

**ABSTRACT**

This lesson uses the thrill of amusement park attractions to teach students how to analyze principles of motion. The Calculator Based Laboratory helps students record and analyze acceleration data collected on amusement park rides. Students can concentrate on the effects of acceleration on their bodies while collecting data. When the ride is over, students analyze the data to determine the acceleration at particular points of the ride. Students relate the feeling of acceleration to the graph of the data they collected.

**TIES TO CURRICULUM**

*Amusement Park Physics* integrates math, science and technology as mandated in the *National Science Education Standards*, the National Council of Teachers of Mathematics (NCTM) Standards and the American Association for the Advancement of Science *Benchmarks*. In particular, the lesson fulfills the call of the NCTM Standards that students must “learn to deal with complex problems that involve multiple aspects of mathematics... [and] apply varied subject matter knowledge and varied reasoning and problem solving skills, in integrated fashion.” (NCTM, p.272)

**LEARNING OBJECTIVES**

After completing *Amusement Park Physics*, students will be able to

- ◆ sketch and explain graphs of distance vs. time, velocity vs. time, and acceleration vs. time;
- ◆ describe the position of a person on a ride and the acceleration experienced by the rider at a given point on a graph of acceleration vs. time;
- ◆ relate acceleration to gravitational forces; and
- ◆ use mathematical models for data including concepts in linear, quadratic, exponential, sinusoidal, and piece-wise functions.

**NUMBER OF LAPTOPS AND GROUP SIZE**

Only one laptop is required but it is best to have one laptop for every four students.

**TIME REQUIREMENT**

Time varies with distance to field site and number of laptops and CBL systems. Approximate time requirements for each activity are as follows:

<b>Task</b>	<b>Time</b>	<b>Location</b>
Introduction	1 hour	Classroom
Field activity	2–4 hours	Amusement park
Data analysis	3 hours	Classroom/home
Presentations	1 hour	Classroom

**MATERIALS**

- ◆ Laptop computers, and extension cord with multiple outlet strip
- ◆ Calculator Based Laboratory (CBL) system by Texas Instruments (TI) (one per group)
- ◆ TI-83 graphing calculator (one per student)
- ◆ Acceleration software for the TI-83
- ◆ TI Graph-Link software and cable
- ◆ Vernier Single or Triple Axis Low-g Accelerometer
- ◆ Fanny pack
- ◆ Stopwatch with rubber band for wrist strap
- ◆ Lab notebook and writing utensil
- ◆ Amusement park maps
- ◆ Schematic drawings of each amusement park ride/ attraction giving heights, lengths, and times

*Optional Software*

- ◆ Vernier's Graphical Analysis or PASCO's DataStudio
- ◆ Spreadsheet software

**LESSON DESCRIPTION**

This type of activity is traditionally conducted with a spring accelerometer. However, the subjective data obtained with such a tool is not quantifiable, and offers only an approximation of the acceleration felt on a ride. In addition, the thrill and excitement of many of the newer attractions makes watching the spring accelerometer impossible.

**Teacher Preparation**

Obtain maps of the amusement park and schematic diagrams of park rides. Establish a "command center" at the amusement park, where the laptops will be accessible to transfer, analyze, and save data. An ideal location is near food, restrooms, tables, and an electrical outlet. Mark the bus pickup point and the command center on the amusement park map for each student.

Familiarize yourself with the CBL system and all associated software. Prepare a description of a mythical amusement park ride (see Class Activities).

**Introduction**

Divide students into groups of four (an even number works best since most park attractions seat riders in pairs). Students fearful of heights or susceptible to motion sickness should not be required to ride all of the attractions, but each group of students should have at least one member willing to ride any attraction. Review mathematical calculations, energy concepts, and graph types.

Use one class session to teach students how to operate the CBL and software. Students can wear the CBL and run up and down steps, swing the CBL in a circle, or attach the accelerometer to a pendulum or spring in harmonic motion. Students can also practice on the swings or merry-go-round at a local playground.

## Activity

Groups must report to the command center every two hours. Stagger starting times to spread out groups. At the command center, students upload data to the computer, look at graphs, and get assistance with questions.

Groups must collect acceleration data from at least four different rides. Suggest which rides and what sections of the rides may be most appropriate for data collection. Students should first observe the ride in operation and create a lab journal.

Figure 1: How to carry the CBL in a fanny pack



**SUGGESTIONS**

- ◆ Many amusement parks hold a "Physics Day" and invite physics students to collect data and study the rides.
- ◆ Contact the park's education coordinator or safety officer ahead of time. Many parks allow an individual to wear the CBL system only as long it is securely fastened. The safety officer should approve all equipment before the trip.
- ◆ Use a securely fastened fanny strap to carry the CBL system.
- ◆ Use schematic drawings of each amusement park ride giving heights, lengths, and times. The park's education coordinator or publicity department may be able to provide these.
- ◆ Bring other teachers along, making sure there is always one teacher sitting with the computers and equipment.
- ◆ Use a heavy rubber band to secure a stopwatch to the wrist. If the watch becomes lodged in the ride, slip or cut the rubber band to prevent serious injury.
- ◆ If distance or cost prohibits a trip to an amusement park, use a playground with swings, slides, and other rides.

The journal should include:

- ◆ a sketch of the position (height) of the rider as a function of time;
- ◆ a sketch of the apparent velocity vs. time graph;
- ◆ the portion of the ride from which the group has decided to collect acceleration data; and
- ◆ the length of time and number of data points to be collected. The time interval between data points is the total collection time divided by the number of data points.

Program the CBL system for the proper settings as discussed above using the program ACC1TRIG or ACC3TRIG. One student in each group should carry the CBL in a fanny pack (Figure 1), or another method approved by the park's safety officer.

Board the ride and press the "Trigger" button on the CBL at the appropriate place on the ride.

After exiting the ride, groups should use the program GETACC to download the data from the CBL to each student's calculator. Graph the acceleration vs. time data and save it. Using a word processing program, record the name of the stored data, the ride, the number of data points, the time interval and the point on the attraction where data sampling began. With a paint or draw program, each student should sketch a time-acceleration graph. Number each significant point on the graph, such as a local maximum or local minimum acceleration and values where the acceleration is zero. Using the word processor, describe the feeling at each point on the ride. Discuss possible mathematical models and make notes for evaluation on the way home.

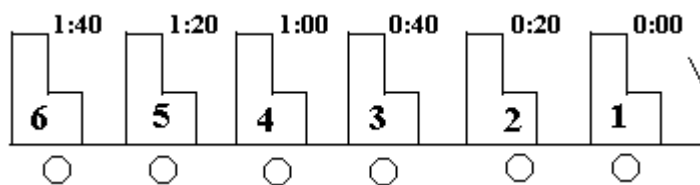
Repeat the process on the same ride or a different attraction. Every two hours, the group should go to the command center and use the laptop computers to store the data using the TI Graph-Link cable and software.

### Class Activities

After groups have collected data from individual rides, you may wish to conduct some activities with the entire class. The class can research whether there is a difference in acceleration when riding in the front versus the back car. Two groups should ride the same attraction, with one group sitting in the front car and the other in the back car. At a pre-determined point, the rider in the front car lowers his hand and both groups trigger their CBLs. The two groups get together at the end of the ride to discuss results.

A good class activity is to meet at a specified time to map the acceleration during an entire ride. Pick the longest ride in the park (probably a roller coaster). Time the length of the entire ride and divide the time proportionately among the number of CBLs. Program the CBLs with an additional two seconds of time. (For example, if the required time is 20 seconds, record data for at least 22 seconds.) Board the ride, positioning each student with a CBL, and a timing partner, in consecutive rows on the ride. At the starting point, the timer in the first car drops his or her hand, the data recorder in the first car starts the CBL, and all other passengers start stopwatches, and then record data at intervals along the ride (see Figure 2). When finished,

**Figure 2: Class amusement park ride**



In the figure above, six pairs of students divide a two-minute ride into six equal time periods. The passenger in Car 1 drops his or her hand while the other rider in Car 1 triggers the CBL. The other passengers simultaneously start their stopwatches. In the two-minute ride, each pair of students records 20 seconds of data. Hence, the CBL in Car 2 is triggered at 20 seconds after the start of the ride, Car 3 at 40 seconds, etc.

## REFERENCES

## Books

- American Association for the Advancement of Science. *Benchmarks for Science Literacy-Project 2061*. New York: Oxford University Press, 1993.
- Gastinaue, John, et al. 1998. *Physics with CBL*. Portland, OR: Vernier Software, 1998. <http://www.vernier.com/cmat/PWCBL.html>
- National Council of Teachers of Mathematics. *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: NCTM, 1989.
- National Research Council. *National Science Education Standards*. Washington DC: National Academy Press, 1996.

## Articles

- Clemens-Walatka, Bernadette. 1998. "Amusement Park Inquiry." *The Science Teacher*. 65 (1): 20.
- Honig, Carlye. 1987. "The Ups and Downs of Roller Coaster Design." *Exploratorium Quarterly*. Summer.

## Web sites

- Amusement Park Physics. A different lesson than this one:  
<http://www.learner.org/exhibits/parkphysics/>

upload all of the data to a spreadsheet. Delete the duplicate data points at the start and end of each CBL's collection and graph acceleration for the entire ride.

For another class activity, give each group a description and drawing of a mythical amusement park attraction, including various components of rides studied during the day. Students should formulate a sketch of the position vs. time, velocity vs. time, and acceleration vs. time graph for the ride. This mythical ride may include dropping from a height and returning to a position about one-half as high, traveling through a vertical loop and nearly horizontal loop, and rolling up an incline to a stop.

On the return trip to school, students can begin to prepare a presentation of a selected ride for the class.

**Data Analysis**

During the final class sessions, students will analyze data and give presentations. Depending upon the types of data curves collected and the math background of the students, these activities may take several hours of preparation. Students may discover mathematical concepts in linear, quadratic, exponential, sinusoidal and piece-wise functions.

Students with a background in precalculus and calculus may also analyze data with Vernier's Graphical Analysis software or PASCO's DataStudio software. For larger graphs, export the data to a commercial spreadsheet package such as Microsoft Excel or ClarisWorks.

**Written Report**

Each student should write a report presenting data on one of the rides and on the class ride. The written reports should include introduction, materials and methods, results, analysis, and conclusion. Students should also answer the following questions: Does position in a ride have an effect upon the data? How

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did the data match the feeling experienced on the ride? How does the acceleration match the sketch drawn prior to boarding the ride?

### **Group Presentations**

In addition to mapping out the ride, groups should present mathematical models where appropriate, including linear, quadratic, sinusoidal, and exponential functions. Students may use piece-wise functions to describe the collected data, or force diagrams and motion maps describing period, amplitude, and frequency.

## **ASSESSMENT**

Assess student performance based on lab activity journals, written reports, and group presentations. In particular, the lab activity journal should include:

- ◆ sketches of distance vs. time, velocity vs. time, and acceleration vs. time graphs for a minimum of four rides;
- ◆ description of methodology for data collection;
- ◆ sketch of the recorded data; and
- ◆ interpretation of acceleration data relating position.

### **REFERENCES, cont'd.**

Energy in Motion. Physics programs from an amusement park:  
<http://www.knotts.com/advinedu/energy/energy.htm>

Jerel Welker's Amusement Park Physics. The author's Web site, with diagrams and instructions on downloading acceleration software programs  
[http://lhs.lps.org/instruct/amusement\\_park.htm](http://lhs.lps.org/instruct/amusement_park.htm)

PASCO Scientific:  
<http://www.pasco.com/>

Vernier Software:  
<http://www.vernier.com/>