The Energy of Motion

A RIVER STUDY

TEACHER

Activity Overview

In recent years, Louisiana's coastal wetlands have been disappearing and projects have been started to restore them. Sediment reintroduction projects seek to reverse erosion by diverting sediment carried by the Mississippi River through channels. This sediment is deposited in wetlands eroded areas to form new land. In planning reintroduction projects, engineers must consider the kinetic energy of water. Failure to do so may have costly consequences.

In this activity, students will simulate sediment reintroduction channels using a ramp at two slopes. They will roll a ball, which represents water, down the ramp and measure its velocity using a motion sensor connected to a TI CBL 2™ or Vernier LabPro and a TI-73 Explorer™. Students will then find the kinetic energy of the ball at different times as it rolls down the ramp.

Conclusions: Increasing the slope of the ramp increases the velocity of the ball. Increasing the velocity increases kinetic energy. Increasing the slope increases the kinetic energy of the ball. The energy of water in the Mississippi River is important in wetland restoration projects. Energy is a measure of the ability to do work. Engineers rely on water's ability to do work in moving sediment.

Activity at a Glance

Grade: 6–9
Subject: Science
Category: Physical Science, Earth Science
Topic: Velocity, Kinetic Energy, Work, Wetland Restoration

Time Required

- Three 45-minute periods

Level of Complexity

- High

Materials*

- TI-73 ExplorerTM
- TI CBL 2™ or Vernier LabPro
- TI-73 DataMate
- Motion sensor
- Playground or soccer ball
- Balance
- Table or board (at least 1 meter wide and 1.5 meters long)
- Meter stick

TI-73 Explorer™

Motion Sensor

* This activity has been written for the TI-73 Explorer™ but you can easily substitute the TI-83 or TI-83 Plus. Also see Appendix A for steps on how to transfer DataMate to your graphing device and how to use DataMate for data collection.

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Concept Background

- The flow of water in a stream is due to the force of gravity. The steeper the gradient of a stream's channel, the faster the water will flow. Positions upstream are higher relative to positions downstream. A large difference in height will cause the flow of water to be very powerful and possess a lot of kinetic energy.
- The rough rocks and material along the bed of a stream create friction that slows the flow of water. Water in a stream moves fastest near the surface and slowest near the bottom. Vegetation along the banks of streams can also create friction that slows flowing water.
- As water in the Mississippi River flows downstream, it applies a force on sediment, which is then carried over some distance. The use of force to move an object over a distance is called work. River water does work on sediment. The ability of water to do work depends on its energy. In order to successfully restore wetlands, engineers must divert sediment and deposit it in eroded areas. Sediment reintroduction projects rely on the energy of moving water to do work and carry massive amounts of sediment through a channel and into eroded wetland areas.
- A stream flowing at a high velocity is capable of carrying large sediment loads. As the velocity decreases, the sediment load the stream can carry also decreases.
- Kinetic energy is the energy of motion. The kinetic energy of an object depends on velocity and mass and is found using the following equation:

$$KE = \frac{1}{2} \times m \times V^2$$

  where *m* is the mass of the ball in kilograms and *V* is its velocity in meters per second. Kinetic energy is measured in units of Joules (J).

- The volume of river water is an important factor in determining the amount of sediment being carried downstream. Although this activity does not explore this concept, you may consider discussing it with your students.

Preparation and Classroom Management Tips

- This activity requires a ramp about 2.0 meters long. The ramp can be created using a rectangular table with the legs raised using books or bricks.
- It is important that the ball rolls in a straight line down the ramp. You may need to make adjustments to the ramp if the ball rolls towards one side. Narrow boards or meter sticks can be used to form a track.
- Students will collect data twice. In Part A they will collect velocity data as they roll the ball on a ramp at a steep slope. The steep slope should be at least 30°. In Part B they will collect velocity data as they roll the ball on a ramp at a gentle slope. The gentle slope should be about 10°.
- The motion sensor will work best with a larger ball such as a playground ball or a soccer ball. Smaller balls may also be used but will require more careful setup of the ramp and motion sensor.

National Education Standards

Science Standard A: Science As Inquiry

Students should understand scientific inquiry and develop abilities necessary to perform it.

Science Standard B: Physical Science

Students should develop an understanding of properties and changes in matter, motions and forces, and transfer of energy.

Math Standard: Numbers and Operations

Students should develop an understanding of numbers — ways to represent and manipulate them and the relationships among different numbers and between number systems.

Math Standard: Algebra

Students should develop an understanding about patterns, relations, and functions. They should learn to analyze mathematical situations using algebraic symbols and use mathematical models to represent quantitative relationships.

Math Standard: Data Analysis & Probability

Students should develop an understanding about how to collect, organize, display, and interpret data.

Math Standard: Problem Solving

Students should develop an understanding of mathematical concepts by working through problems that allow applications of mathematics to other contexts.

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- The typical weight of a soccer ball is about 0.5 kg. Make sure you have a balance capable of measuring the mass of the ball.
- In Part A — Data Analysis Step 6, students are asked to convert the mass of the ball from grams to kilograms. They may use their TI-73 Explorer™ to verify the unit conversion by pressing [2nd] [UNIT] to access the unit conversion tool.
- The motion sensor automatically collects time, distance, velocity, and acceleration data. In this activity, students will only use time and velocity data.
- The motion sensor cannot accurately detect objects closer than 0.4 meters.
- The area around the ramp should be cleared of all objects that may be detected by the motion sensor.
- If your students are using a Calculator Based Ranger™ (CBR) with the CBL instead of a motion sensor, procedural changes are not necessary. If the CBR is used without the CBL, this activity will require a few changes in the procedures.
- Groups of students can run the experiment using different slopes and compare results. The activity can also be extended to investigate the effects of changing mass. Students can explore differences in kinetic energy when using balls of different mass.
- Discuss with students the concepts of velocity, kinetic energy, and work. It is important that students should have an understanding of these concepts prior to starting the activity.
- Energy is measured in units of Joules (J). A Joule is the energy needed to push with a force of one Newton (N) over a distance of one meter (N x m). A Newton is a unit of force measured in kg x m / s^2. Therefore, a Joule is a kg x m^2 / s^2. You may demonstrate to students how the equation for kinetic energy yields units of Joules.
- This activity works well with students working in groups or as a demonstration. If students are working in groups it is best to set up one ramp. Use one table, one motion sensor, and one ball. Each group will take turns connecting their TI-73 Explorer™ to the motion sensor and run the experiment.
- Encourage students to answer the Data Analysis questions in their journal.
- Create your own student questions for use on your students' TI graphing devices using the Texas Instruments StudyCard applications. For more information, go to http://education.ti.com/us/product/apps/studycards/scresources.html.

Vocabulary

Artificial Reef A ridge of sand or an arrangement of rocks or other materials placed near the water's surface by humans to simulate a natural reef.

Breached Split into multiple parts.

Dredged Made deeper by removing sediment and other material.

Freshwater Reintroduction Diverting fresh river water along with its nutrients and sediments into a coastal ecosystem.

Friction A force that slows down a moving object.

Gravity The force of attraction between two masses; the force that pulls an object toward the Earth.

Hydrology The patterns of water flow in a system.

Kinetic Energy The energy an object has because it is moving.

Levee A raised bank of earth that protects nearby land from flooding.

Mass The amount of matter in an object.

Sediment Reintroduction Project A project designed to transport enough sediment into wetlands to prevent additional land loss in the system.

Slurry Pipelines Pipelines that carry sediments dredged from a river to areas where the sediments are needed.

Spillway A passage built to safely contain water that overflows the banks and levees of a river.

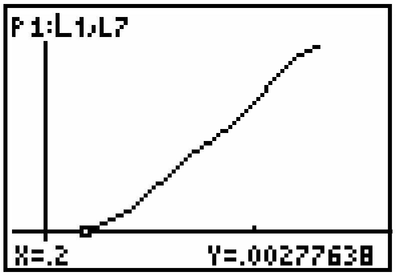
Stakeholder A person living and working in an area that will be affected by a decision about that area.

Velocity Description of an object's motion that includes both its speed and its direction of travel.

Work The use of force to move an object over a distance.

Part A — Collect Velocity Data: Steep Slope

Data Analysis



Sample Velocity and Time Graph.

1 Q. By observing your graph, describe how the velocity of the ball changed as it rolled down the steep slope ramp.

A. The velocity of the ball increased as it rolled down the steep slope ramp.

2 Q. Copy Table 1 into your journal.

Table 1

		Steep Slope Ramp			Gentle Slope Ramp		
	Time (s)	**Velocity (m/s)**	**Mass (kg)**	**KE (J)**	**Velocity (m/s)**	**Mass (kg)**	**KE (J)**
Time A	*0.2*	*0.050*	*0.5*	*6.3×10^{-4}*	*0.007*	*0.5*	*1.2×10^{-5}*
Time B	*0.5*	*0.429*	*0.5*	*4.6×10^{-2}*	*0.125*	*0.5*	*3.9×10^{-3}*
Time C	*1.0*	*1.399*	*0.5*	*4.9×10^{-1}*	*0.294*	*0.5*	*2.2×10^{-2}*

Sample Data

Note: The kinetic energy values are small and therefore are represented in scientific notation.

3 Q. Select a point at the beginning of the experiment and record the time in seconds next to Time A in Table 1.

A. Answers may vary. See sample data in Table 1.

4 Q. Select a point half way through the experiment and record the time in seconds next to Time B in Table 1.

A. Answers may vary. See sample data in Table 1.

5 Q. Select a point at the end of the experiment and record the time in seconds next to Time C in Table 1.

A. Answers may vary. See sample data in Table 1.

6 Q. Record the velocity for the steep slope ramp at Time A in Table 1.

A. Answers may vary. See sample data in Table 1.

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7 Q. Record the velocity for the steep slope ramp at Time B in Table 1.

A. Answers may vary. See sample data in Table 1.

8 Q. Record the velocity for the steep slope ramp at Time C in Table 1.

A. Answers may vary. See sample data in Table 1.

9 Q. At which time (Time A, Time B, or Time C) was the velocity of the ball the least?

A. The velocity of the ball was the least at Time A.

10 Q. At which time was the velocity of the ball the greatest?

A. The velocity of the ball was the greatest at Time C.

11 Q. Use the balance to measure the mass of the ball in grams and record the value in the table in kilograms (1000 grams = 1 kilogram). You will use the same ball for both experiments, so record the mass in all table cells under both Mass columns.

A. Answers may vary. Make sure students enter the same mass in all table cells under both Mass columns.

12 Q. Use the KE formula to calculate the kinetic energy of the ball for the steep slope ramp at each of the three times. Enter the values in Table 1. You may use your TI-73 Explorer™ to perform the calculations.

A. Answers may vary. See sample data in Table 1.

13 Q. At which time was the kinetic energy of the ball the least?

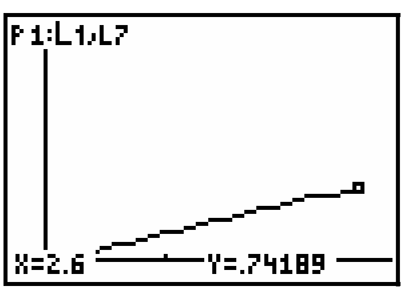
A. The kinetic energy of the ball was the least at Time A.

14 Q. At which time was the kinetic energy of the ball the greatest?

A. The kinetic energy of the ball was the greatest at Time C.

Part B — Collect Velocity Data: Gentle Slope

Data Analysis



Sample Velocity and Time Graph

1 Q. By observing your graph, describe how the velocity of the ball changed as it rolled down the gentle slope ramp.

A. The velocity of the ball increased as it rolled down the gentle slope ramp.

2 Q. Record the velocity for the gentle slope ramp at Time A in Table 1.

A. Answers may vary. See sample data in Table 1.

3 Q. Record the velocity for the gentle slope ramp at Time B in Table 1.

A. Answers may vary. See sample data in Table 1.

4 Q. Record the velocity for the gentle slope ramp at Time C in Table 1.

A. Answers may vary. See sample data in Table 1.

5 Q. At which time was the velocity of the ball the least?

A. The velocity of the ball was the least at Time A.

6 Q. At which time was the velocity of the ball the greatest?

A. The velocity of the ball was the greatest at Time C.

7 Q. Compare the velocity of the ball for the two slopes as time increased from Time A to Time C.

A. As time increased, the velocity for the steep slope was greater than the velocity for the gentle slope.

8 Q. Calculate the kinetic energy (KE) of the ball for the gentle slope ramp at all selected times. Enter the values in Table 1.

A. Answers may vary. See sample data in Table 1.

9 Q. At which time was the kinetic energy of the ball the least?

A. The kinetic energy of the ball was the least at Time A.

10 Q. At what time was the kinetic energy of the ball the greatest?

A. The kinetic energy of the ball was the greatest at Time C.

11 Q. Compare the kinetic energy of the ball for the two slopes as time increased from Time A to Time C.

A. As time increased, the kinetic energy for the steep slope was greater than the kinetic energy for the gentle slope.

12 *Q.* Based on your data from Table 1, how did kinetic energy change when velocity increased?

A. An increase in velocity caused an increase in kinetic energy. Notice in the equation for kinetic energy that velocity is squared. Increasing the velocity of an object has a greater effect on kinetic energy than increasing mass.

13 Q. Based on your data from Table 1, how did kinetic energy change when slope increased?

A. Increasing the slope increased kinetic energy. This is because the increase in slope increased the velocity of the ball.

14 Q. Based on your data from Table 1, how did velocity change when slope increased?

A. Increasing the slope increased the velocity of the ball.

15 Q. Based on the results of your investigation, describe how engineers can control the energy of the moving water as it moves sediment through the channel and deposits the sediment into the eroded wetland areas.

A. Engineers could increase the kinetic energy of the water in the channel by increasing the slope of the channel. A steep slope will increase the velocity of the water and therefore increase its kinetic energy. The slope of the land is an important factor in deciding where to start the reintroduction channel. The channel has to start far enough upstream to create a steep slope. As the slope of the land decreases at eroded areas, sediment begins to settle.

Table 2 represents two wetlands locations. Copy Table 2 into your journal.

16 Q. *Location 1* represents a sediment reintroduction channel. Using the terms *high* or *low*, describe the velocity of the moving water in the channel. Use the same terms to describe the kinetic energy of the moving water. Record your choices in the table.

Location 2 represents a wetlands eroded area. In order for the sediment to be deposited successfully, the velocity and kinetic energy of water in the channel and eroded areas must be appropriate. Using the terms *high* or *low*, describe the velocity of the moving water in the eroded areas. Use the same terms to describe the kinetic energy of the moving water. Record your choices in the table.

A. *See Table 2.*

Table 2

Location		**Velocity (V)**	**Kinetic Energy (KE)**
1	**Sediment Reintroduction Channel**	*High*	*High*
2	**Wetlands Eroded Area**	*Low*	*Low*

Sample Data

17 Q. Based on what you learned in this experiment, why do you think more particles carried by the Mississippi River settle near the mouth of the river than upstream?

A. The kinetic energy of the water carrying the particles is greater upstream than near the mouth of the river. Upstream, there is a steep slope and water has a greater velocity. Near the mouth of the river there is a gentle slope and water has a low velocity. Water with greater kinetic energy is able to do more work and carry more particles. The kinetic energy near the mouth is low and the water is unable to do the work necessary to carry the particles. Therefore, these particles settle out.