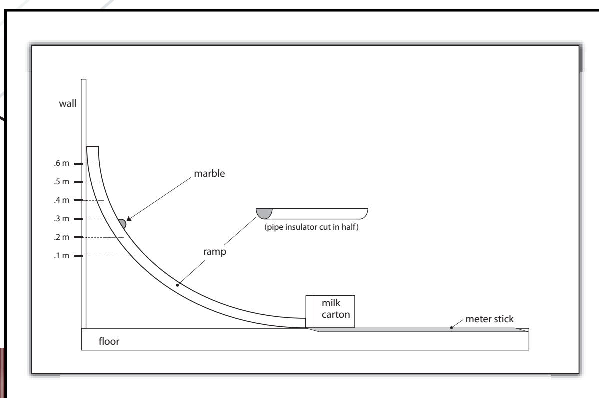
Educators | **Grades 6-8**

EG-2004-12-18-LARC

NASA CONNECT™

ROCKET to the Stars

An Educator Guide with Activities in Mathematics, Science, and Technology



http://connect.larc.nasa.gov

http://dlcenter.larc.nasa.gov

NASA CONNECT™: *Rocket to the Stars* is available in electronic format through NASA Spacelink - one of NASA's electronic resources specifically developed for the educational community. You may access this publication and other educational products at the following address: **http://spacelink.nasa.gov/products**

Find a PDF version of the educator guide for NASA CONNECT™ at the NASA CONNECT™ web site: **http://connect.larc.nasa.gov**

NASA CONNECT™ is produced by the NASA Center for Distance Learning, a component of the Office of Education at NASA's Langley Research Center, Hampton, VA, and is a collaborative endeavor of NASA with the organizations below. The NASA Center for Distance Learning is operated under cooperative agreement NCC-1-02039 with Christopher Newport University, Newport News, VA. Use of trade names does not imply endorsement by NASA.

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NASA CONNECT™

ROCKET to the Stars

An Educator Guide with Activities in Mathematics, Science, and Technology

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Hands-On Activity

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AIAA FOUNDATION Registered users of NASA CONNECT™ may request an American Institute of Aeronautics and Astronautics (AIAA) classroom mentor. For more information or to request a mentor, e-mail **nasaconnect@aiaa.org**.

Acknowledgments: Special thanks to Summer 2004 Educators in Residence, Chris Giersch, and the National Council of Teachers of Mathematics (NCTM).

program overview

educator guides

SUMMARY & OBJECTIVES

In NASA CONNECT™: *Rocket to the Stars*, students will learn the basic science concepts of work and energy and see how algebra can be used to help explain both concepts. NASA is working on new ways of powering spacecraft that would increase power available to scientific instruments, and might even reduce the travel time to the Moon, Mars and beyond. Students will be introduced to two cutting edge innovative propulsion technologies programs, Prometheus and VASIMR, that would enable crewed and uncrewed vehicles to explore the distant reaches of the solar system. By conducting inquiry-based and web activities, students will make connections between NASA research and the mathematics, science, and technology they learn in their classrooms.

STUDENT INVOLVEMENT

Inquiry-Based Questions

Host, Jennifer Pulley, and NASA engineers and scientists will pose inquiry-based questions throughout the program. These questions allow the students to investigate, discover, and critically think about the concepts being presented. When viewing a videotape or DVD version of NASA CONNECT™, educators should pause the program at the designated segments so students can answer and discuss the inquiry-based questions. During the program, Jennifer Pulley and NASA engineers and scientists will indicate the appropriate time to pause the tape or DVD. For more information about inquiry-based learning, visit the NASA CONNECT™ web site, **http://connect.larc.nasa.gov**.

Teacher note: : It is recommended that you preview the program before introducing it to your students so that you can become familiar with where the pauses occur.

Hands-On Activity

The hands-on activity is teacher created and is aligned with the National Council of Teachers of Mathematics (NCTM) Standards and the National Science Education (NSES) Standards. Students will do an inquiry investigation on the relationship between the height from which a marble on a ramp is released and the distance a milk carton at the end of the ramp moves along the floor after the ball collides with the carton.

Teacher note: Students will need to have background knowledge how to convert from grams to kilograms and from centimeters to meters.

Web Activity

The activity is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science Education (NSES) Standards, and the International Technology Education Association (ITEA) Standards for Technology Literacy. Join Norbert and Zot in an investigation of kinetic and potential energy. To access the Squeak Activity, go to the NASA CONNECT™ web site **http://connect.larc.nasa.gov.**

RESOURCES

Teacher and student resources enhance and extend the NASA CONNECT™ program. Books, periodicals, pamphlets, and web sites provide teachers and students with background information and extensions.

hands-on activity

BACKGROUND

BACKGROUND

Energy is the ability to cause a change. Energy can take a variety of forms and can be transformed from one form to another. Some examples are mechanical energy, thermal energy, nuclear energy, chemical energy, solar energy, electrical energy, wind energy, and geothermal energy. For example, chemical energy is stored energy in food and eventually is turned into energy that allows our bodies to move (kinetic energy). Radios work by turning electrical energy into sound energy. Cars work by turning chemical energy from gasoline into mechanical energy.

The focus of this activity is mechanical energy, which is the energy an object has due to its motion or its stored energy determined by its position. The two types of mechanical energy are potential energy and kinetic energy. Potential energy refers to stored energy. Gravitational potential energy is a type of potential energy that is based on the height of an object. For example, a book that is held at a certain height has gravitational potential energy. The higher the book is held, the more potential energy it has. When the book is released, gravity works on the book and causes the book to fall to the ground, putting it in motion. Kinetic energy is the energy of motion. Kinetic comes from the Greek word "kinetos," which means, "moving." Any object that has mass and velocity has kinetic energy. Energy can change from one form to another. The process of energy changing from one form to another is called work. Work requires a force, in the direction of motion, to act on an object over a distance.

Students will do an inquiry investigation on the relationship between the height from which a marble on a ramp is released and the distance a milk carton at the end of the ramp is moves along the floor after the ball collides with the carton. Students will roll the marble from measured heights of .1 m, .2 m, .3 m, .4 m, and .5 m.

When you hold the marble at the top of the ramp, it has gravitational potential energy. To bring the marble to the top of the ramp, your body has to work against gravity on the marble to move it to the top of the ramp. When you release the marble and allow it to roll down the ramp, gravity works on the marble and causes the original potential energy to transform into kinetic energy.

Near the Earth's surface, the equation for Gravitational Potential Energy (GPE) is

$$GPE = mgh$$

where m = mass

g = acceleration due to gravity (9.8 $\frac{m}{s^2}$ at sea level)

h = height

The equation for Kinetic Energy (KE) is

$$KE = \frac{1}{2}mv^2$$

where m = mass

v = velocity (*note: only velocity is squared*)

Recall that work is equal to the change in energy. According to the Law of Conservation of Energy, energy cannot be created or destroyed. Ignoring energy loss due to friction, the total amount of potential energy of the marble at the top of the ramp is equal to the kinetic energy of the marble at the bottom of the ramp.

Note: There is actually slightly less kinetic energy at the end of the ramp than the original potential energy because the marble encounters friction as it rolls down the ramp, and a small amount of the energy is turned into thermal energy. But for this experiment, friction can be ignored.

Because the potential energy of the marble at the top of the ramp is equal to the kinetic energy that the marble has at the end of the ramp (ignoring friction on the ramp), then the original potential energy calculation can be used to find the theoretical velocity of the marble at the end of the ramp.

Let's solve for velocity given the following formula:

$GPE = KE$ *(Remember, ignore friction.)*

$$mgh = \frac{1}{2} mv^2$$

Multiplying both sides by 2, we get

$$2\ mgh = mv^2$$

Divide both sides by m to get

$$2\ gh = v^2$$

Finally, taking the square root of both sides, we have

$$v = \sqrt{2\ gh}$$

Note: the velocity of a falling object does not depend upon its mass!

Note: This formula also ignores the energy required to rotate the marble as it rolls down the ramp. If we include the energy component to rotate the marble, the formula will become more complicated. Often times it is easier to simplify science concepts initially so students can develop a basic understanding. As students mature and improve their science and math skills, a more in-depth explanation of the science concepts can be addressed. The actual formula for finding the velocity of the marble as it hits the milk carton is

$$V = \sqrt{\frac{2\ gh}{1.4}}$$

Figure 1 shows the diagram of the activity setup.

When the marble hits the milk carton, the kinetic energy causes work to be done on the milk carton, moving it forward. As the carton moves forward, the frictional force of the carton rubbing on the floor causes the carton to slow down, and the kinetic energy (energy in motion) is turned into thermal energy (heat between the floor and the carton). Thus, according to the Law of Conservation of Energy, all the original potential energy of the marble is first turned into kinetic energy as the marble rolls and gains velocity, and then the kinetic energy of the marble works on the carton, moving it a distance. Therefore, in this experiment, GPE = KE = the energy used to do work.

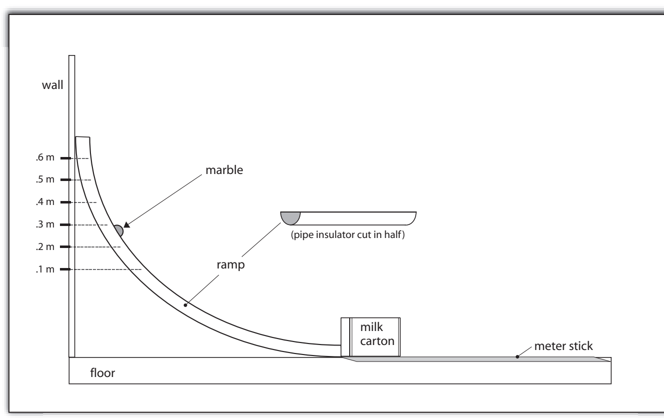


Figure 1: Activity Setup

INSTRUCTIONAL OBJECTIVES

The students will

- do an inquiry investigation on the relationship between the height from which a marble on a ramp is released and the distance a milk carton at the end of the ramp moves along the floor after the ball collides with the carton.
- use algebra to apply the concepts of work, potential energy, and kinetic energy.
- calculate the velocity of the marble by using the law of conservation of energy.

NATIONAL STANDARDS

NCTM Mathematics Standards

Algebra

Understand patterns, relations, and functions.

- Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and when possible, symbolic rules.
- Relate and compare different forms of representation for a relationship.
- Identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations.

Represent and analyze mathematical situations and structures using algebraic symbols.

- Use symbolic algebra to represent situations and to solve problems, especially those that involve linear relationships.

Use mathematical models to represent and understand quantitative relationships.

- Model and solve contextualized problems using various representations, such as graphs, tables, and equations.

Analyze change in various contexts.

- Use graphs to analyze the nature of changes in quantities in linear relationships.

Measurement

Apply appropriate techniques, tools, and formulas to determine measurements.

- Solve simple problems involving rates and derived measurements for such attributes as velocity and density.

Data Analysis and Probability

Develop and evaluate inferences and predictions that are based on data.

- Use conjectures to formulate new questions and plan new studies to answer them.

Connections

Recognize and apply mathematics in contexts outside of mathematics.

Representation

Use representations to model and interpret physical, social, and mathematical phenomena.

NSES Science Standards

Science as Inquiry

Abilities necessary to do scientific inquiry

Understandings about scientific inquiry

Physical Science

Motions and forces

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

Transfer of Energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical.

NASA RELEVANCE

Lifting a rocket into space against the force of gravity requires a great deal of energy. As a rocket burns fuel, it expels exhaust gases. When the gases are forced out of the rocket, they exert an equal and opposite force back on the rocket and the rocket accelerates upward. This fuel energy continues to be relied on as it navigates through its mission. But conventional rockets and fuel aren't practical as we reach farther into the solar system and beyond. NASA is currently exploring new nuclear, plasma, and solar propulsion systems to create more efficient methods of providing rockets the energy needed for future space exploration.

PREPARING FOR THE ACTIVITY

Student Materials *(for each group of students)*

- A 1.5–2.0 m long ramp with a concave curve so marbles don't roll off.
  (Semi-split pipe insulation that fits 1-in. copper, .75-in. iron, cut in half works well. Pipe insulation can be found at Home Depot, Lowes, or any other home improvement/hardware store.)
- one marble
- metric scale to measure mass of marble
- meter stick
- 8–fl–oz (240–ml) milk carton with the top cut off
  (The students' lunch milk cartons work well.)
- calculator
- masking tape
- data collection chart

Time for Activity

- 60 minutes (watching the video and discussing the inquiry-based questions)
- 75 minutes (the activity)

Vocabulary

Energy is the ability to cause a change.

Joule is the metric unit of energy and work. One Joule equals 1 kg ($\frac{m^2}{s^2}$).

Gravitational Potential Energy is stored energy. It is related to the mass and height of an object.

Kinetic Energy is energy of motion and is related to the mass and the velocity of an object.

Speed refers to the distance in a specific direction an object travels divided by the time it takes to travel that distance. Speed = distance/time. Speed is a scalar quantity, meaning it includes only magnitude and not the direction.

Velocity refers to the distance in a specific direction that an object travels divided by the time it takes to travel that distance. Velocity is a vector, meaning that it includes magnitude and direction.

Conservation of Energy is energy that is not created and is not destroyed, but rather it can be transformed from one form to another. (Example: the potential energy of a falling book turns into kinetic energy as it gains velocity falling)

Work is a constant force being applied on an object multiplied by the distance the object moves. It is also equal to the change in energy.

THE ACTIVITY

Rolling Along

Lesson Description

ENGAGE

Show students the NASA CONNECT™ program, *Rocket to the Stars*.

Students will do an inquiry investigation on the relationship between the height from which a marble on a ramp is released and the distance a milk carton at the end of the ramp moves along the floor after the ball collides with the carton. Students will roll the marble from measured heights of .1 m, .2 m, .3 m, .4 m, and .5 m. Before starting the activity, set up a demonstration for students to see. Ask and discuss the following questions by concentrating on prior knowledge and vocabulary, rather than an extended understanding of energy at this point. Figure 2 shows the diagram of the activity setup.

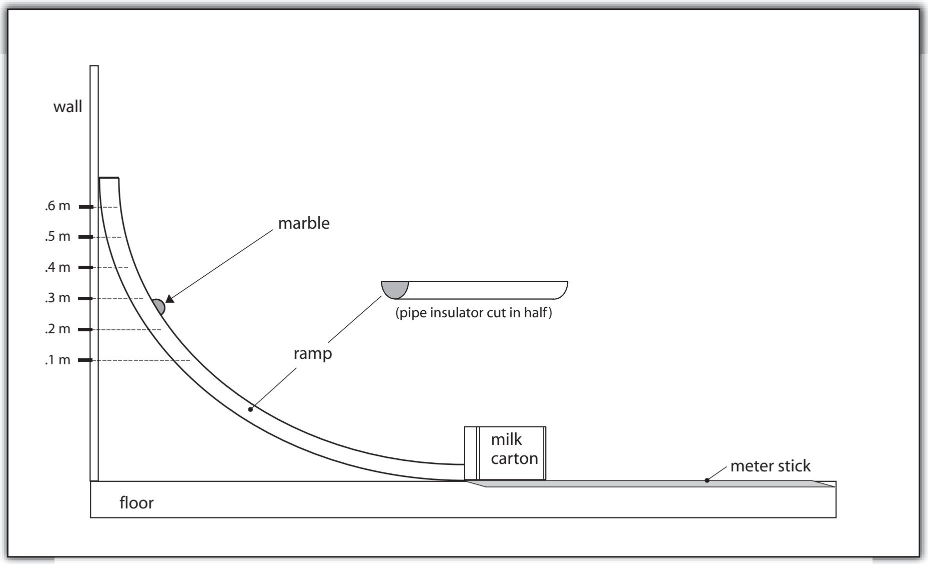


Figure 2: Activity setup

Teacher led discussion

1. Does the marble at the top of the inclined plane have energy? Why or why not?

   Answer: *Yes, the marble has potential (stored) energy because it has the ability to fall.*

2. How will changing the height from which the marble is released change the potential (stored) energy?

   Answer: *The higher the marble is placed, the more potential energy it has.*

3. When does the potential (stored) energy of the marble begin to change into kinetic (moving) energy?

   Answer: *As the ball begins to roll down the ramp, some potential energy turns into kinetic energy.*

4. What happens to the kinetic energy of the marble when it hits the milk carton?

   Answer: *The kinetic energy of the marble moves the milk carton, doing work on it.*

5. Predict how many meters the marble will move the milk carton, when the marble is let go at .3 m.

   Teacher demonstrates and records the distance the milk carton moved after letting the marble go from .3 m. Record and repeat four more times in order to get the average distance.

6. Compare student predictions with outcome.

EXPLORE

Setup

- Working in groups, students will set up the ramp by taping one end .7 m high up a wall and place the empty milk carton at the other end of the ramp so that it will catch the marble after it rolls down the ramp.
- Mark with tape on the ramp heights of .1 m, .2 m, .3 m, .4 m, .5 m, and .6 m.
- Line the meter stick on the floor along the distance that the milk carton will travel after being hit by the rolled marble. See figure 2 under **ENGAGE** for the activity setup.

Data collection

1. Starting at the .1–m mark on the ramp, release the marble down the ramp. Students will record in the data collection chart for "trial 1" the distance that the milk carton travels after the marble hits it.

   Hint: Use the front of the milk carton for distance traveled measurements.

2. Again starting from .1 m high, repeat step one for trials 2 through 5. Be sure to record each distance on the data collection chart.
3. Calculate the average distance the carton travels and record the average in the appropriate column on the data collection chart.
4. Now continue your experiment by increasing the height from which you drop the marble by .1 m each time. Repeat steps 1–3 for .2 m, .3 m, .4 m, and .5 m high.

   Teacher note: *Do **NOT** drop marble from .6 m high yet! This distance will be used later to make a prediction.*

EXPLAIN

The students will analyze their data. They will calculate the potential energy that the marble has at each height, the kinetic energy (neglecting energy lost to friction) at the end of each roll, and the velocity that the marble has given the kinetic energy. The students will also make a graph showing the relationship between the height from which the ball is released and the distance the carton is moved. Students will be asked to explain and interpret their data and graph.

Calculation

- Measure and record the mass of the marble (in kilograms).

Mass of Marble ________________ kg

- Calculate the potential energy of the stationary marble at each marked height on the ramp using the equation

$$GPE = mgh$$

Teacher note: *Remember that the acceleration due to gravity is 9.8 $\frac{m}{s^2}$ and the unit of energy is the joule. Record your answer on the data collection chart.*

$$v = \sqrt{2gh}$$

Teacher note: *Teachers may want advance students to derive the equation for velocity. This is done for you in the background section.*

- Determine and record the amount of work the marble does on the carton for each height.

Teacher note: *The amount of work done on the carton is equal to the kinetic energy of the marble at the bottom of the ramp.*

Graphical Analysis and Prediction

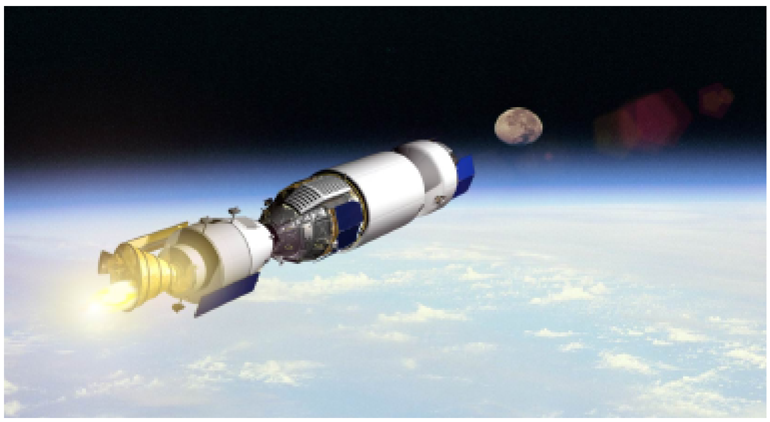
- Using the data the students collected, have them make a graph that compares the height at which the marble was released to the distance that the carton moved. Students may choose any type of graph they believe will best display their results.

Teacher note: *Scatter plots or bar graphs are good choices.*

- Using the graph the students made, have them predict how far the carton will move if they release the marble from .6 m high.

Prediction ________________ m.

- Have students test their prediction! Release the marble down the ramp starting from .6 m. Record the distance the carton moved on the data collection chart. Students should conduct four more trials and record the distance on the data collection chart. Determine the average distance the marble traveled. Was their prediction correct? Have them explain.



Upon completion of the activity, students should be able to answer the following questions.

End of activity questions

1. How does the starting height on the ramp affect the distance that the milk carton moves?

   Answer: The higher the marble is when dropped, the farther the carton moves.

2. Identify potential energy, kinetic energy, and work in this activity.

   Answer: Potential energy refers to the stored energy that the marble has because of its height. Kinetic energy refers to the moving energy the marble has as it rolls down the ramp. Work is done in this activity on the carton as the rolling marble moves it and when it is lifted to get its potential energy.

3. How does changing the starting height of the marble on the ramp change the potential energy of the marble? The kinetic energy when the marble rolls to the end of the ramp?

   Answer: The higher the marble starts, the more potential energy it has at the top of the ramp and the more kinetic energy it has at the end of the ramp.

4. How did you know how much work was done on the carton?

   Answer: The amount of work done on the carton is equal to the amount of kinetic energy the marble has at the end of the ramp.

5. What does "conservation of energy" mean and how does it apply to this activity?

   Answer: "Conservation of Energy" means that energy cannot be created and it cannot be destroyed, but instead it is transferred from one form to another. In this activity, the gravitational potential energy of the marble at the top of the ramp turns into kinetic energy as it rolls down the ramp. The kinetic energy of the ramp is used to do work on the carton.

6. What trend does your graph show?

   Answer: The students' graphs should show that as they increase the height, from which they roll the marble, the distance that the carton moves increases as well. The graph from distance versus height should be linear (in a straight line).

7. List at least three conclusions you can draw from analyzing your data chart and your graphs?

   Possible Answers:

   -As the marble height is increased, potential energy increases.

   -As the potential energy of the marble at the top of the ramp increases, the kinetic energy at the bottom increases.

   -As the potential and kinetic energy increase, the amount of work done on the milk carton increases.

   -As the amount of work done on the carton increases, the farther it moves.

EXTEND

- Have students make a graph comparing the height from which the marble is dropped to the velocity of the marble at the end of the ramp. Students can use this square root function to predict what the velocity would be after being dropped from any height.

- In the "Rolling Along" activity, the variable was the changing height. There are a variety of other possible variables that students could investigate as an extension to this activity. Some possibilities are using marbles of different mass, changing the surface of the ramp, or changing the weight of the carton. With your class, make a list on the board of all the other factors that affect the distance the carton will move. Then allow students in groups to test one of the variables and carry out the same calculations, graphing, and data analysis as in the "Rolling Along" activity.

EVALUATE

Have students describe and explain their graphs. What is the pattern that the data points make? Why do the data points make this pattern? Also, check for correct use of algebra in determining the potential and kinetic energy and velocity of the marble. Ask students to describe in their journals the transfer of energy involved in launching a rocket into space.

Student Handout

Rolling Along

Student Materials *(for each group of students)*

- A 1.5–2.0-m ramp with a concave curve so marbles don't roll off.
  (Semi-split pipe insulation that fits 1-in. copper, .75-in. iron, cut in half works well. Pipe insulation can be found at Home Depot, Lowes, or any other home improvement/hardware store.)
- one marble
- metric scale to measure mass of marble
- meter stick
- 8-fl-oz (240-ml) milk carton with the top cut off
  (The students' lunch milk cartons work well.)
- calculator
- masking tape
- data collection chart

Setup

- Working in groups, set up the ramp by taping one end .7 m high up a wall and place the empty milk carton at the other end of the ramp so that it will catch the marble after it rolls down the ramp.
- Mark with tape on the ramp heights of .1 m, .2 m, .3 m, .4m, .5 m, and .6 m.
- Lay the meter stick on the floor along the distance that the milk carton will travel after being hit by the rolled marble. See figure 1.

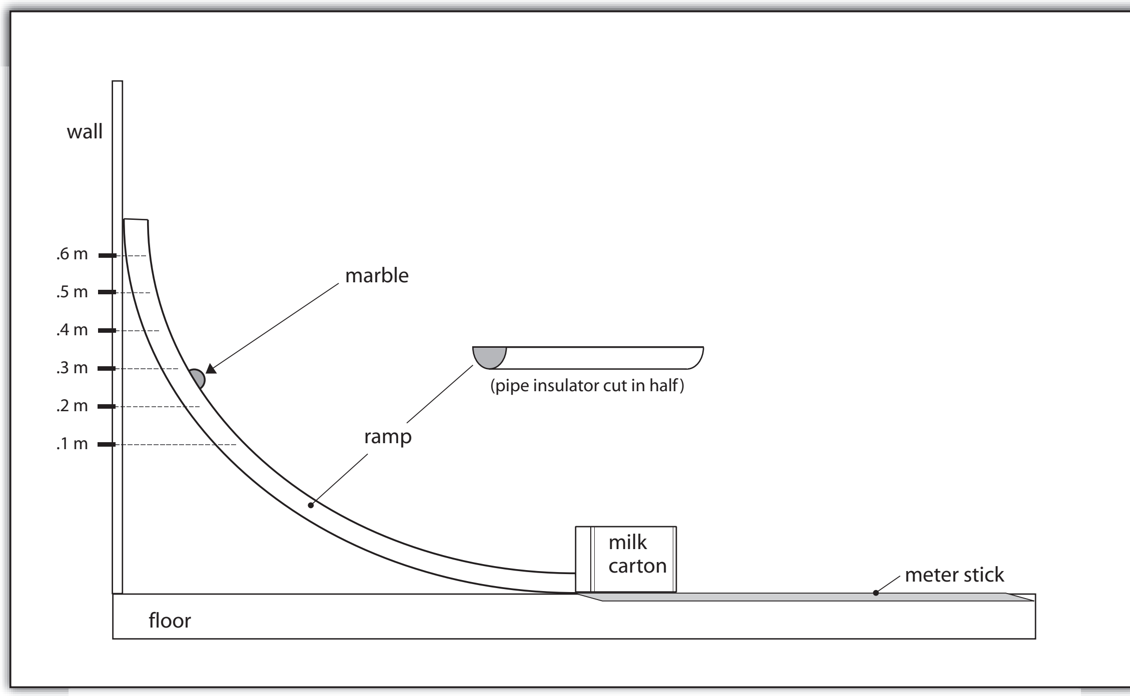


Figure 1

Rolling Along

STUDENT HANDOUT

Rolling Along

Data collection

1. Starting at the .1-m mark on the ramp, release the marble down the ramp. Record in the data collection chart for "trial 1" the distance that the milk carton travels after being hit by the marble.

   Hint: Use the front of the milk carton for distance traveled measurements.

2. Again starting from .1 m high, repeat step one for trials 2 through 5. Be sure to record each distance on the data collection chart.

3. Calculate the average distance the carton travels and record the average in the appropriate column on the data collection chart.

4. Continue your experiment by increasing the height from which you drop the marble by .1 m each time. Repeat steps 1–3 for .2 m, .3 m, .4 m, and .5 m high.

Calculation

- Measure and record the mass of the marble (in kilograms).

  Mass of Marble _________________ kg

- Calculate the potential energy of the stationary marble at each marked height on the ramp using the equation

$$GPE = mgh$$

  Student note: Remember that the acceleration due to gravity is 9.8 $\frac{m}{s^2}$ and the unit of energy is the joule. Record your answer on the data collection chart.

- Ignoring friction, record how much kinetic energy the marble has at the bottom of the ramp for each starting height.

- Calculate and record the velocity of the marble at the bottom of the ramp for each height. The equation to determine the velocity of the marble is

$$v = \sqrt{2\,gh}$$

- Determine and record the amount of work the marble does on the carton for each height.

Student Handout

Rolling Along

Graphical Analysis and Prediction

- Using the data you have just collected, make a graph that compares the height that you dropped the marble to the distance that the carton moved. Choose any type of graph that you believe will best display your results.

- Now using the graph that you made, predict how far the carton will move if you roll the marble from .6 m high.

Prediction _________________ m.

- Test your prediction! Release the marble down the ramp starting from .6 m. Record on the data collection chart the distance the carton moved. You should conduct four more trials and record the distance on the data collection chart. Determine the average distance the marble traveled. Was your prediction correct? Explain.

End of Activity Questions

1. How does the starting height on the ramp affect the distance that the milk carton moves?
2. Identify potential energy, kinetic energy, and work in this activity.
3. How does changing the starting height of the marble on the ramp change the potential energy of the marble? The kinetic energy when the marble rolls to the end of the ramp?
4. How did you know how much work was done on the carton?
5. What does "conservation of energy" mean and how does it apply to this activity?
6. What trend does your graph show?
7. List at least three conclusions you can draw from analyzing your data chart and your graphs?

Student Handout

Rolling Along

Data Collection Chart

HEIGHT *of* RAMP	Distance Carton Moved **Trial 1** *(m)*	Distance Carton Moved **Trial 2** *(m)*	Distance Carton Moved **Trial 3** *(m)*	Distance Carton Moved **Trial 4** *(m)*	Distance Carton Moved **Trial 5** *(m)*	Average Distance Carton Moved *(m)*	Potential Energy at top of Ramp *(J)*	Kinetic Energy at top of Ramp *(J)*	Velocity at end of Ramp $(\frac{m}{s})$	Work that is done on Carton *(J)*
0.1 m										
0.2 m										
0.3 m										
0.4 m										
0.5 m										
0.6 m										

Formulas:

GPE = mgh

$KE = \frac{1}{2}mv^2$

$v = \sqrt{2gh}$

Work = change in energy

Resources

BOOKS

Trefil, James; Calvo, Rita Ann; Cutler, Kenneth: *Motion and Forces*, McDougal Littell, 2004

Kahn, Peter: *Science Explorer: Motion, Forces and Energy*, Prentice Hall, 2000

WEB SITES

Work, Potential Energy, and Kinetic Energy
http://www.pwc.k12.nf.ca/PROJECTS/energy/
http://www.canteach.ca/elementary/physical16.html
http://www.miamisci.org/af/sln/
http://www.glenbrook.k12.il.us/gbssci/phys/Class/energy/u5l1a.html
http://www.eduref.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Physics/PHS0036.html
http://www.grc.nasa.gov/WWW/K-12/BGA/Mike/energy_act.htm

Project Prometheus
http://www.nasaexplores.com/search_nav_5_8.php?id=04-027&gl=58

Plasma Propulsion
http://www.nasaexplores.com/search_nav_5_8.php?id=03-027&gl=58
http://aerospacescholars.jsc.nasa.gov/has/Students/finalgall.cfm?id=460

Vision for Space Exploration
http://www.nasa.gov/missions/solarsystem/explore_main.html