PHYSICS DAY

Six Flags®
AMERICA
Baltimore/Washington, D.C.

Teacher's Resource Manual

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Dear Teachers & Students,

Our Physics, Math and Science Day programs continue to provide real-world learning in a thrilling, experiential environment. Our goal is to make learning fun. For years, these programs have become annual events in many of our theme parks nationwide. Our company is derived from students and teachers, like yourselves, who one day decided to branch off from common career paths to create an industry full of thrills that today continues to entertain hundreds of millions of visitors each year.

We deliver entertainment primarily through our rides that are founded upon physical and mathematical principles. There exists true science and math behind each unique design of every ride experience. Simple rides like carousels that have routine circular motions with predictable movements, mixed with sound, lights, and other actionable media have thrilled people of all ages for over a century.

Nowadays, extreme roller coaster rides and simulators create unpredictable motion with varying g-forces, speeds subject to weather conditions, and carriages designed to hold people safely in place are all designed by large networks of physicists, mathematicians, architectural & civil engineering designers.

I encourage you to view our industry from this perspective and hope your visit with us inspires the next generation of creative thinking that will carry the next genre of entertainment into the next definable dimension. We thank you for your past patronage and hope that you enjoy our product offering enough to return with your families and friends to experience the entire property.

Ride-on!

Rick Howarth

Six Flags America Park President

Introduction

Physics Day at an amusement park such as Six Flags America is an appropriate end of the year activity for both middle and high school physical science students. The physics of the rides is the basic material of a first-year physics course. Roller coasters demonstrate the conversion of gravitational potential into kinetic energy; rotating swing rides illustrate the vector addition of forces. Rotating rides of all sorts allow for computation of centripetal accelerations and all of those terrifying falls allow students to experience free fall and near weightless conditions.

Students who think about and experience physics in the park develop a deeper understanding of the principles taught in the classroom. By becoming part of the laboratory equipment, the students experience the excitement of understanding and learning along with the enjoyment of the rides. In addition, a visit to an amusement park might serve as a stimulus for younger middle school students to continue their study of science, especially physics, in high school.

The contents of this booklet have been taken from a number of sources. The material on pages 3 through 11 comes from the book *Amusement Park Physics*. Carole Escobar edited this book with contributions from many teachers. The book is available from the American Association of Physics Teachers and includes many other useful resource materials and references. The materials on pages 84-92 are used with the permission of Clarence Bakken from the Gunn High School in Palo Alto, California. Finally, some of the ride activities are from the Six Flags America High School Activities Handbook written by David Myers and Tom Wysocki of Eleanor Roosevelt High School in Greenbelt, Maryland.

This booklet, along with the references provided, is intended to present the basic information needed to both plan a trip to a park and to use the physics of amusement park rides in the classroom. Some of the materials are to be used by the teacher; other sections can be copied and used by the students.

Warren W. Hein
American Association of Physics Teachers
whein@aapt.org

Michael Sivell
Hammond High School
Howard County Schools
msivell@hcpss.org

Learning Goals and Objectives

Cognitive Goal

Upon the completion of the activities, the student will have an enhanced understanding of the following laws and concepts of physics:

1. Forces
2. Work
3. Power
4. Friction
5. Kinematics
6. Newton's laws of motion
7. Rotational motion
8. Conservation of energy
9. Conservation of momentum

The student will:

1. Determine the forces acting on a passenger in circular motion rides and roller coasters.
2. Determine the changes in forces as the student moves in a vertical circle on a roller coaster.
3. Calculate the work done against friction on roller coasters.
4. Estimate the power required to haul a roller coaster train and its passengers up the first hill.
5. Apply the method of triangulation to determine the heights of and distances to various structures.
6. Measure the linear displacement of a chair on the rotating swing ride as it moves through a complete revolution.
7. Calculate the centripetal acceleration of a passenger in circular motion by the use of an accelerometer.
8. Apply Newton's laws of motion.
9. Apply the rules of kinematics and principles of conservation of energy to determine the velocity and acceleration of an object after falling a given vertical distance.
10. Calculate the momenta of objects and quantitatively determine conservation of momentum.
11. Measure and record the student's personal responses to experiences during various rides.

Attitude Goal

Upon completion of the activities, the student will develop a positive attitude toward the physical sciences.

The student will:

1. Be motivated to study physics by being challenged with significant tasks that allow the student to comprehend personal experiences.
2. Gain an appreciation of the physics involved in the design and engineering of the rides.
3. Gain an appreciation for the safety devices built into the rides and controls.

Appreciation Goal

Upon completion of the activities, the student will bridge the gap between school, work, and life education by seeing them as interactive rather than isolated from one another.

The student will:

1. Gain an appreciation of the applicability of physical principles studied in the classroom to large-scale phenomena.
2. Gain an appreciation of the value of working in teams to accomplish measuring and calculating tasks.

Pre-Trip Class Activities

1. Review kinematics and dynamics. It is helpful to present the students with workbook pages for preview in class. You can give students typical data and have them perform the calculations.

2. To demonstrate a ride, set up a model of a rotating swing ride or a Hot Wheels track with a vertical loop. Students can take measurements of the angle of the swing chains as a function of the speed of rotation, or of the mass of the passengers. They can practice measuring the time needed for a car to pass through a point on the track by taping two cars together to make a measurable train. Ask from what minimum height the car must fall in order to stay on the track of the vertical loop. This experiment is good for both demonstration and laboratory purposes. It leads naturally to the role of friction in consuming energy that would otherwise be available for increased speed. Students are prepared for the fact that their calculation, using ideal conditions, will differ from the actual velocities that they will measure in the park.

3. Construct accelerometers. If you cut the plastic tubing ahead of time, both horizontal and vertical devices in the PASCO scientific kit can be constructed easily in a single class period. Calibrating the horizontal device takes some explanation and is a good homework assignment. Accelerometer kits come in class sets of 15 (15 vertical and 15 horizontal devices).

   Order using catalog no. ME9426, from PASCO scientific, 10101 Foothills Blvd., Roseville, CA 95678, 1-800-772-8700 E-mail: sales@pasco.com Website: http://www.pasco.com/

4. Run one of the triangulation activities as a laboratory exercise. The flagpole in front of the school is a favorite object for measuring heights. Remember that the equations assume that the pole is perpendicular to the baseline. If your pole is on a mound, the activity will not give accurate results.

5. Practice measuring by pacing. Triangulating a horizontal distance can lead into a discussion of how we know the distances to stars and across unabridged rivers.

6. Show a videotape, Website, or slides of actual rides to give students some concept of the size and speed of certain rides. Slides can be used to practice estimating heights and angles of elevation of devices such as roller coasters.

7. Emphasize that students do not have to ride all the rides. Only the accelerometer readings are taken on the rides. All other measurements are taken by an observer on the ground.

8. Post a map of the park if you can. Encourage students to ride the most popular attractions *before* the park becomes crowded. Locate the First Aid station and discuss how students can reach you if necessary. Some teachers have students check in with them during a designated time period.

9. Set up laboratory groups for the park. Students should stay in groups for educational and safety reasons. Announce requirements and options, when the work is due, and how it will be graded. Make sure students know that line cutting is grounds for expulsion from the park by Six Flags America Security. Students who cut lines and are made to leave the park must wait outside park gates for the rest of the school to leave for the day.

10. Preview the workbooks in class and then collect them for distribution on the bus.

Tips to the Teacher

1. Equipment needed in the park:
   a) Stopwatch (at least one per group)
   b) Accelerometers (doubling as clinometers for angles of elevation)
   c) Measuring string or knowledge of their pace
   d) Calculator, pen, pencil
   e) Ziploc™ bag for student workbook and equipment (for water rides)
   f) Dry clothes.

2. Hand out tickets as they exit the bus. This speeds entry into the park.

3. Remind students to double-check the restraints on each ride. Be sure that they understand that safety is not a joke.

4. Check with park personnel for meal deals or catered outing. There is an all-you-can-eat catered meal option that provides everyone with lunch, affordably. Be sure that students are aware that no outside food is allowed in the park.

5. Announce the lateness penalty for either boarding the bus at school or leaving the park.

6. If the student workbooks are due as the bus arrives back at school, you will get them on time but they will be more ragged than if they are due the next day. Have each team leave one copy of the workbook on the bus. That's the one that will be submitted for grading.

7. An interesting option is to allow students to design activities for rides that are not covered in the workbook.

8. Be sure that your students know how to identify your bus. Put a sign in the front window or a scarf on the antenna.

9. If you do not have students check in with you during the day, make a habit of being visible, and check Guest Relations every hour or so. Students can **leave notes for you** there.

10. Be sure you have a minimum of two adults on each bus in case you need someone to stay with an ill student.

11. Be sure to explain to students that stopwatches should be used for timing rides while **watching** and not **riding.**

Trip Checklist

- ❑ **Authorization. Obtain** this from both your school and the district administrator. Date of trip: ____________
- ❑ **Transportation.** Contact the bus company.
  Total cost: ________Number of seats: __________
  Number of hours: ________From ______a.m. to______ p.m.
  Deposit: $_________ Deadline for balance:_________
- ❑ **Tickets.** When you call the park, ask for Group Sales
- ❑ (301-249-1500 Ext. 3700).
  $ per ticket: ________Deadline for order: __________
  Complimentary ticket with ______________paid.
- ❑ **Obtain permission slips or student contracts and make copies of them.** Be sure that emergency contact numbers cover all of the hours of the trip and that both parents and the administration each receive copies of the contract.
- ❑ **Collection of money and permission slips.** Have students pay by check (made out to the school). Have them deposit the checks in a manila envelope and sign a numbered line on the outside of the envelope. This will provide you with an automatic count and will help to prevent loss of money. Don't accept ticket money without a permission slip. Don't accept cash under any circumstances.
- ❑ **Student workbooks.** Choose the appropriate activities and have the booklets reproduced.
- ❑ **Chaperones.** Ask school administrators, parents, and faculty to join you. Their tickets are usually complimentary.
- ❑ **Lesson plans.** Have an alternate activity for students who are unable to go on the trip. Try a workbook for which you supply typical data, so students can do the calculations.
- ❑ **Order accelerometer kits.**
- ❑ **In-class activities.** Plan time for reviewing kinematics and dynamics, building an accelerometer, and conducting laboratory exercises based on the rides. Practice making measurements based on pacing and begin to collect the essential materials for the trip.
- ❑ **Professional relations.** Leave a copy of the student workbook in the faculty lounge so that your colleagues will know what students will be doing and what you will be grading.
- ❑ **Public relations.** Invite representatives of the yearbook, school, local papers, and TV stations to attend your field trip. Pictures of students doing calculations next to the roller coaster can be very helpful in dispelling opposition to this type of field trip.

Physics Day Field Trip Student Contract

Faculty Sponsor: ____
On ____________, students participating in the trip to____________________________ will leave _________________________ School at _______a.m. by bus and return that day at about __________p.m. The cost of the trip will be $_______, which must be paid by check made out to the school. This agreement, when signed, informs those concerned that the following stipulations are understood and agreed upon prior to departure.

1. Completion of the physics exercises and write-up is mandatory for each student.
2. Each student is responsible for being on time according to the day's schedule.
3. No student is to engage in any activity that might endanger individual safety or cause property damage.
4. No alcoholic beverages will be brought on the buses or consumed on the trip.
5. No drugs (except those prescribed by a doctor) will be permitted on the trip.
6. Any violation of school district or park policy will result in appropriate disciplinary action. Line cutting at the theme park is groups for expulsion from the theme park for the remainder of the day as mandated by Six Flags America.

This agreement is meant to alleviate any misunderstanding that this trip is not a serious educational activity. Physics Day is an opportunity for students to experience physics principles in a meaningful and enjoyable way.

Your signature below indicates that you have read and understood this agreement and that you would like to participate in this experience. **Please have your parent(s) or guardian(s) read this agreement and sign it. Both signatures are necessary before space on the trip can be reserved for you.**

Important notes:
No student is required to go on the rides in order to earn full credit. Many of the exercises can be done at ground level.

Please list here any medication currently prescribed for you or that you take routinely and any medical information, such as bee sting allergies, that might be needed by First Aid personnel.
Medication:____

Other medical information:____

Student: ______________________________Signature: __________________________

Parent/guardian:________________________Signature:__________________________

Emergency contact #s: Business:__________________Home:______________________

Safety Precautions

1. Medical records, including information about current medication, should be part of the permission slip. Be sure to carry the slips with you on the trip.

2. Be sure that students are aware of the location of Guest Relations. Let them know that they can leave messages for you there. Before the trip, let parents or guardians know that you will check with Guest Relations for messages periodically.

3. Form laboratory groups of four to six students.

4. Shoes or sneakers are a must. Sandals, loose footwear, loose jackets, and long hair are dangerous on some rides. Remind your students that they must observe any posted regulations.

5. Evaluate your measuring devices for safety before you leave school. Avoid anything with sharp ends. Devices must be lightweight and capable of being tethered to the wrist to avoid loss during a ride. Tethered devices are not allowed on round rides (i.e. teacups).

6. Remind students to check that seat belts and harnesses are secured. The rides are designed to be safe. Students should double-check for themselves.

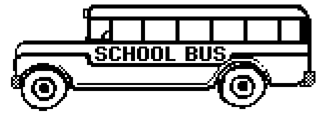
7. The sun can be a problem. Sun block and sun visors are a must on what may be their first full day in the sun this year.

8. Remember -*No one is forced to ride.* Measurements can be taken from the ground and accelerometer readings can be shared.

9. Remind students to follow all safety guidelines listed on park map and at each attraction site.

MIDDLE SCHOOL

CONSCIOUS COMMUTING



As you ride to the amusement park, be conscious of some of the PHYSICS on the way.

A. Starting Up

THINGS TO MEASURE:

As you pull away from the school or from a stop light, find the time it takes to go <u>from stopped to 20 miles per hour</u>. You may have to get someone up front to help on this.

t = ______________ sec

THINGS TO CALCULATE: Show Equations used and your substitutions.

1. Convert 20 mph to m/s. (1.0 mph = 0.44 m/s)

   v = ______________

2. Find the acceleration of the bus in m/s^2.

   a = ______________

3. Using your mass in kilograms, calculate the average force on you as the bus starts up. (1 kg of mass weighs 2.2 lbs)

   F = ______________

4. How does this compare to the force gravity exerts on you (your weight in newtons)?

   Circle One: More Less

   (Force calculated)/(Force gravity normally exerts) = _______ g's

THINGS TO NOTICE AS YOU RIDE:

5. As you start up, which way do you FEEL thrown, forward or backward?

6. If someone were watching from the side of the road, what would that person see happening to you in relation to the bus? What

would that person see happening to you in relation to the ground underneath you?

7. How can you explain the difference between what **you feel** as the bus starts up and what **the observer** sees? (You may want to use the concept of FRAME OF REFERENCE.)

B. Going at a Constant Speed

THINGS TO NOTICE

8. Describe the sensation of going at a constant speed. Do you feel as if you are moving? Why or why not? (Try to ignore the effects of road noise.)

9. Are there any forces acting on you in the direction you are moving? Explain what is happening in terms of the principle of inertia.

C. Rounding Curves

THINGS TO NOTICE:

10. If your eyes are closed, how can you tell when the bus is going around a curve? Try it and report what you notice. (Do NOT fall asleep!)

11. As the bus rounds a curve, concentrate on a tree or a building that would have been STRAIGHT AHEAD. See if you can sense that you are TRYING TO GO STRAIGHT but are being pulled into the curve by a centripetal force.

    What is supplying the centripetal force, the seat, your seatmate, the wall, the arm of the seat, or a combination?

    How does this change when the curve is tighter or the bus is going faster?

Write a few sentences about this experience. How does it connect with what happens on the rides at the amusement park?

THE SOUND OF MUSIC

OVERVIEW

Music is used extensively throughout Six Flags America to enhance the customer's experience and create special moods. Music is a mood-inducer and affects how we interact with our environment. Listen to the beat and notice how it affects you as you move through Six Flags America!

GOALS

Listening
Analysis of Forms
Music
Writing
Aesthetic

MATERIALS

Paper and Pencil
Tape Recorder

DIRECTIONS/ACTIVITY

1. Select an area in Six Flags America.
2. Listen to the music.
3. Describe the tempo (fast, upbeat, slow, romantic etc.)
4. Close your eyes. Try to develop a mental image created by the music. What emotions do you feel?
5. What mood does the music try to create?
6. How does Six Flags America use music to enhance this area?

EXTENSIONS/ENRICHMENT

1. Identify the song title and performer. Why was this selection chosen for this area? Would you recommend another selection? Defend your choice.
2. How would different types of music influence different groups of people? Would you use heavy metal music in an area developed for small children?
3. Research the use of music in different environments (hospitals, groceries etc.).
4. Tape record the music in one area. Take the tape to another area. Play the music. How is the mood affected by different music?

LOOP -THE- LOOP

OVERVIEW

A loop is any roughly circular or oval pattern or path that closes or nearly closes on itself. Many rides at Six Flags America use a loop to create a “thrill” ride. Several principles of physics make such rides possible. Inertia is a physical property that keeps moving things moving or keeps motionless things still, unless an outside force acts on them. (When a bus driver slams on the brakes, the bus stops but your body keeps moving until the seat in front of you stops you.) Centripetal force causes an object to turn in a circular path. (When you speed around a corner, inertia sends you in a straight line and centripetal force is pushing the car into the curve, pressing you against the door.) The loops and curves on roller coasters and other looping rides put these factors to use.

GOALS

Observing
Patterns
Systems and Interactions

MATERIALS

Paper
Pencil

DIRECTIONS/ACTIVITY

1. Select one of the following rides: Two-Face: The Flip Side; Jokers Jinx; Mind Eraser; or Bat Wing.
2. Observe the ride.
3. Predict where you will: a.) feel weightless; b.) feel the heaviest.
4. Ride the ride.
5. Were your predictions correct? Answer the following questions.
6. What two forces, working together, keep you and the cars on the track?
7. What is the force that keeps you in the seat?
8. When did you feel weightless? Heaviest?
9. Where does the centripetal force occur?
10. Identify at least one place where you see a transfer of energy. Identify the type of energy.

EXTENSIONS/ENRICHMENT

1. Diagram the path of the ride. Label where you see energy transfers and centripetal force and where you are weightless.
2. How does friction affect the ride? Investigate.
3. Research the history of roller coasters.

SPINNING WHEELS

OVERVIEW

Some of the rides at Six Flags America have one or more circular routes. The diameter of the circle, the number of circles, and the speed of the ride all contribute to unique ride experiences. Centripetal force, the gravitational force, and inertia work together to keep you in your seat. Inertia is a physical property that keeps moving things moving or keeps motionless things still, unless an outside force acts on them. Centripetal force provided by the seat causes an object to turn in a circular path.

GOALS

Observing
Classifying
Patterns
Mathematical Structure

MATERIALS

Paper
Pencil

DIRECTIONS/ACTIVITY

1. Select three rides that travel in a circle.
2. Compare and contrast the rides by filling in the data table. Fill in the names of three rides.
3. Count how many circles are involved in the ride.
4. Identify where centripetal force (if any) is used and how.
5. Using the numbers 1 through 3 and with the number 1 being the fastest circle, rate the three rides from fastest to slowest.
6. Diagram the path you take as you ride the ride.
7. Does the location where you sit in the rides have an effect on your ride? Explain for each ride.
8. Which ride would you least like to ride in a car with a 350-pound gorilla?

EXTENSIONS/ENRICHMENT

1. Select another geometric shape and define. Try to find examples of these definitions.
2. How could the rides be applied to everyday uses? Does the idea of a Ferris wheel relate to anything you know? Find other rides that correspond to something in your daily life.
3. Calculate the actual speed of each circular ride.

SPINNING WHEELS WORKSHEET

DATA TABLE			
Ride			
Number of Circles			
Use of Centripetal Force			
Rank the Speed 1-3			
Actual Speed of Each Ride			

PACING THE PATH

OVERVIEW

One definition of a circle is a cycle, a period, or a complete or recurring series usually ending as it begins. The paths throughout Six Flags America all circle back to the entrance to the park. You can estimate the length of the paths by using your pace.

GOALS

Computing
Patterns
Problem-Solving

MATERIALS

Meter Stick
Chalk to Mark on Pavement
Paper
Pencil
Map of Six Flags America

DIRECTIONS/ACTIVITY

Find your pace

1. Mark a starting point.
2. Measure ten meters.
3. Mark an ending point.
4. Using a natural stride, pace off the ten meters three times. Total the number of steps.
5. Find the average number of steps in ten meters for the three trials (Average = total number of steps divided by 3). This is your "pace."
6. Use your "pace" to measure distances and complete the following formula:

$$\text{Distance in meters} = \frac{(\text{number of steps}) \times 10\text{ m}}{\text{your "pace"}}$$

7. Start at the entrance to Six Flags America.
8. As you enter, turn right and proceed to the Two-Face: The Flip Side ride.
9. Keep count of your normal paced steps.
10. Figure the distance in meters to the Two-Face: The Flip Side ride.
11. This is an estimated figure. How can you check your answer?
12. Retrace your steps and figure again.
13. Keep a log for the day of how far you travel while visiting Six Flags America.

EXTENSIONS/ENRICHMENT

1. Using the map of Six Flags America, find a "circle" to measure.
2. Have another student measure the same circle. How do the two measurements compare? Take an average of the two measurements. Is this a better estimate? Explain.
3. How could you get an exact measurement of the circle? Try it if you have the material.

BUMPER CARS AND THRILL RIDES

OVERVIEW

There seem to be different patterns of facial expressions of riders as they ride the bumper cars and as they ride the thrill rides.

GOALS

Observation
Production
Creative Thinking

MATERIALS

Notebook Paper
9” x 12” Manila Paper
Pencil

DIRECTIONS/ACTIVITY

1. Observe the faces of riders as they ride one of the coaster rides and as they ride the bumper cars at Coches Chocos. List different emotions or feelings that you see on their faces. What indicators did you use to come to that conclusion?
2. Make two sketches. Each sketch should be a close-up look at a rider’s face as this person rides a coaster ride and then as they ride the bumper cars.
3. Write a paragraph on the back of each drawing describing how you think the person was feeling as he or she rode the ride.

EXTENSIONS/ENRICHMENT

Back in the classroom, have students focus on one of the drawings and make a mask that captures the emotion of riding the ride.

SPEED DEMONS

OVERVIEW

Climbing, climbing, climbing. It can seem to take forever to get to the top of a tall amusement park ride. Then, just as you reach the top and begin to settle back, the rush of wind intensifies to a crushing force. Just how fast are you going anyway?

GOALS

Observing
Mathematical Reasoning
Mathematical Procedures
Data
Expanding Existing Knowledge
Measuring
Writing
Measurement
Independent Learning

MATERIALS

Stopwatch or Watch With a Second Hand
Chart of Distances

DIRECTIONS/ACTIVITY

You can do this from a distance. The length of the train can be obtained from the data table and by timing how long it takes the train to pass a certain point; you can find its average speed.

1. Don't blink you might miss it.
2. Find the points on the ride where each timing will begin.
3. As the car reaches the start, begin timing the ride.
4. When the end of the train passes that point, stop the watch.
5. Record your time on the data table.
6. Repeat the timing to ensure its accuracy (take an average of your times).
7. Record your data on the data table.
8. Before riding, observe the speed of the ride from the ground. Describe your thoughts.
9. As you ride the ride, describe the effect its speed has on you.
10. Explain the effects "velocity" has on the degree of thrill or entertainment provided by the ride.

EXTENSIONS/ENRICHMENT

1. Find the number of feet in a mile and seconds in an hour. Now, determine the speed of the ride in miles per hour.
2. Determine the velocity of the ride at other points in its travel.

   Discuss the reasons people might give for liking "fast rides." Poll 25 people before they ride. Poll another 25 people who have already ridden.

DATA TABLE

Speed = __________(length of train)_____________
(time for train to pass a point on the track)

Name of Ride (you select)____

Steepest Climb:

Length of train (given)____________________________________

Time for train to pass a point on track (seconds)___________________

Speed (m/s)____

Steepest Drop:

Length of train (given)_____________________________________

Time for train to pass a point on track (seconds)___________________

Speed (m/s)____

Total Ride:

Length of entire ride (given)________________________________

Total time for ride (seconds)_________________________________

Average speed (m/s)______________________________________

ROUND IN CIRCLES

OVERVIEW

Sometimes you just go and go, yet never seem to get anywhere. You're just running in circles. So, how far did you really go to get nowhere?

GOALS

Observing Computing Creative Thinking
Mathematical Reasoning Number Problem Solving
Data Resourcefulness and Creativity
Expanding Existing Knowledge

MATERIALS

Watch with Second Hand or Stopwatch (for extension only)

DIRECTIONS/ACTIVITY

1. As the ride begins to move (you can do this as you ride or while watching the ride from the side), count the number of times you go around before the ride stops.
2. Record this number on the data table.
3. Repeat your count several times to ensure its accuracy. You may want to take an average of your counts.
4. Which ride took you the greatest distance?
5. Explain what it means if a person says, "You get your money's worth out of these rides."

EXTENSIONS/ENRICHMENT

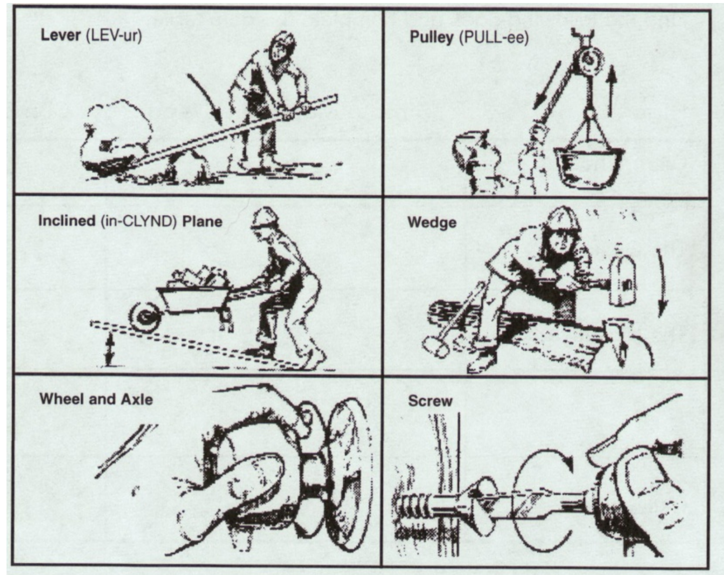
1. By timing each of the rides you can also determine its speed. How long did the average ride last? Which of the rides was the fastest? Do you prefer a long ride or a fast ride? Explain.
2. The horses on the carousel are always jumping. How many jumps do they make during one full revolution of the carousel? How far can they jump? If the ride continued non-stop for an hour, how far would they run and how many times would they jump?
3. Discuss the reasons people might give for liking "go-nowhere" rides. Poll 25 people before they ride. Poll another 25 people who have already ridden. Graph the results of your poll. What can you infer about this type of ride.

DATA TABLE

(Use pi=3.14)

Ride	Radius (m)	Circumference C=2(pi)(radius)	Number of Revolutions (N)	Distance Traveled
Carousel				
Flying Carousel				
Pirate’s Flight				

CREATING FUN THROUGH WORK



OVERVIEW

A simple machine is a device that changes a force or direction of a force. Simple machines allow us to work easier or faster. ***Here are the six kinds of simple machines.*** Complex machines are a combination of two or more simple machines. All of the rides at Six Flags America are made of simple and complex machines.

GOALS

Observing
Identifying and Analyzing Systems
Collecting Data
Drawing Conclusions

MATERIALS

Copy of the Data Table
Pencil

DIRECTIONS/ACTIVITY

1. Look at the examples of simple machines. Identify how we use these machines in everyday life.
2. What combinations of simple machines can you name? Make a list. Identify the simple machines that combine to make the complex machine. What work do they make easier or faster?
3. Observe the amusement park rides on the data table. Fill in the information.

CREATING FUN THROUGH WORK DATA SHEET

Find the following rides and complete the data table.

Ride	Simple Machines Used	Complex Machines Used
Carnival Ferris Wheel		
Tower of Doom		
Falling Star		
Superman-Ride of Steel		
High Seas		

DIRECTIONS/ACTIVITY

After completing the data table, select one of the rides you observed and answer the following questions.

1. How does the machine add to the sensation of the ride?
2. How does the machine make work easier on the ride?
3. Would the ride be possible without the machines working? Explain.
4. What other forces are at work on the ride?

EXTENSIONS/ENRICHMENT

Using one or more simple machines, design an amusement park ride. Draw the ride, label the simple machines, and describe how the machines operate together to create a ride. Is your ride designed for thrill or pleasure? Explain.

UP, UP, UP THEN DOWN!

OVERVIEW

As you slowly ascend towards the sky on the **Tower of Doom**, prepare yourself for a lunge into the nether world.

GOALS

Observing
Measuring
Collecting Data
Applying Data
Identifying Variables

MATERIALS

Stopwatch
Paper
Pencil

DIRECTIONS/ACTIVITY

1. Select a spot near the Tower of Doom to observe one of the sets of seats. Make sure you have a clear view.
2. Using a stopwatch, time the interval from release of the car at the top to the braking (slowing down) near the bottom.
3. Time the car at least 3 times.
4. Create a data table to display your observations.
5. Did you get the same results for each car?
6. What variables contribute to the difference in times?
7. If you observed another car, would your results be the same?
8. How could you get the same results each time?

EXTENSIONS/ENRICHMENT

Ride the Tower of Doom (or interview someone who has). Compare the sensation of a free-fall ride to another type of ride (like a roller coaster or a spinning ride). What creates the different sensations?

PENGUIN'S BLIZZARD RIVER

OVERVIEW

A raft 2.40 m in diameter is lifted up a hill and then descends down a flume through two twists before splashing into Chiller Bay. Spectators can fire wire cannons at the riders as they pass through Chiller Bay.

GOALS

Observing
Measuring
Collecting Data
Applying Data
Identifying Variables

MATERIALS

Stopwatch
Paper
Pencil

DIRECTIONS/ACTIVITY

1. Select a spot near the Penguin's Blizzard River to observe one of the rafts. Make sure you have a clear view.

2. Using a stopwatch, determine the time it takes the raft to pass a point at the top of the flume and at the bottom of the flume.

3. Time at least 3 different rafts.

4. Create a data table to display your observations.

5. Did you get the same results for each raft?

6. What variables contribute to the difference in times?

7. Could you get the same results each time? How?

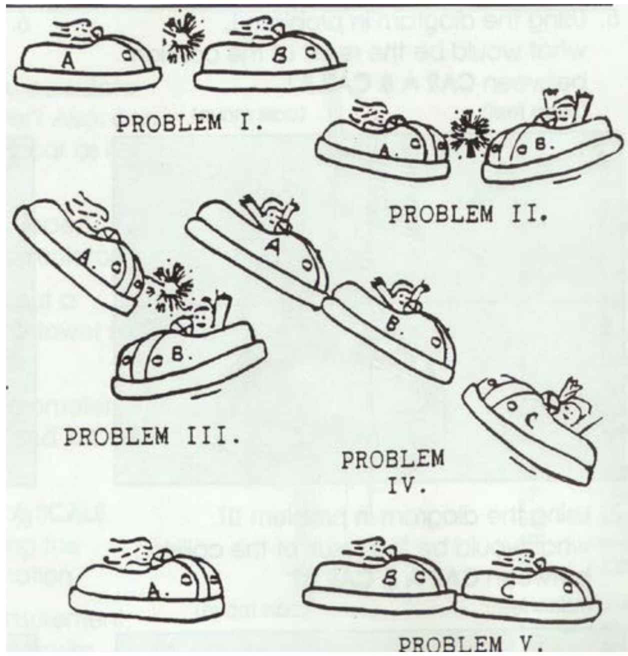
EXTENSIONS/ENRICHMENT

1. Why is there water on the slide and not just at the bottom?

2. At what point on this ride is the speed the greatest?

3. What causes the raft to rotate as moves down the flume?

COYOTE CREEK CRAZY CARS



OVERVIEW

In a collision between two or more cars, the force that each car exerts on the other is equal in magnitude and opposite in direction according to Newton's Third Law. The speed and direction that each car will have after a collision can be found from a law called Conservation of Momentum.

GOALS

Observation
Analysis
Computing

MATERIALS

Calculator
Mass of Car = 200 Kg
Paper
Pencil

Maximum Car Speed = 1.7 m/s
Assume Rider Mass = 65 Kg

PROCEDURE

1. Calculate the **momentum** of one car traveling at maximum speed (add your mass to the mass of the car).

   Momentum = mass X speed
   or in symbolic form $p = mv$

2. Define **momentum**.

3. Define the **Law of Conservation of Momentum**.

USE THE DIAGRAMS ON THIS PAGE TO ANSWER THE FOLLOWING QUESTIONS ON THE NEXT PAGE:

4. Using the diagram in problem I, what would be the result of the collision between car A and car B?

(riders feel)	(cars move)
A	
B	

5. Using the diagram in problem II, what would be the result of the collision between car A and B?

(riders feel)	(cars move)
A	
B	

6. Using the diagram in problem III, what would be the result of the collision between car A and B?

(riders feel)	(cars move)
A	
B	

7. Using the diagram in problem IV, what would be the result of the collision between cars A and B crashing into car C?

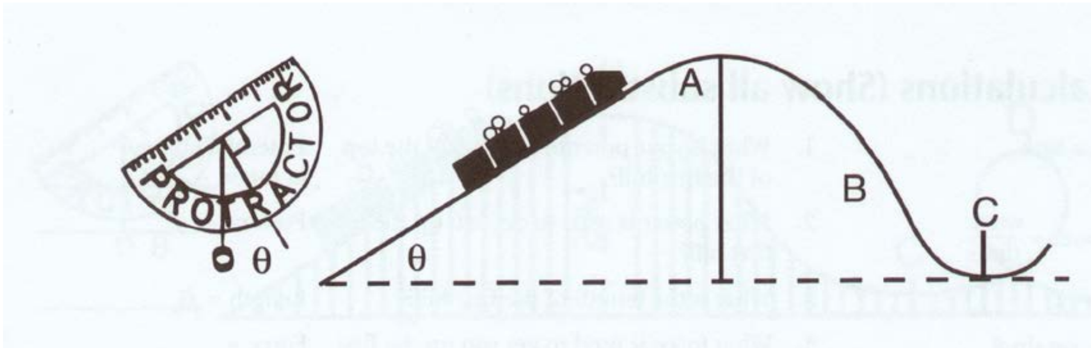
(riders feel)	(cars move)
A	
B	
C	

8. Why do automobiles have “airbags” and specials headrests on the back of seats?

HIGH SCHOOL

THE WILD ONE

(Non-looping coaster)



Data*
Height at the top of the first hill (A) ________ Height at the bottom of the first hill (C) ________
Height at top of second hill (D)________________Length of a train _______________
Angle of rise, first hill, θ = ___________ ^{o} Length of lift incline_______________
Time for a train to pass a point A at the top of the first hill __________________________s
Time for a train to pass a point C at the bottom of the first hill ______________________s
Time for first car to reach top of first hill = ______________s

Sensations (normal, heavier, lighter):
At A, just before descending _____________________
At B, about half way down_______________________
At C, bottom of the curve________________________
At D, top of second hill_________________________

Meter readings:
Force meter =
Force meter =
Force Meter =
Force Meter =

Observations

1. What is the advantage of a long, shallow first incline?

____

2. Why is the first hill always the highest?

____

3. Why is the track of the roller coaster banked?

4. Where does your meter read closest to zero?

5. How do you feel at this point?

6. What does the near-zero reading tell you about the shape of the track at that point?

7. Where does the meter give a maximum reading?

8. Why is it a maximum here?

***Note that data for the rides is given at the end of the manual.**

THE WILD ONE

Calculations (Show all substitutions)

E_p = mgh

1. What is your potential energy at the top of the first hill?

   Potential Energy at top =________________

Power = $\frac{\text{work}}{\text{time}}$

2. What power is used to get you up the first hill? Power =______________________

3. What is the length of the first hill? Length =______________________

F= mg sin θ

4. What force is used to get you up the first hill? Force =_______________________

$v_{average} = \frac{\text{distance}}{\text{time}}$

5. Calculate the speed at C from the length of the train and the time to pass C. Average speed =________________

E_k = 1/2 mv^2

6. What kinetic energy does this speed give at the bottom of the first hill? Kinetic energy at bottom = ___________________

7. Within experimental error, was your energy conserved? Explain your answer.

____

____

____

Finding the force factor at the bottom of the first drop

At the bottom of the first drop, the track makes an almost-circular arc, as if it were part of a circle of radius 30 m. Use the steps given below to find the force factor that you experience as you go through the low point on the track.

$\Delta E_p = \Delta E_k$
E_k = 1/2 mv^2

8. Assuming no friction, find the maximum speed at the bottom of the first drop. Speed =_______________________

$F = \frac{mv^2}{R} + mg$

9. In order to go through this curve, the track must exert enough force to both hold you in a circle and balance your weight Calculate the force that the track exerts on you at the bottom of the loop. Force applied=_________________

Force factor = $\frac{\text{force applied}}{\text{weight}}$

10. Calculate the force factor at the bottom of the first valley. Force factor =__________________

11. How did the force factor that you calculated compare with the meter reading at C?

____

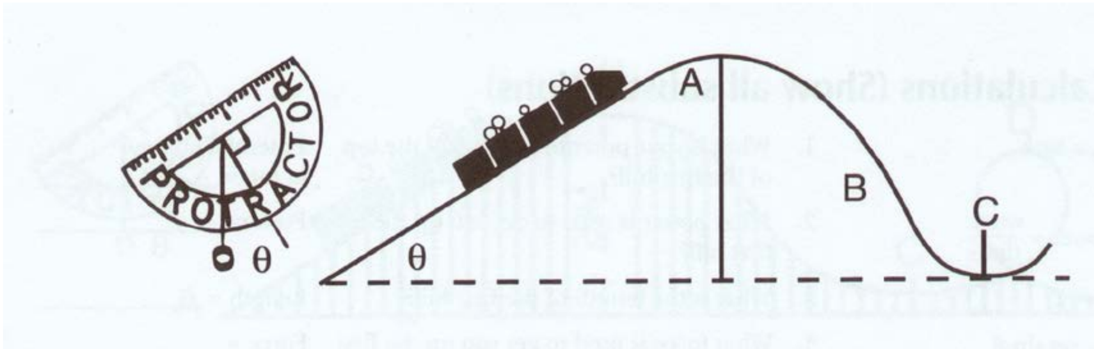
THE WILD ONE

Finding the force factor at the top of the second hill

At the top of the second hill, the track makes an almost-circular arc, as if it were part of a circle of radius 25 m. Repeat steps 8-11 to find the force factor that you experience as you go over the second hill.

$\Delta E_p = \Delta E_k$ $E_k = 1/2\ mv^2$	12.	Assuming no friction, find the maximum speed at the top of the second hill.	Speed =______________________
$F = mg - \frac{mv^2}{R}$	13.	Calculate the force the track exerts at the of the second hill.	Force applied=_______________
	14.	Calculate the force factor at the top of the second hill. Compare with the meter reading at the top of the second hill.	Force factor =_________________

ROAR



(Non-looping coaster)

<u>Data*</u>
Height at the top of the first hill (A) ________ Height at the bottom of the first hill (C) ________
Height at top of second hill (D)________________Length of a train _______________
Angle of rise, first hill, θ = ___________° Length of lift incline_______________
Time for a train to pass a point A at the top of the first hill __________________________s
Time for a train to pass a point C at the bottom of the first hill _______________________s
Time for first car to reach top of first hill = ______________s

Sensations (normal, heavier, lighter):
At A, just before descending _____________________
At B, about half way down_______________________
At C, bottom of the curve________________________
At D, top of second hill_________________________

Meter readings:
Force meter =
Force meter =
Force Meter =
Force Meter =

Observations

1. What is the advantage of a long, shallow first incline?

____

2. Why is the first hill always the highest?

____

3. Why is the track of the roller coaster banked?

4. Where does your meter read closest to zero?

5. How do you feel at this point?

6. What does the near-zero reading tell you about the shape of the track at that point?

7. Where does the meter give a maximum reading?

8. Why is it a maximum here?

***Note that data for the rides is given at the end of the manual.**

ROAR

Calculations (Show all substitutions)

E_p = mgh

1. What is your potential energy at the top of the first hill?

Potential Energy at top =_______________

Power = $\frac{\text{work}}{\text{time}}$

2. What power is used to get you up the first hill? Power =_____________________

3. What is the length of the first hill? Length =_____________________

F= mg sin θ

4. What force is used to get you up the first hill? Force =______________________

$v_{average} = \frac{\text{distance}}{\text{time}}$

5. Calculate the speed at C from the length of the train and the time to pass C. Average speed =_______________

$E_k = 1/2\ mv^2$

6. What kinetic energy does this speed give at the bottom of the first hill? Kinetic energy at bottom = __________________

7. Within experimental error, was your energy conserved? Explain your answer.

____

____

____

Finding the force factor at the bottom of the first drop

At the bottom of the first drop, the track makes an almost-circular arc, as if it were part of a circle of radius 27 m. Use the steps given below to find the force factor that you experience as you go through the low point on the track.

$\Delta E_p = \Delta E_k$

$E_k = 1/2\ mv^2$

8. Assuming no friction, find the maximum speed at the bottom of the first drop. Speed =___________________

$F = \frac{mv^2}{R} + mg$

9. In order to go through this curve, the track must exert enough force to both hold you in a circle and balance your weight Calculate the force that the track exerts on you at the bottom of the loop. Force applied=______________

Force factor = $\frac{\text{force applied}}{\text{weight}}$

10. Calculate the force factor at the bottom of the first valley. Force factor =_________________

11. How did the force factor that you calculated compare with the meter reading at C? ____

ROAR

Finding the force factor at the top of the second hill

At the top of the second hill, the track makes an almost-circular arc, as if it were part of a circle of radius 21 m. Repeat steps 8-11 to find the force factor that you experience as you go over the second hill.

$\Delta E_p = \Delta E_k$ $E_k = 1/2\ mv^2$	12.	Assuming no friction, find the maximum speed at the top of the second hill.	Speed =____________________
$F = mg - \frac{mv^2}{R}$	13.	Calculate the force the track exerts at the of the second hill.	Force applied=_______________
	14.	Calculate the force factor at the top of the second hill. Compare with the meter reading at the top of the second hill.	Force factor =__________________

SUPERMAN: RIDE OF STEEL

Faster than a speeding bullet, this ride will take you high up into the clouds and down around sharp turns for a thrilling experience.

OBJECTIVE
To analyze a rider's motion on a roller coaster using the concepts of kinetic and potential energy, energy conservation, and circular motion.

MEASUREMENTS

WHILE WATCHING FROM THE GROUND

Measurement	**Time (seconds)**
Time for first car to reach top of lift incline	
Time for entire train to pass point at top of lift incline	

READINGS ON RIDE
Use the Accelerometer on the ride and record your data below

Section of Ride	**Accelerometer Reading**	**Sensation compared to normal weight (normal, larger, smaller, none)**
At top of lift inline		
Half way down first hill		
At bottom of first hill		
Moving through first horizontal loop		

OBSERVATIONS

1. In terms of forces, explain why there is an advantage to using a long, shallow lift incline.

2. If the time to go up the lift incline were shorter, what would happen to the power needed?

3. Why is the first hill always the highest?

4. Describe the way potential and kinetic energies are exchanged as the rider progresses through the ride.

CALCULATIONS
(Show all work)
FINDING YOUR TOTAL ENERGY

1. Calculate your potential energy at the top of the lift incline. The height at the top of the incline is 61.0 m.

   PE = mgh

Potential Energy = ____________ J

2. The velocity of the train at the top of the incline can be calculated by taking the length of the train and dividing it by the time it takes for the train to pass a point at the very top of the lift incline. The length of the train is 16.2 m and the time was recorded in the measurements section. Calculate the train's velocity at the top of the lift incline.

   $$v = \frac{L}{t}$$

Velocity = __________ m/s

3. Calculate your kinetic energy at the top of the lift incline. Use the velocity calculated in #2.

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

Kinetic Energy = _____________ J

4. If we ignore friction, the total energy is the sum of your potential and kinetic energies at any given moment. Calculate the total energy at the top of the lift incline. This is now your total energy during the entire ride.

   TE = PE + KE

Total Energy = _____________ J

GETTING TO THE TOP – FORCES AND POWER

5. The work done moving you up the lift incline is equal to the total energy. The length (distance) of the lift incline is 122 m. Calculate the Force used on your back to push you to the top of the lift incline.

   Work = Fd

Force = ________ N

6. Calculate the power used to get you up the incline. The time up the lift incline was recorded in the measurements section.

   $$P = \frac{Work}{t}$$

Power = _______ W

ENERGY AND SPEEDS DOWN AT BOTTOM

7. The track height at the bottom of the first hill is 1.2 m. Calculate your potential energy at the bottom of the first hill.

PE = mgh

Potential Energy = ____________ J

8. Calculate your kinetic energy at the bottom of the first hill. The total energy was calculated in #4.

TE = PE + KE

Kinetic Energy = _____________ J

9. Calculate your velocity at the bottom of the first hill. This is the maximum speed of the ride.

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

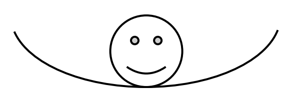
Velocity = __________ m/s

10. Convert m/s to mile per hour (mph). 1 m/s = 2.2 mph

Velocity = _________ mph

FORCE FELT GOING THROUGH FIRST HORIZONTAL LOOP

11. Going through the horizontal loops, the seat must exert enough force to both hold you in a circle and counter gravity. Draw a vector (free body) diagram showing both the seat force and gravity force.



12. Calculate your potential energy during the first horizontal loop. The average height above the ground for the first horizontal loop is 5.5 m.

PE = mgh

Potential Energy = ____________ J

13. Calculate your kinetic energy during the first horizontal loop. The total energy was calculated in #4.

TE = PE + KE

Kinetic Energy = _____________ J

14. Calculate your velocity during the first horizontal loop.

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

Velocity = __________ m/s

15. Calculate the centripetal force exerted on you during the first horizontal loop. The radius for the first horizontal loop is 30.5 m.

$$F_c = m\frac{v^2}{r}$$

Centripetal Force = __________ *N*

16. Calculate the seat force exerted on you during the first horizontal loop. The seat provides the centripetal force and also counters the gravitational force.

$$F_{seat} = F_c + mg$$

$Force_{seat}$ = _____ *N*

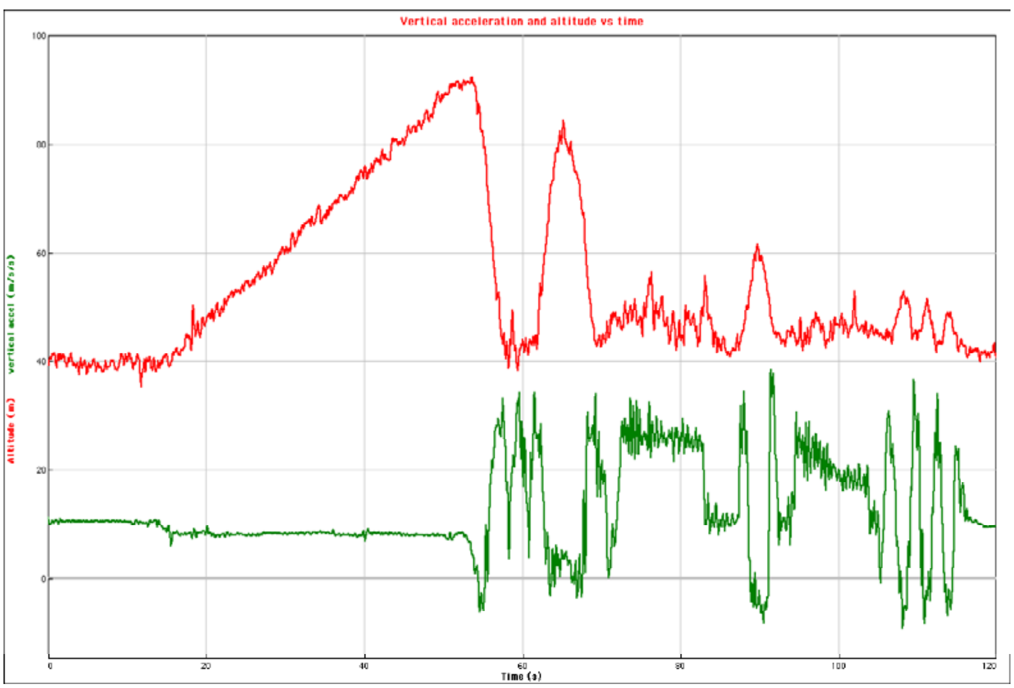
17. Calculate the Force Factor (F.F.) the seat exerts on you as you move through the first horizontal loop.

$$F.F. = \frac{Seat\ Force}{Weight}$$

F.F. = _____

18. Label the following sections on the graph below. Use brackets to indicate an entire section.

A Lift Incline
B Top of Lift Incline
C Bottom of first hill
D Top of second hill
E First horizontal loop
F Second horizontal loop
G Final three small hills



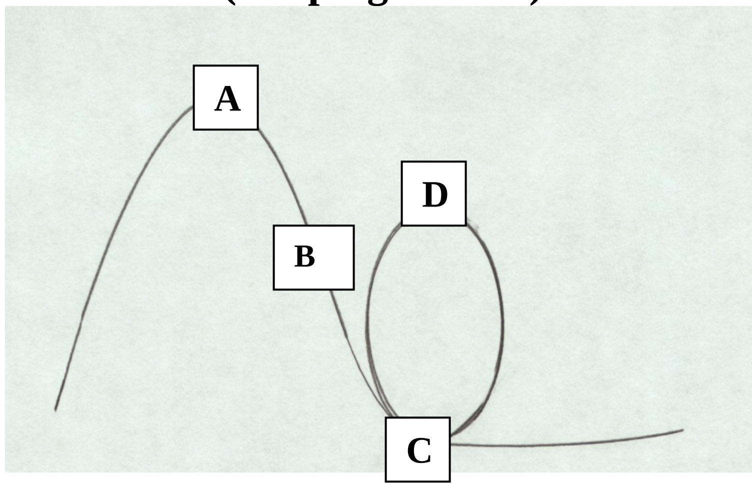
19. Force Factors (F.F.) can be calculated by taking the acceleration value from the graph and dividing it by g (we'll use 10 m/s/s for simplicity). Calculate the Force Factor (F.F.) during the first horizontal loop.

$$F.F. = \frac{graph\ value}{g}$$

F.F. = ______

20. How does this Force Factor compare to what was calculated in #17? How does it compare to what the accelerometer you took on the ride indicated?

MIND ERASER
(Looping coaster)



Data*
Height at top of first hill (A) ________ Height at bottom of vertical loop (C)________________
Length of a train _________ Curvature radius at the bottom of the first vertical loop_________
Length of lift incline_____________ Curvature radius at the top of the first vertical loop_________
Angle of rise, first hill, θ = ___________^{o} Height at top of vertical loop (D) _____________
Time for a train to pass point A at the top of the first hill _____________________s
Time for a train to pass a point C at the bottom of the first vertical loop ________________s
Time for first car to reach top of first hill = ______________s

Sensations (normal, heavier, lighter):	**Meter readings:**
At A, just before descending ______________________	Force meter =
At B, about half way down________________________	Force meter =
At C, bottom of the vertical loop____________________	Force Meter =
At D, top of the vertical loop_____________________	Force Meter =

Observations:

1. What is the advantage of a long, shallow first incline?
 ____

2. Why is the first hill always the highest?

3. Why is the track of the roller coaster banked?

4. Where does your meter read closest to zero?

5. How do you feel at this point?

6. What does the near zero reading tell you about the track at that point?

7. Where does the meter give a maximum reading?

8. Why is it a maximum here?

***Note that data for the rides is given at the end of the manual.**

MIND ERASER

Calculations (Show all substitutions)

E_p = mgh	1.	What is your potential energy at the top of the first hill?	Potential energy =______________
Power = $\frac{\text{work}}{\text{time}}$	2.	What power is used to get you up the first hill?	Power =______________________
	3.	What is the length of the first hill?	Length =_____________________
F= mg sin θ	4.	What force is used to get you up the first hill?	Force =______________________
. $v_{ave} = \frac{\text{distance}}{\text{time}}$	5.	Use the length of the train and the time to pass point C to find the speed at C.	Average speed =______________
E_k = 1/2 mv^2	6.	What kinetic energy does this speed give at the bottom of the vertical loop?	Kinetic energy =_______________
E_p = mgh	7.	What was your potential energy at the bottom of the vertical loop?	Potential energy =______________

8. Compare the change in potential energy to the gain in kinetic energy. Within experimental error, was energy conserved? Explain your answer.

____

____

____

____

$\Delta E_p = \Delta E_k$	9.	If there had been no friction, what would be the maximum speed at the bottom of the first vertical loop?	Speed =______________________
$F_{bottom} = \frac{mv^2}{R} + mg$	10.	Going through the curve, the track must exert enough force to both hold you in a circle and counteract gravity. Calculate the force on you at the bottom of the vertical loop.	$Force_{bottom}$=_________________
Force factor = $\frac{\text{force felt}}{\text{weight}}$	11.	Calculate the force factor at the bottom of the vertical loop.	Force factor =________________

12. Why is it important that the radius be large at point C?

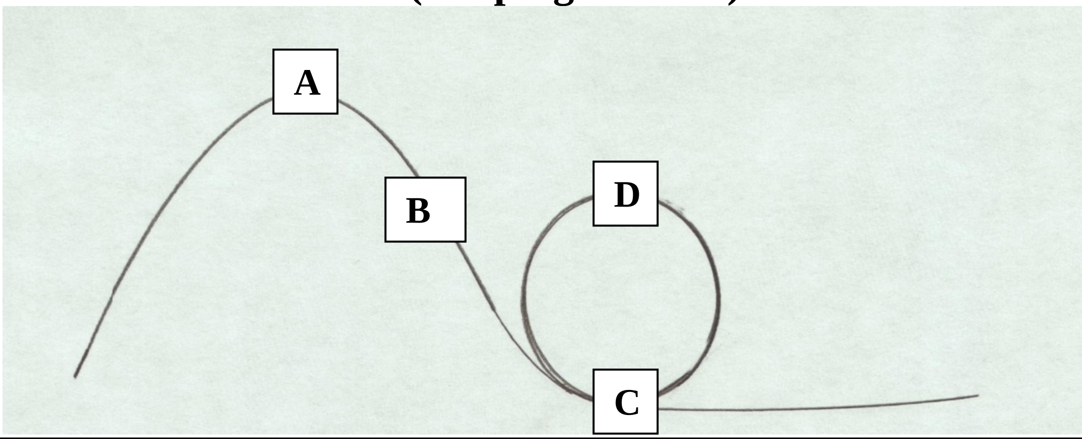
____

____

MIND ERASER

$E_p = mgh$	13.	Calculate your potential energy at the top of the loop. (Point D)	Potential energy=______________
$E_k = E_{total} - E_p$	14.	Assuming conservation of energy, calculate your kinetic energy at the top of the loop.	Kinetic energy =_______________
$E_k = \frac{mv^2}{2}$	15.	What is your speed at the top of the loop?	Speed top =_________________
$F_{track} - mg = -\frac{mv^2}{R}$	16.	At the top of the loop, gravity works with the track to hold you in a circle. Calculate the force the track exerts on you.	Force track =________________
	17.	Why is it important that the top radius be small? _____________________ ____	
Force factor = $\frac{\text{track force (force felt)}}{\text{normal weight}}$	18.	What should the force meter read at the top?	Force factor =_________________
	19.	In the space below, draw a diagram showing the forces acting on you when you are at the bottom of the vertical loop and at the top of the vertical loop when you and the force meter are upside down.	

BATWING
(Looping Coaster)



Data*

Height at top of first hill (A) ________ Height at bottom of vertical loop (C)________________

Length of a train __________ Curvature radius at the bottom of the first vertical loop__________

Length of lift incline______________ Curvature radius at the top of the first vertical loop__________

Angle of rise, first hill, θ = ____________° Height at top of vertical loop (D) ______________

Time for a train to pass point A at the top of the first hill _______________________s

Time for a train to pass a point C at the bottom of the first vertical loop ________________s

Time for first car to reach top of first hill = _______________s

Sensations (normal, heavier, lighter):	**Meter readings:**
At A, just before descending _______________________	Force meter = ______________________
At B, about half way down_________________________	Force meter = ______________________
At C, bottom of the vertical loop_____________________	Force Meter = ______________________
At D, top of the vertical loop______________________	Force Meter = ______________________

Observations

1. What is the advantage of a long, shallow first incline?
   ____

2. Why is the first hill always the highest?
   ____

3. Why is the track of the roller coaster banked?
   ____

4. Where does your meter read closest to zero?

____

5. How do you feel at this point?

____

6. What does the near zero reading tell you about the track at that point?

____

7. Where does the meter give a maximum reading?

____

8. Why is it a maximum here?

____

***Note that data for the rides is given at the end of the manual.**

BATWING

Calculations (Show all substitutions)

E_p = mgh	1.	What is your potential energy at the top of the first hill?	Potential energy =______________
Power = $\frac{\text{work}}{\text{time}}$	2.	What power is used to get you up the first hill?	Power =______________________
	3.	What is the length of the first hill?	Length =_____________________
F= mg sin θ	4.	What force is used to get you up the first hill?	Force =______________________
. v_{ave} = $\frac{\text{distance}}{\text{time}}$	5.	Use the length of the train and the time to pass point C to find the speed at C.	Average speed =_______________
E_k = 1/2 mv^2	6.	What kinetic energy does this speed give at the bottom of the vertical loop?	Kinetic energy =________________
E_p = mgh	7.	What was your potential energy at the bottom of the vertical loop?	Potential energy =______________

8. Compare the change in potential energy to the gain in kinetic energy. Within experimental error, was energy conserved? Explain your answer.

____

____

____

____

$\Delta E_p = \Delta E_k$	9.	If there had been no friction, what would be the maximum speed at the bottom of the first vertical loop?	Speed =_______________________
$F_{bottom} = \frac{mv^2}{R} + mg$	10.	Going through the curve, the track must exert enough force to both hold you in a circle and counteract gravity. Calculate the force on you at the bottom of the vertical loop.	$Force_{bottom}$=_________________
Force factor = $\frac{\text{force felt}}{\text{weight}}$	11.	Calculate the force factor at the bottom of the vertical loop.	Force factor =_________________
	12.	Why is it important that the radius be large at point C?	

____

BATWING

$E_p = mgh$ 13. Calculate your potential energy at the top of the loop. (Point D) Potential energy=______________

$E_k = E_{total} - E_p$ 14. Assuming conservation of energy, calculate your kinetic energy at the top of the loop. Kinetic energy =_______________

$E_k = \frac{mv^2}{2}$ 15. What is your speed at the top of the loop? Speed top =_________________

$F_{track} - mg = -\frac{mv^2}{R}$ 16. At the top of the loop, gravity works with the track to hold you in a circle. Calculate the force the track exerts on you. Force track =________________

17. Why is it important that the top radius be small? _____________________

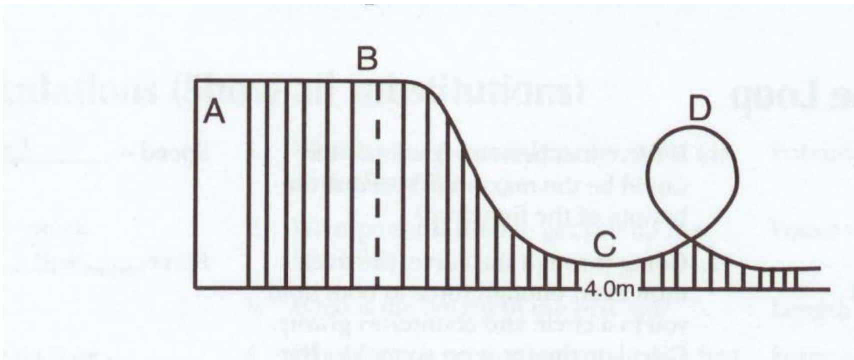
____

Force factor = $\frac{\text{track force (force felt)}}{\text{normal weight}}$ 18. What should the force meter read at the top? Force factor =_________________

19. In the space below, draw a diagram showing the forces acting on you when you are at the bottom of the vertical loop and at the top of the vertical loop when you and the force meter are upside down.

JOKER'S JINX

(Induction coaster)



Observations

1. Describe what happens between positions A and B and tell how it felt:

____

2. Explain why this portion of the ride is necessary for safety. Think about what would happen at point D if this portion did not exist:

____

Position B

3. If you were frightened, it was most likely at point B. Describe how you felt:

____

4. On what part(s) of your body did you feel the largest force?

____

5. Describe what would happen at point B if there were no harness:

____

6. Since the cars are all attached, which car will be fastest at B, first or last?

____

Position C

7. Did you feel heavier or lighter than normal at point C?________________________________

8. Estimate the force factor for point C:____

9. At position C, what parts of your body felt the most force?_______________________________

Position D

10. Did you feel right side up or upside down at D?
____

11. Explain the body clues you used. What forces were felt and where? Did you feel as if the harness was holding you in?
____
____

12. How did your reactions differ going backwards from going forward?
____

13. Can you tell when you are on the sides of the loop?
____

How?
____

JOKER'S JINX

Calculations (show all substitutions)

$E_k = \frac{mv^2}{2}$	1.	Your speed at point B is about 27 m/s. What is your kinetic energy at point B?	Kinetic energy =_____________
work $= F \cdot L$	2.	The induction motors push the train 61 meters. Calculate the average force exerted on you by the induction mechanism.	Force =_____________________
$E_P = mgh$	3.	Calculate your potential energy at point B.	Potential energy =____________
$E_T = E_p + E_k$	4.	What is your total energy at point B?	Total energy =_______________
$E_T = \frac{mv^2}{2}$	5.	If there had been no friction, what would be the maximum speed at the bottom of the first drop (Point C)?	Speed =____________________
$F_{bottom} = \frac{mv^2}{R} + mg$	6.	Going through the curve, at the bottom, the track must exert enough force to both hold you in a circle and to balance your weight. Calculate the force on you at the bottom of the loop.	Force bottom =______________
Force factor = $\frac{\text{force felt}}{\text{weight}}$	7.	Calculate the force factor at the bottom of the first drop.	Force factor = ________________
	8.	Why is it important that the radius be large at point C? ____	
$E_P = mgh$	9.	Calculate your potential energy at the top of the loop (Point D).	Potential energy =______________
$E_k = E_{total} - E_P$	10.	Assuming conservation of energy, calculate your kinetic energy at the top of the loop.	Kinetic energy =_______________
$E_k = \frac{mv^2}{2}$	11.	What is your speed at the top of the loop?	Speed top=_________________
$F_{track} - mg = -\frac{mv^2}{R}$	12.	At the top of the loop, gravity works with the track to hold you in a circle. Calculate the force that the track exerts on you.	Force track =__________________
	13.	Why is it important that the top radius be small? ______________________________	
Force factor = $\frac{\text{track force (force felt)}}{\text{normal weight}}$	14.	What should the force meter read at the top?	Force factor =__________________

COASTER COMPARISON

Superman-Ride of Steel, Mind Eraser, Jokers Jinx, Batwing

For the true coaster lover here is a chance to study and compare the four major coaster rides at Six Flags America. Each has unique characteristics to give it a special appeal.

EXPERIMENTS

OBJECTIVE: Compare features of the four rides and relate them to the sensations experienced on each ride.

Procedure: Look at the Data Chart below and assign duties in your student group to make all the observations necessary to complete the chart.

Data Chart:

	Superman Ride of Steel	***Mind Eraser***	***Jokers Jinx***	***Batwing***
Number of hills (all sizes)				
Number of right turns				
Number of left turns				
Number of times riders are upside down				
Total time for ride				
What structure is made of				
Height of power hill (rank them highest (1) to lowest (4)				
Any other unique or special features				

Discussion:

1. Where on each ride is the gravitational potential energy the greatest? the least?

2. Where on each ride is the kinetic energy the greatest?

3. In which ride do you feel the greatest <u>changes</u> in the vertical force on you?

4. Where on each ride is the kinetic energy the greatest?

5. In which ride do you feel the greatest <u>changes</u> in the vertical force on you?

6. Do you ever feel weightless in any of these rides? If so, at what point(s) in which ride(s)?

7. In which ride do you feel the greatest centripetal force?

8. Which of the characteristics listed in the Data Chart do you think contribute most to the "thrill" of a coaster ride? Why do you think this is true? (You may answer this last question by describing the features you would put into a coaster you would design and explaining why you would include them.)

PENGUIN'S BLIZZARD RIVER

A raft that is 2.40 m in diameter is lifted up a hill 18.5 m high. The raft descends down a flume 143 m long through two twists of 540 degrees and 360 degrees before splashing into Chiller Bay. Spectators can fire wire cannons at the riders as they pass through Chiller Bay.

GENERAL QUESTIONS

1. Why is there water on the slide and not just at the bottom?

2. At what point on this ride is the speed the greatest?

3. What causes the raft to rotate as moves down the flume?

4. At what point on the ride is the angular velocity of the raft the greatest?

5. At what point on the ride do the riders lunge forward? Why does this happen?

EXPERIMENTS

OBJECTIVE: Measure the speed and angular speed of the raft at several points and analyze the slowing of raft as it descends into Chiller Bay.

Procedure: Take time measurements that are used to determine the speed of the raft at the top of the flume, the bottom of the flume, the angular velocity of the raft in the first loop, and the angular velocity of the second loop.

Apparatus: Stopwatch

Data: Time for raft to move its own length at the top of flume:____________

Time for raft to move its own length at the bottom of the flume:_________

Time for raft to make one revolution in the first loop:_________________

Time for raft to make one revolution in the second loop:_______________

Results: Speed at top of flume: $\frac{\text{diameter of raft}}{\text{time to pass}}$ ______________m/s

Speed at bottom of flume: $\frac{\text{diameter of raft}}{\text{time to pass}}$ _____________m/s

Angular velocity in 1st loop: $\frac{2*\pi}{\text{time for one revolution}}$ ____________rad/s

Angular velocity in 2nd loop: $\frac{2*\pi}{\text{time for one revolution}}$ ____________rad/s

Discussion: At the top of the flume, the energy of the raft is mainly potential energy. As the raft descends down the flume, what happens to this potential energy? What other forms of energy are present as the raft descends down the flume? Does all of this energy come from the initial potential energy at the top of the flume?

Using the angular velocity in the loops as calculated above, find the centripetal acceleration of a rider in the first loop and in the second loop:

First loop: $a_c = r*\omega^2$ _____________ m/s^2

Second loop: $a_c = r*\omega^2$ _____________ m/s^2

Compare these accelerations to the acceleration of gravity. If you have an accelerometer, measure the acceleration in the two loops and compare with the calculated values. Why might the values not agree?

Carousel

DATA AND OBSERVATIONS:

1. Time to complete one revolution.

2. Number of horses or other animals along the outer edge of ride.

3. Estimated distance between two adjacent animals along the outer edge of ride.

4. Centripetal acceleration of an outside rider (measured).

CALCULATIONS:

1. Use the number of animals and the spacing between them to calculate the circumference of the ride (show method clearly).

2. Use the circumference and the time to determine the speed of an outside rider (show method).

3. Use the circumference to determine the radius of the ride (or use another method). Show work.

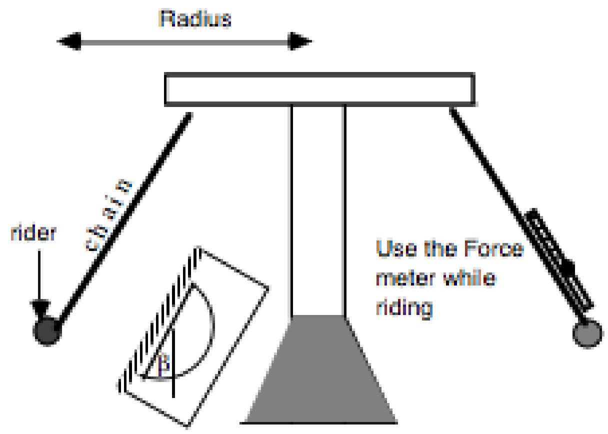
4. Use the speed and the radius to calculate the centripetal acceleration of an outside rider.

5. Convert this centripetal acceleration to number of g's.

6. Compare the experimental (measured) value you made for the centripetal acceleration with the calculated one. Explain any major differences.

7. Explain how the acceleration value for a rider on an inside animal would differ from that of an outside animal.

Pirate's Flight



Chain-suspended boats send kids of all ages outward and upward into the air.

OBJECTIVE: To calculate and compare the ride's seat force using three different methods.

MEASUREMENTS:
WHILE WATCHING FROM THE GROUND

Measure the time it takes a boat to make 3 complete revolutions at top speed. *t* = _______ *s*

$$T = Period = \frac{time}{3\,revs}$$

T = _______ s

Line up the horizontal acceleration meter with its edge parallel to the chain of the boat as shown in the diagram above. Record the number of degrees in the angle β. You may need to subtract the reading from the meter from 90^0 to get β.

β = _________

READINGS ON RIDE
Use the vertical accelerometer to record the force factor reading to the nearest tenth of a "g" while the ride is moving at top speed.

F.F. = ______

OBSERVATIONS

1. While you are waiting in line sketch what happens to a boat's chain as the ride speeds up.

Before Start	Slow Speed	Fast Speed

2. Compare the chain angle on an empty boat with that of an occupied one. Does the boat's mass affect its motion?

3. What happens to the vertical accelerometer reading as the ride gets faster? Compare this observation to what happens to the chain angle as the ride gets faster.

4. State the direction of the boat's velocity as it moves around. The direction of the boat's acceleration?

CALCULATIONS
(Show all Work)

CALCULATING SEAT FORCE FROM ACCELEROMETER MEASUREMENT

1. Calculate the ride's frequency in RPM (revolutions per minute). The period was calculated in the measurements section.

$$f_{RPM} = \frac{1}{T} \times \frac{60\,\text{sec}}{1\,\text{min}}$$

f_{RPM} = ______ *RPM*

2. Calculate the seat force, exerted on you by the boat, by multiplying the Force Factor (recorded in the measurements section) with your weight (measured in Newtons). Also, record this measurement in the table found in question #14.

$$F_{seat} = F.F. \times Weight$$

F_{seat} = ______ *N*

CALCULATING SEAT FORCE FROM PERIOD MEASUREMENT

3. Calculate the boat's velocity as it travels around at top speed. The average radius, r, of the boat's path is 10.4 m.

$$v = \frac{2\pi r}{T}$$

V = _________ *m/s*

4. Calculate the boat's centripetal acceleration as it travels around at top speed.

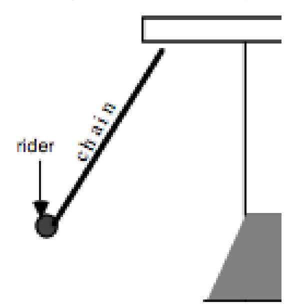
$$a_c = \frac{v^2}{r}$$

a_c = _______ *m/s/s*

5. Calculate the centripetal force acting on you by the boat as it travels around at top speed. Your mass should be in kg.

$$F_c = ma_c$$

F_c = ________ *N*



6. Draw a free-body diagram, on the drawing to the right, labeling all the forces acting on the boat/rider as it travels in a circle at top speed.

7. In addition to supplying the centripetal force, causing you to move in a circle, the seat force also counters your weight. Add these two vectors together to calculate the seat force. Also, record this measurement in the table found in question #14.

$$F_{seat} = \sqrt{\left(F_c^2 + Weight^2\right)}$$

F_{seat} = ______ *N*

8. Calculate the chain's angle based upon your period measurement. How does this compare to the angle measurement recorded in the measurements section?

$$\beta = \tan^{-1}\left(\frac{F_c}{Weight}\right)$$

β = ________°

CALCULATING SEAT FORCE FROM ANGLE MEASUREMENT

9. On the graph to the right draw a straight line, originating at the origin, at the angle recorded in the measurements section.

10. Draw a horizontal line with a y-axis value equal to your weight.

11. Draw a vertical line where the lines from questions 9 and 10 intersect.

12. Record the x-axis value for this line as the Centripetal Component or F_c.

F_c = __________ *N*

13. Calculate the seat force by using the centripetal component obtained from the graph and the angle recorded in the measurements section. Also, record this measurement in the table found in question #14.

$$F_{seat} = \frac{F_c}{\sin\beta}$$

F_{seat} = ________*N*

14. You have measured the seat force, acting on you as you move around the ride, using three different methods. Compare these values by calculating a percent difference between the measured accelerometer reading and the other two.

Seat Force Measured by Accelerometer (N)	Seat Force Calculated from Period (N)	Seat Force Calculated from Angle (N)

$$\%\ diff = \left|\frac{measured - calc}{measured}\right| \times 100\,\%$$

% diff (Period) = _______ *%*

% diff (Angle) = _______ %

FLYING CAROUSEL

Passengers on the Flying Carousel sit in chairs that are swung in a circle. The top of the ride can also tilt. The angle of hang is the angle the chains supporting the chairs make with respect to the vertical as they move along their arcs. The radius of rotation is the distance from the center of the central column to the chairs while the chair is in motion. The radius for the inner chairs is 8.5 meters and the radius for the outer chairs is 9.9 meters.

GENERAL QUESTIONS

1. Describe the two motions that occur simultaneously during this ride.

2. Does the tilt of the top make a difference in the angle at which the cables hang? If so, at what position is the angle the greatest?

3. What is the general direction of the acceleration during this ride?

4. At what position in the motion is the tension in the cables the largest?

EXPERIMENTS

OBJECTIVE: Determine the speed of a chair and the minimum and maximum angles at which it hangs while in motion.

PROCEDURE: Measure the period (time for one revolution) by measuring the time for a given number of rotations and using (Period = time/# revolutions). Determine the minimum and maximum angle using a protractor.

Apparatus: Stopwatch, protractor with plumb line.

Data: Number of Revolutions__________________ Time____________________

Minimum angle_________________ Maximum angle _____________

Results: Circumference___________________ Period____________________

$$\text{Speed} = \frac{\text{Circumference}}{\text{Period}} = \text{-------------}$$

Discussion:

a. Draw the force diagram for a gondola when the gondola is moving..

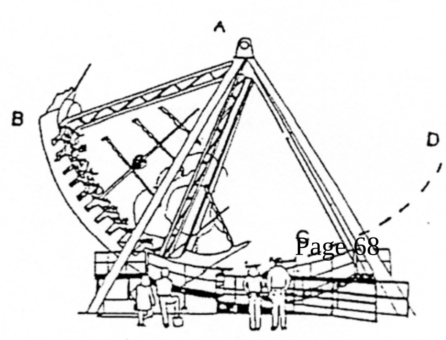
b. Identify the centripetal force in your diagram.

c. Show that the expected angle of hang (θ) is given by $\tan \theta = v^2/rg$.

d. Calculate the value of angle θ from your data.

e. How does this calculated value compare to your maximum angle values?

HIGH SEAS



A swinging pirate ship that moves like a pendulum in motion giving riders the sensation of weightlessness.

OBJECTIVE

To measure the period of the boat and compare it to the period of a pendulum with the same length. To calculate Force Factors at various locations on the ride.

MEASUREMENTS

Measure the period of the boat swing when it is near the start of the ride, when the angle is small, and when the boat is swinging at its maximum angle.

WHILE WATCHING FROM THE GROUND

Measurement	**Time to make three cycles (seconds)**	**Period (time/3) (seconds)**
Small angle		
Large angle		

READINGS ON RIDE
Use the accelerometer on the ride and record your data below.

Use the diagram above to help answer the following questions. Point B represents the higher extreme position, point D represents the lower extreme position, and point C represents the lowest position in the middle of the cycle.

Section of Ride	Accelerometer Reading	Sensation compared to normal weight (normal, larger, smaller, none)
Point C during small angle		
Point C during large angle		
Greatest reading at point B		
Greatest reading at point D		

OBSERVATIONS

1. Look at the Period measurements above. Did the size of the angle effect the period of the boat's swing?

2. At what point or points was the speed of the boat a minimum? Maximum?

3. At what point or points did you feel the heaviest? Lightest?

4. Was there a difference in sensation when comparing points B and D?

CALCULATIONS

(Show all Work)

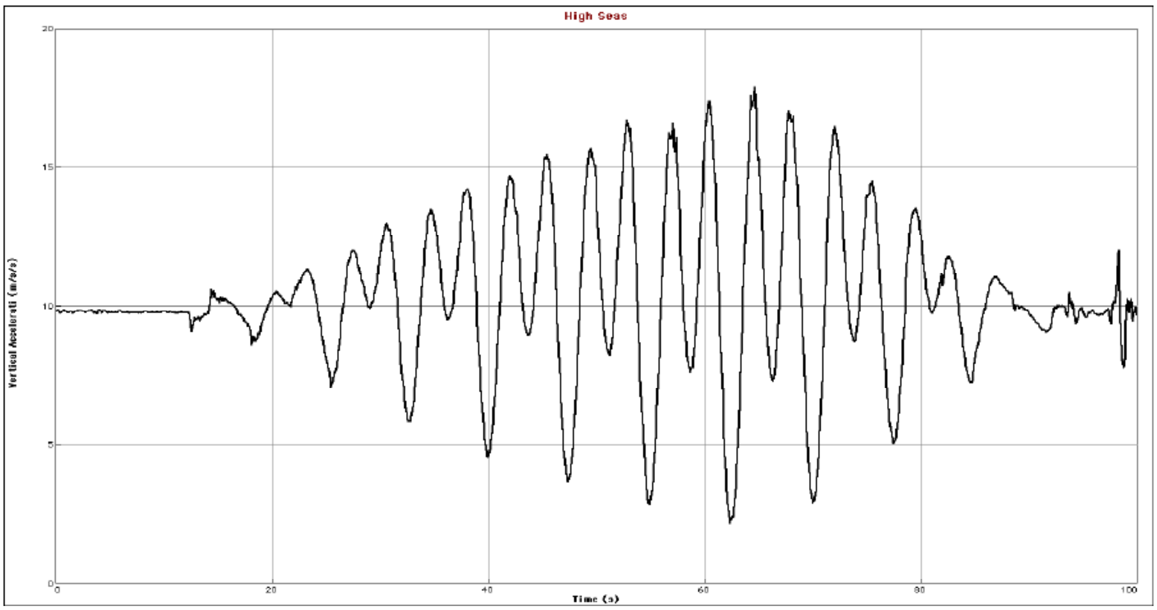
1. Calculate the period of a simple pendulum that has a length of 12.2 m. (The same length as the High Seas ride.)

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Period = __________ *s*

2. Compare this period to the periods you measured for the small and large angle swings. Within experimental error can the High Seas ride be considered a simple pendulum?

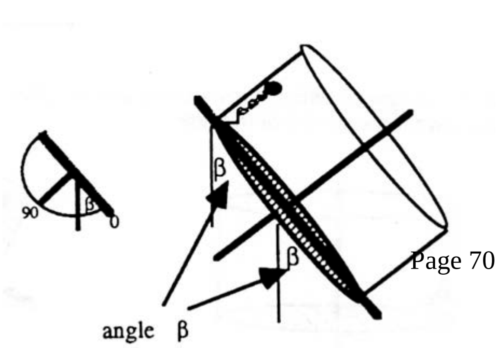
3. Label the following locations on the graph below:
   C (lowest position) On the graph these are the maximum crests.
   B (higher exteme position) On the graph these are the most extreme minimum troughs
   D (lower exteme position) On the graph these are the least extreme minimum troughs.



4. A Force Factor value can be calculated by taking an acceleration value from the graph and dividing it by g (we'll use 10 m/s/s for simplicity). Compare the Force Factor values in the graph to the readings recorded in the measurements section. How well do they agree? Would where you sit on the boat effect your measurements?

RIDDLE ME THIS

Be prepared to spin, spin, spin on an exhilarating ride that takes you around and around.



OBJECTIVE:
To calculate the force exerted on a rider by the ride's wall at different points on the ride.

MEASUREMENTS

WHILE WATCHING FROM THE GROUND — Time for five revolutions at top speed $t =$ _______ s

$$T = Period = \frac{time}{5\ revs}$$

$\boxed{T = \_\_\_\_\_\_\_\ s}$

READINGS ON RIDE
Use the accelerometer on the ride and record your data below. **Hold the accelerometer horizontally** out from your stomach pointing it towards the center of the ride.

Section of Ride	Accelerometer reading	Force felt from wall 0-10 0 = no force felt 10 = maximum force felt
At beginning before ride starts		
At top speed before ride tilts		
At highest point while ride is tilted		
At lowest point while ride is tilted		

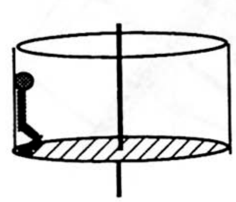
OBSERVATIONS

1. Describe how the force against your back changes as the ride speeds up before it begins to tilt.

2. If your eyes were closed, describe the physical sensations that would tell you the ride had tilted. Include a discussion of the force on your back at various points in the rotation.

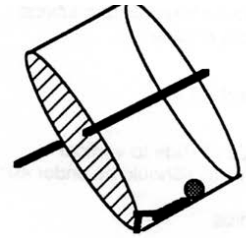
3. Did you ever feel as if you were going to fall into the center of the ride? Explain.

4. On the diagrams below draw vectors showing the relative size of the force the wall exerted on you back pushing you towards the center of the ride. The greater the force the larger the arrow.



A: ride horizontal and at top speed

B: Ride tilted rider at highest point



C: Ride tilted rider at lowest point

5. Since the ride was moving at the same speed in all the pictures above, the total (centripetal) force pushing you towards the center is the same at all times.
    a. The force of the wall in case B is clearly less that in diagram A. What other force provides a pull downward allowing the wall to push with less force?

    b. In picture C you should have showed the wall exerting a very large force on your back. Why does the wall need to push so much more when you are in this position?

CALCULATIONS
(Show all Work)

1. Calculate the top velocity of the ride. The ride's radius is 4.2 m and the period was recorded in the measurements section.

$$v = \frac{2\pi r}{T}$$

Velocity = __________ *m/s*

2. Calculate the centripetal force needed to hold you in the circle of the ride at this speed. This force will be the same no matter what angle the ride is at.

$$F_c = m\frac{v^2}{r}$$

$Force_{cent}$ = _____ *N*

3. When the ride is horizontal the wall on your back exerts the entire centripetal force. Calculate the Force Factor when the ride is horizontal and moving at top speed.

$$F.F. = \frac{F_c}{Weight}$$

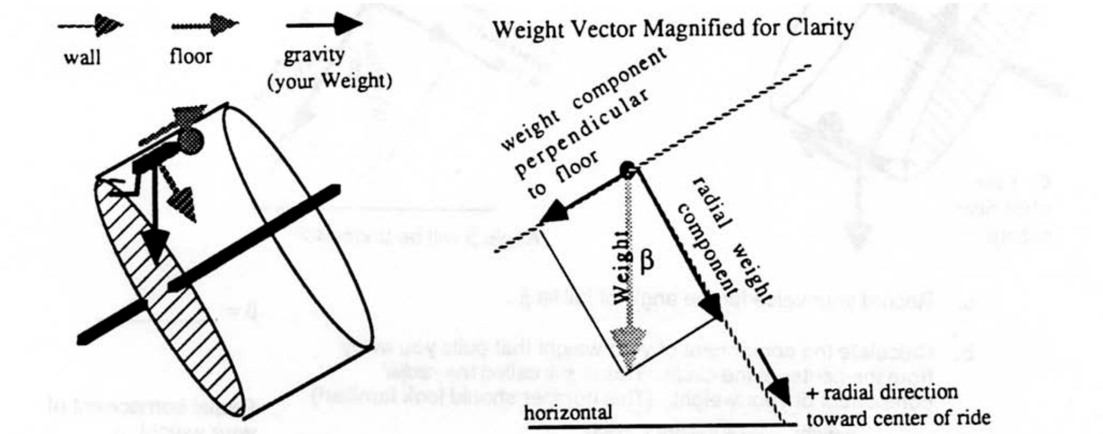
F.F. = __________

4. Compare this Force Factor to the accelerometer reading at top speed before ride tilts.

RIDE TILTED AND RIDER AT HIGHEST POINT

When the ride tilts, the force gravity exerts on you, your weight, F_g, has a component in the radial (along the radius of the circle either toward or away from the center) direction. Now, the force the wall exerts on you and the radial component of your weight combine to create the force holding you in motion (centripetal force).

$$F_{wall} + F_{gravity\ radial} = mv^2/r$$



5. Calculate the component of your weight that helps you to move in a circle. This is called the radial component of your weight. The angle at full tilt, β, is 48^0. Make sure your calculator is in degrees mode.

   $Weight_{radial} = Weight \times \cos\beta$

$Weight_{radial}$ = _____N

6. At the top of the tilt the force by the wall and the radial component of the weight work together to produce the centripetal force needed for you to move in a circle. Calculate the force the wall exerts on you at the top of the tilt. The centripetal force was calculated in #2.

   $F_{wall} + Weight_{radial} = F_c$

F_{wall} = __________ N

7. Calculate the Force Factor exerted on you by the wall when at the top of the tilt.

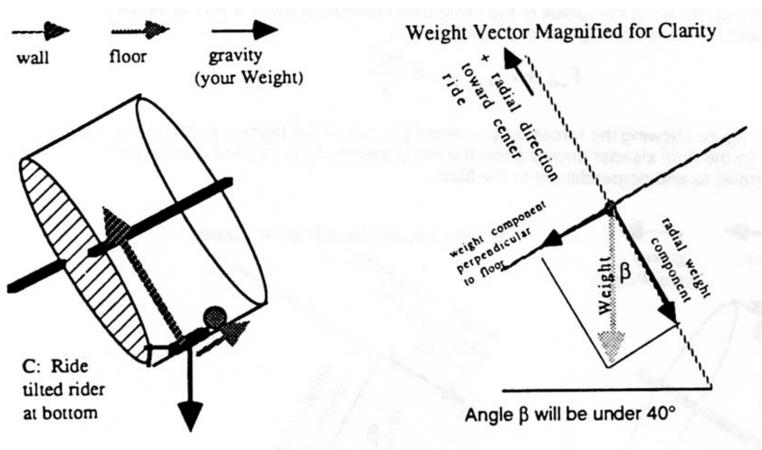
   $$F.F. = \frac{F_{wall}}{Weight}$$

F.F. = _________

8. Compare this Force Factor to the accelerometer reading at highest point while ride is tilted.

RIDE TILTED AND RIDER AT LOWEST POINT

The diagram on the next page shows the forces on you when you are at the lowest point of the ride. Now, the component of your weight, which acts in the radial direction, is in the "wrong" direction for circular motion. To compensate, the wall force increases so that the centripetal force stays the same.



9. At the bottom of the tilt the force by the wall and the radial component of the weight work against each other to produce the centripetal force needed for you to move in a circle. Calculate the force the wall exerts on you at the bottom of the tilt. The centripetal force was calculated in #2 and the radial component of your weight was calculated in #5.

F_{wall} - $Weight_{radial} = F_c$

F_{wall} = ___________N

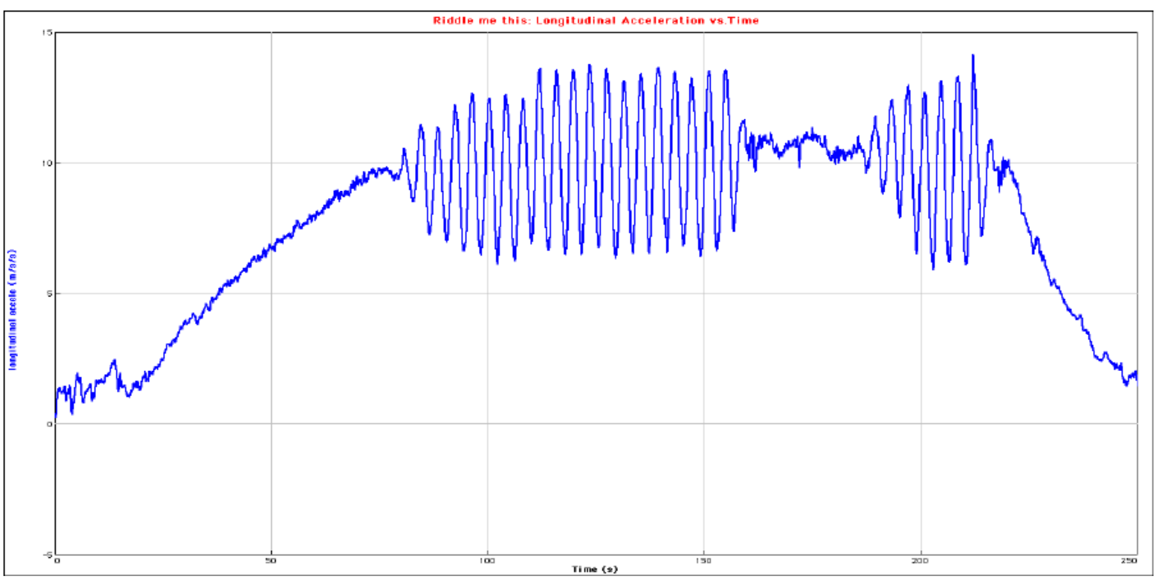
10. Calculate the Force Factor exerted on you by the wall when at the bottom of the tilt.

$$F.F. = \frac{F_{wall}}{Weight}$$

F.F. = _________

11. Compare this Force Factor to the accelerometer reading at lowest point while ride is tilted.

12. Below is a graph showing the force that the wall exerts on you during the ride. Explain the shape of the graph.



TOWER OF DOOM

Have you ever wondered what it feels like to be in free fall? The Tower of Doom lets you have the experience (without the unpleasant crash at the bottom!)

OBJECTIVE:
To analyze how forces acting on you change during a free fall ride by using the concepts of kinematics and the impulse-momentum theorem.

MEASUREMENTS

WHILE WATCHING
Time several drops and record the average time here.

Section of Ride	**Measured Times (seconds)**			**Average Time (seconds)**
Going Up				
Free fall Section				
Stopping Section				

READINGS ON RIDE
Use the Accelerometer on the ride and record your data here

Section of Ride	**Accelerometer Reading**
Going Up	
Waiting at Top	
Free Fall Section	
Stopping Section	

OBSERVATIONS

1. For each portion of the ride, describe the FORCES THE RIDER actually FEELS.

Section of Ride	**Sensation compared to normal weight (normal, larger, smaller, none)**
Going Up	
Waiting at Top	
Free Fall Section	
Stopping Section	

2. When did the accelerometer read closest to zero? Why does this make sense?

3. When did the accelerometer read closest to 1.0? What was your motion at this location?

4. When did you experience the greatest force?

CALCULATIONS

(Show all work)

GETTING TO THE TOP – POWER

1. Calculate the work done in lifting you to the top. The average lifting force is the upward force needed to lift your weight. The full distance from the ground to top is 42.7 m.

W = Fd = mgh

Work = _______ J

2.Calculate the power used getting you to the top. The time is the average you recorded in the measurements section.

$$P = \frac{W}{t}$$

Power = _______ *W*

1. Convert the power from Watts to horsepower. (1 horsepower = 746 W)

Power = _______ hp

COMING DOWN – CHECKING THE FREE FALL

2. Calculate the time it should take for you to drop if the track were frictionless. The length of the free fall section is 38.4 m.

$$d = \frac{1}{2}gt^2$$

time = _________ *s*

3. Compare the free fall time you measured (the one you wrote in the measurements section) with the time you calculated in #4. Within experimental error were you truly in free fall?

4. Does the accelerometer reading and your own sensation during the drop support this conclusion? Explain.

5. A typical description of free fall is "My stomach jumped into my throat." Relate this to what happened to the mass in the accelerometer.

STOPPING – MOMENTUM AND IMPULSE

6. Calculate your maximum velocity at the end of the free fall section. Use the time you calculated in #4.

$V_f = V_i + gt$

Velocity = ___________ *m/s*

7. Calculate your initial momentum as you enter the stopping section. Use the velocity you calculated in #8 as your initial velocity for the stopping section.

$p_i = mv_i$

Momentum$_i$ = ______ *kg-m/s*

8. Your momentum after stopping is 0 kg-m/s. Use the average stopping time recorded in the measurements section and your initial momentum to calculate the average breaking force acting on you while stopping.

$$F = \frac{\Delta p}{\Delta t} = \frac{(p_f - p_i)}{\Delta t}$$

Breaking Force = _______ *N*

9. Calculate the Force Factor (F.F.) you experienced during stopping by taking the average force calculated in #10 and dividing it by your normal weight.

$$F.F. = \frac{breaking\ force}{Weight}$$

F.F. **= ______**

10. Compare this Force Factor (F.F.) to the accelerometer reading you measured during the stopping section. How close in agreement are they?

ENTIRE RIDE – GRAPHING EXERCISE

1. Label the following sections on the graph found on the following page. Use brackets to indicate an entire section.

A Going Up	**C** Free Fall
B Waiting at the Top	**D** Stopping

2. Does the time of free fall indicated by the graph agree with the time you calculated above? With the time recorded while watching? What was this time?

3. Force Factors (F.F.) can be calculated by taking the acceleration value from the graph and dividing it by g (we'll use 10 m/s/s for simplicity). Calculate the Force Factor (F.F.) during the free fall section.

$$F.F. = \frac{graph\ value}{g}$$

F.F. $_{free\ fall}$ = _________

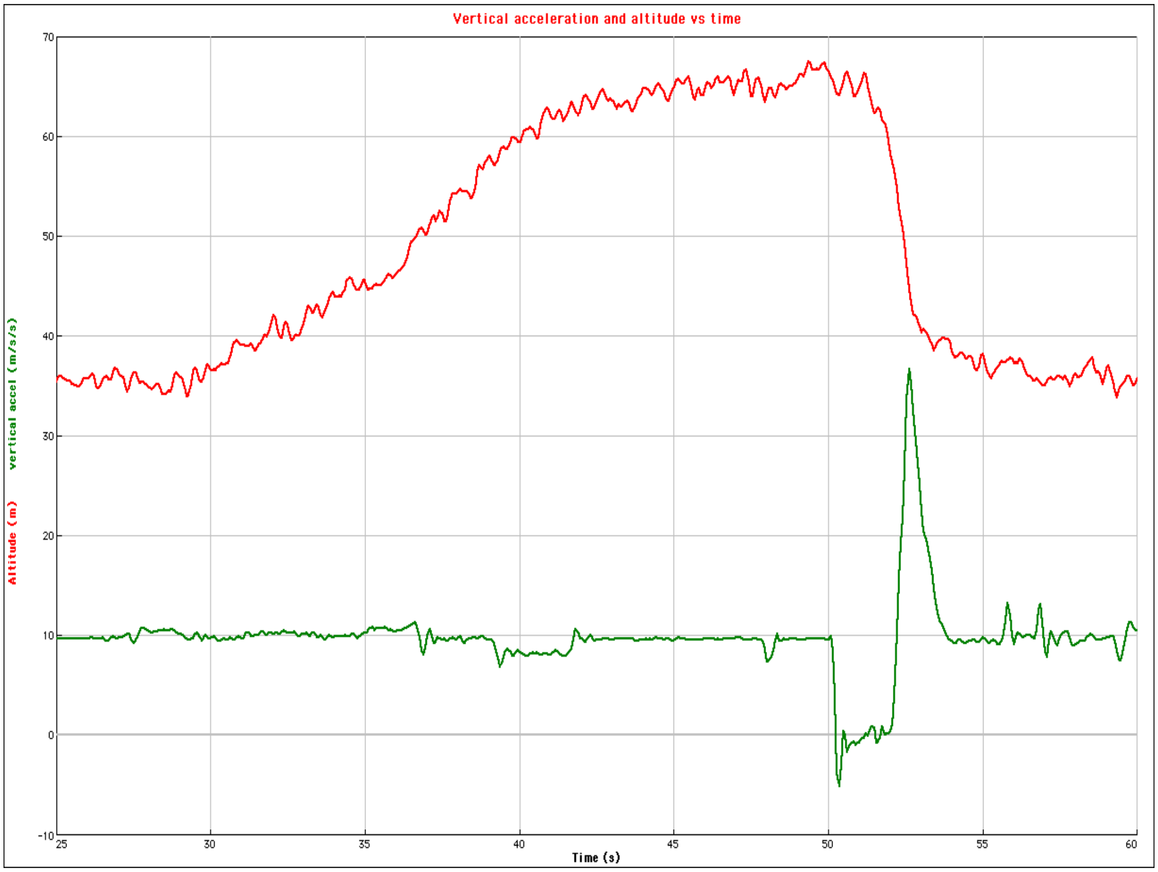
4. How does this Force Factor compare to what the accelerometer you took on the ride indicated?

5. Calculate the maximum Force Factor (F.F.) experienced during the stopping section.

$$F.F. = \frac{graph\ value}{g}$$

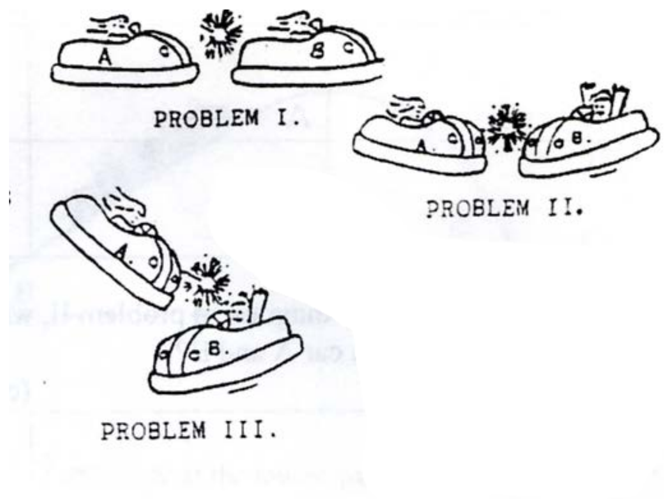
$F.F._{stopping}$ = ________

6. How does this Force Factor compare to what the accelerometer you took on the ride indicated?



COYOTE CREEK CRAZY CARS

Once aboard, road rage is the rule of thumb as guests challenge their friends and family in a thrilling bumper-to-bumper traffic jam.



OBJECTIVE

To observe multiple collisions and to apply the concept of momentum and its conservation to understand the results.

OBSERVATIONS

1. FILL IN THE MISSING TERMS:
   In a ____________ between two or more cars, the ________ that each car exerts on the other is ________ in magnitude and ___________ in direction according to Newton's ________ law. The speed and direction that each car will have after a collision can be found from the ______ of conservation of ___________.

2. Define the term momentum.

3. Define the Law of Conservation of Momentum.

4. As you walk across the floor, compare the frictional force you feel while walking on this surface to the frictional force you feel walking on the pavement outside the ride. The coefficient of friction between the rubber soled sneakers and concrete is about 1.0.
   a. Is the coefficient of friction between the floor and your shoe larger or smaller than the coefficient of friction between your shoe and the pavement outside? How can you tell?

   b. Would you expect the coefficient of friction between the floor and car to be larger or smaller than 1.0?

   c. What would happen if the coefficient of friction were to decrease?

   d. What would happen if the coefficient of friction were to increase?

5. Using diagram 1, what would be the result of the collision between cars A and B?

Rider feels	Car's Motion
A	
B	

6. Using diagram 2, what would be the result of the collision between cars A and B?

Rider feels	Car's Motion
A	
B	

7. Using diagram 3, what would be the result of the collision between cars A and B?

CALCULATIONS

Rider feels	Car's Motion
A	
B	

(Show all Work)

1. Calculate the momentum, p, of one car traveling at maximum speed (add your mass to the car's). The car's mass is 200 kg and its maximum speed is 1.7 m/s.

   $p = mv$

   momentum = ___________ kg-m/s

2. Determine the change in momentum, Δp, of one car traveling with an initial momentum of that calculated in #1 if it were to come to a complete stop after running into another car.

   $\Delta p = p_f - p_i$

   Change in momentum = _________ kg-m/s

3. Calculate the force of impact assuming the collision takes place in 0.1 seconds.

   $\Delta p = F\Delta t$

   Force = ____________ N

4. Calculate the Force Factor exerted on you during this collision.

   F.F. = Force/Weight

   F.F. = ______

5. Why do automobiles have "airbags" and special headrests on the back of seats?

BONZAI PIPELINE

1. Where do you feel the greatest force on your body as you come down the tube?
2. Do you lose more gravitational potential energy coming down the green tube or coming down the orange tube?
3. What stops you at the bottom of tube?
4. Does it take a greater distance to stop a larger person at the bottom? Why?

APOCALYPSE

1. At what point on this ride does the coaster have its greatest speed?
2. At what place on this ride are you the highest?
3. Could the highest place have been put at another point on the ride?
4. How does the coaster get to the top of the first hill?
5. How many times during this ride are riders turned completely upside down?
6. Compare the direction that you feel pulled during a curve to the direction that you feel pulled when you are at the top of a loop.

MAKING A FORCE METER

PURPOSE: to create a meter for measuring forces at the amusement park.

OBJECTIVES:

< To build a meter and understand how to use it.

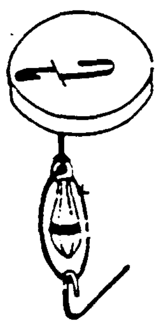
GENERAL STATEMENT:

A mass on a spring or rubber band can be used as a meter to measure the forces experienced on rides in terms of the force gravity normally exerts on a person or object. When the force factor is defined as force experienced divided by normal weight, it turns out that, on a given ride, all objects regardless of mass, experience the same multiple of normal weight.

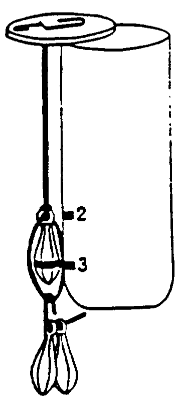
MATERIALS:
Clear tennis ball container or 1 foot section of plastic tubing used to cover fluorescent lights and a pair of end caps, (Tubes are available at commercial lighting supply centers and home improvement stores such as Lowe's or Home Depot), #1 paper clips, three 2 oz fishing sinkers, several #18 rubber bands, indelible pen.

< Part 1. MAKE a thick line across the widest pan of one sinker. PUSH a rubber band (RB) through the eye of one sinker. LOOP one end of the RB through the other end and pull tight

< Part 2. UNBEND paper clip to create a U. LAY the-free end of the RB across the U near one side. SLIDE the sinker through the rubber band loop and pull it tight.



o Part 3. POKE the ends of the U up through the top of the cover so that the weight will hang close to one side of the can. PUSH paperclip up against the top, bend the ends back across the top and tape down. SLIDE the string through the hole of the sinker and tie the ends together. Connect the small paper clip to the string loop. For the tennis can the loop need not be very long. For the plastic tubing, make the string loop long enough so that the masses can be threaded through the tube and hang out the bottom.



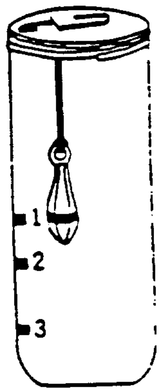
< Part 4: TO MARK FORCE FACTOR CALIBRATIONS HANG two additional sinkers on the small clip. HOLD the top against the edge of the can. PLACE a strip of tape on the can level with the line on the permanent sinker and label it force factor = 3.

< REMOVE one extra sinker and place a strip of tape on the can level with the line on the permanent sinker, and label it force factor = 2.

< REMOVE everything but the PERMANENT SINKER. INSERT the sinker into the can and tape the top on SECURELY. MARK midline of sinker as force factor = 1.

< If you use a spring the marks should be evenly spaced. Twice the force gives twice the stretch.

< If you used a rubber band, the marks are not evenly spaced because rubber bands are not linear. Double the force does not give double the stretch.



< Part 5. ESTIMATE the O or "weightless" position. Turn the can on its side. Jiggle to the unextended position for the rubber band and mark with a strip of tape for force factor = 0.

< TAPE a 3 rubber band chain onto the meter as a wrist strap. It will hold onto the meter on an exciting ride but will break in an emergency.

NOTE: Accelerometer kits are available from PASCO SCIENTIFIC (1-800-772-8700). The kits include both the vertical meter described here using a spring and mass and a horizontal meter, based on a protractor model, for making angle measurements such as those needed for the Flying Wave.

UNDERSTANDING A FORCE METER

The force meter indicates the force exerted on a rider in the direction in which the device is pointing as a multiple of the rider' s own weight. This multiple we have called a force factor.* If the meter, when pointing in the direction of motion, registers 1.5, it means that a force 1.5 times as large as the normal gravitational force on the mass is being used to make the mass accelerate. In this situation, a force 1.5 times the rider 's normal weight is pushing on his or her back. The actual force experienced by each rider, however, would be different. A 120-pound rider would be experiencing a force of 180 pounds. However, a 200-pound rider would be feeling a force of 300 pounds.

When the meter is held vertically (parallel to the backbone) on roller coasters or the Sky Scraper, it can be used to find the force the seat exerts on the rider. When the meter reads 1, the rider feels a seat force equal to his or her normal weight. At this point, the seat is pushing up with a force equal to the rider 's normal weight balancing the force of gravity.

A meter reading of 2 means the mass needs twice its normal weight to keep it moving with the spring. The rider is then feeling an upward force from the seat equal to twice the normal weight. A 200-pound rider would feel an upward push of 400 pounds and a 120-pound rider would feel a force of 240 pounds. Both of the riders are experiencing a force factor of 2. Because we interpret the upwards force of a seat as indicating the downward pull of gravity, riders feel as if they are heavier, as if, somehow, gravity has gotten bigger.

When the meter, held vertically, is reading 0, the seat is exerting no force at all. Gravity is, as always, pulling down with a force equal to the rider's weight, but the seat is offering no resistance. The only time this happens is if the seat and rider are in some form of free fall. This can be when they are coming over the top of a coaster hill or actually falling. Their speed will be increasing in the "down" direction at a rate of 9.8 m/s^2, about 22 mph every second. The meter actually does read 0 on free fall rides and at certain points on roller coasters.

Another interesting case is when the rider is upside down. If the ride goes through the inverted part of a loop fast enough, the meter will read anywhere from .2 to 1. The rider is being forced into a curved motion smaller than the curve a ball thrown in the air might follow. The rider may feel lighter than usual but does not feel upside down. This is particularly evident on the Sky Scraper where the repetitive motion gives riders a chance to get used to the motion and start to notice sensations.

* In the media this is often referred to as a number of g's. Many members of the physics community object to the "g" terminology because it is often confused with the acceleration due to gravity. Here we are talking about the g forces experienced by the student.

MAKING MEASUREMENTS

TIME:

The times that are required to work out the problems can be measured using a digital watch with a stopwatch mode or a watch with a second hand. When measuring the period of a ride that involves harmonic or circular motion, measure the time for several repetitions of the motion. This will give a better estimate of the period of the motion than just measuring one repetition. In any case, measure multiple occurrences and then average.

DISTANCE:

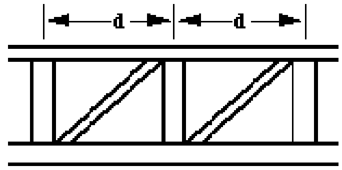
Since you cannot interfere with the normal operation of the rides, you will not be able to directly measure heights, diameters, etc. All but a few of the distances can be measured remotely using one or another of the following methods. They will give you a reasonable estimate. Consistently use one basic unit of distance **-** meters or feet.

1. <u>Pacing:</u> Determine the length of your stride by walking at your normal rate over a measured distance. Divide the distance by the number of steps, giving you the average distance per step. Knowing this, you can pace off horizontal distances.

I walk at a rate of _____ paces per _______.... or.... My pace = _______

2. <u>Ride Structure:</u> Distance estimates can be made by noting regularities in the structure of the ride. For example, tracks may have regularly spaced cross-members as shown in figure A. The distance **d** can be estimated, and by counting

the number of cross members, distances along the track can be determined. This can be used for both vertical and horizontal distances.



3. Triangulation: For measuring height by triangulation, a horizontal accelerometer can be used. Suppose the height **h** of a ride must be determined. First the distance **L** is estimated by pacing it off (or some other suitable method). Sight along the accelerometer to the top of the ride and read the angle **θ** . Add in the height of your eye to get the total height.

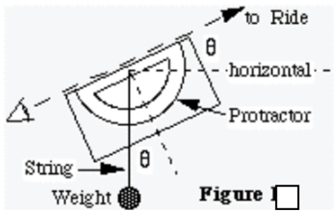


Figure 1

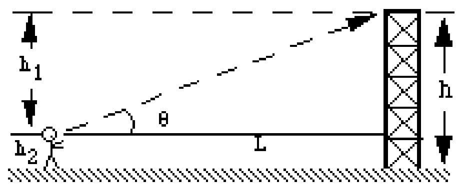


Figure B:

$\tan \theta = h_1 / L$, $h_1 = L \tan \theta$ h_2 = height of eye from ground

h = total height of ride = $h_1 + h_2$

1. A similar triangulation can be carried out where you cannot measure the distance to the base of the ride. Use the law of sines as illustrated in Figure C to the right:

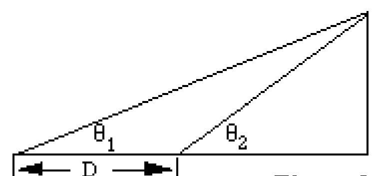


Figure C

Knowing θ_1, θ_2 and D, the height h can be calculated using the expression:

$$h = (D \sin \theta_1 \sin \theta_2) / \sin (\theta_2 - \theta_1)$$

SPEED:

The average speed of an object is simply distance divided by time. For circular motion, it is the circumference divided by time, if the speed is in fact constant.

$$v_{avg} = \Delta d / \Delta t = 2 \pi R / \Delta t \text{ (circular)}$$

To measure the instantaneous speed of a moving train, divide its length by the time it takes to pass a particular point on the track.

$$v_{inst} = \Delta d / \Delta t = \text{length of train / time to pass point}$$

In a situation where friction is ignored and the assumption is made that total mechanical energy is conserved, speed can be calculated using energy considerations:

GPE = KE

$$m g h = 1/2 m v^2$$

$$v^2 = 2 g h$$

$$v = \sqrt{2 g h}$$

Consider a more complex situation:

$GPE_A + KE_A = GPE_C + KE_C$
$mgh_A + 1/2\ mv_A^2 = mgh_C + 1/2\ mv_C^2$

Solving for v_C:

$$v_C = \sqrt{2\,g\,(h_A - h_C) + v_A^2}$$

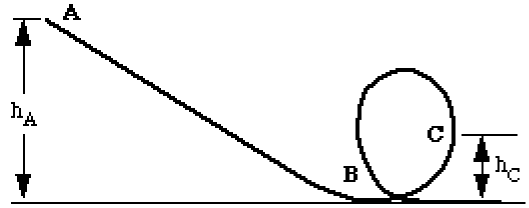


Figure I

ACCELERATION:

Centripetal Acceleration

Calculations of acceleration in uniform circular motion are possible. Where **R** is the radius of the circle and **T** is the period of rotation, centripetal acceleration can be determined by the equations given below.

Centripetal Acceleration: $\mathbf{a_c = v^2 / R = 4 \pi^2 R / T^2}$

Direction of Acceleration

The net force which causes an object to accelerate is always in the same direction as the resulting acceleration. The direction of that acceleration, however, is often not in the same direction in which the object is moving. To interpret the physics of the rides using Newtonian concepts, you will need to determine the direction of the accelerations from the earth's (inertial) frame of reference. From this perspective, the following statements are true.

a) When an object traveling in a straight line speeds up, the direction of its acceleration is <u>the same</u> as its direction of motion.

b) When an object traveling in a straight line slows down, the direction of its acceleration is <u>opposite</u> its direction of motion.

c) When an object moves in a circle at a constant speed, the direction of its acceleration is t<u>oward the center of the circle</u>.

d) When an object moves in a parabola (like those in a coaster ride), the direction of acceleration is <u>along the axis of the parabola</u>.

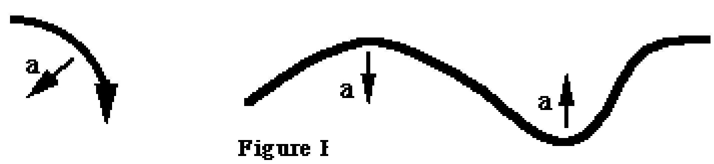
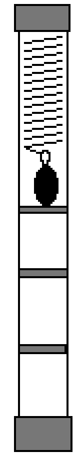


Figure I

Vertical means perpendicular to the track
Longitudinal means in the direction of the train's motion,
Lateral means to the side relative to the train's motion.

The Vertical Accelerometer



The vertical accelerometer gives an acceleration reading parallel to its long dimension. It is normally calibrated to read in "**g's**." A reading of **1 g** means an acceleration of 9.8 m/sec^2, the normal acceleration of gravity here on earth. Another way of stating this is to say that you are experiencing a force equivalent to your normal earth weight.

Note that there are three situations in which you may wish to use the vertical accelerometer: Head Upward, Head Downward, Sideways.

Head Upward:

This is when you are riding and your head is up, even though you may be going over a bump or going through a dip. An analysis of the forces gives us a net acceleration:

$$\mathbf{a_{net} = a_{reading} - 1\ g}$$

Head Downward:

This is when you are at the top of a loop or a vertically circular ride and are upside down. Analyzing the forces here gives a net acceleration:

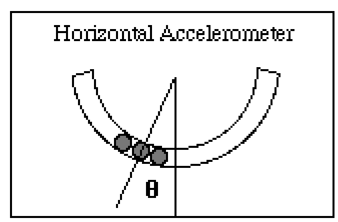
$$\mathbf{a_{net} = a_{reading} + 1\ g}$$

Sideways:

This is when you are going around a horizontal curve, or you are measuring your starting or stopping acceleration. The accelerometer is held horizontal, and the reading is just equal to the net or centripetal acceleration.

$$\mathbf{a_{net} = a_{reading}}$$

The Horizontal Accelerometer



The horizontal accelerometer is able to read accelerations which occur in a lateral or longitudinal direction. When going around a level corner with the horizontal accelerometer held level relative to the ground, pointed to the side, the angle of deflection gives a measure of the centripetal acceleration. The same technique would apply to longitudinal accelerations like the initial acceleration and final deceleration if the accelerometer is pointed forward in the direction of your motion. From a force analysis it can be shown that the rate of acceleration is given by:

$$\mathbf{a = g \tan \theta}$$

Table of Tangents

Angle	Tangent	Angle	Tangent
0	0.00	45	1.00
5	0.09	50	1.19

10	**0.18**	**55**	**1.43**
15	**0.27**	**60**	**1.73**
20	**0.36**	**65**	**2.14**
25	**0.47**	**70**	**2.75**
30	**0.58**	**75**	**3.73**
35	**0.70**	**80**	**5.67**
40	**0.84**	**85**	**11.4**

USEFUL RELATIONS

These handheld devices suffer from three things:

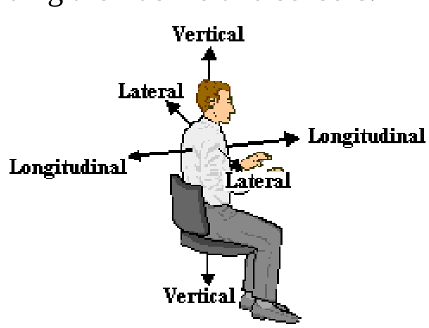
1. Students are trying to watch the measuring instrument while at the same time they are trying to participate in the ride experience and just "hang on."
2. Readings have to be taken "on the fly" and remembered until the end of the ride when they can be written down.
3. It is very difficult to read the devices because of the ride vibrations and readings can only be estimated. Only single readings can be taken and there is no record over the entire ride.

For these reasons, new technology can be employed that takes advantage of electronic accelerometers and other sensors that have been developed over the last few years. Vernier Software & Technology, PASCO scientific, and other educational scientific equipment manufacturers have developed accelerometers that can be connected to an interface that will log the data at preset intervals for the entire ride. Three-axis accelerometers are now available that can monitor accelerations in three directions and a barometer sensor can be added to some systems. The Vernier three-axis accelerometer is shown at the right. The barometer readings can be converted into height readings since atmospheric pressure decreases with altitude.

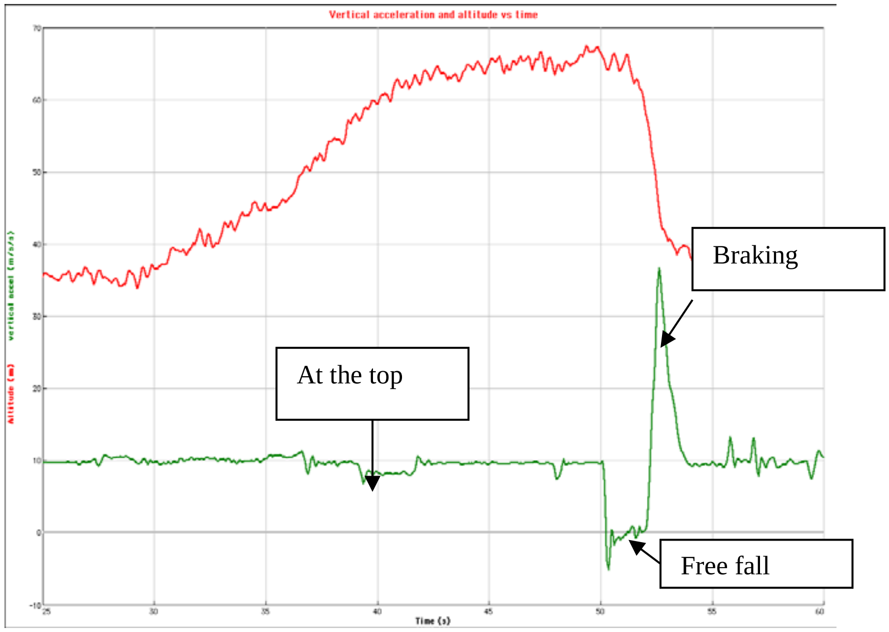
Vernier sensors utilize the LabPro or CBL interface. These interfaces can be used with Texas Instrument graphing calculators or personal computers. The interface can be operated in a remote setting as shown on the the right so it does not need to be connected to the calculator or computer during data collection. The LabPro comes with a software package called Logger Pro for data analysis, plotting, etc.

Similar instrumentation is available from PASCO scientific. PASCO's three –axis accelerometer and altimeter plugs directly into their interface called Xplorer. Data from Xplorer can be downloaded into a computer and analyzed with PASCO's software package called DataStudio. The vest shown on the left can worn on the ride and the instruments inserted for complete hands free operation. Vernier sells a similar vest for holding the LabPro and sensors.

For the purposes of electronic data collection and analysis, it is convenient to define the three perpendicular acceleration axes as the riders "vertical," "longitudinal," and "lateral" directions. These directions are relative to the rider but can change relative to the ground. These directions are shown in the diagram at the right.

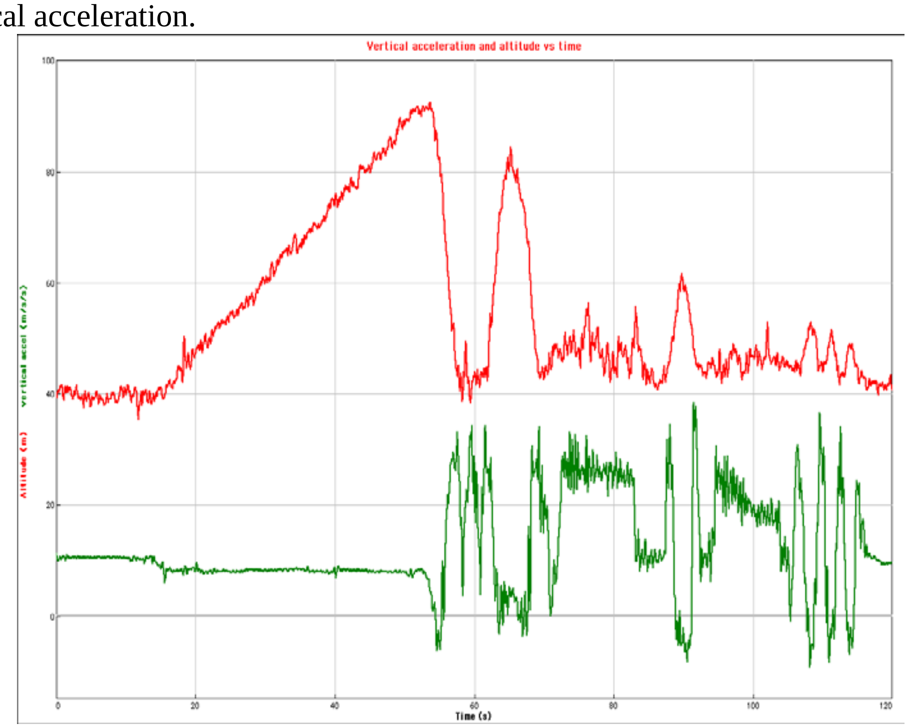


The “Tower of Doom” ride at Six Flags America is a free fall ride and can be analyzed by only considering the vertical acceleration and the altitude. A typical graph for the Tower of Doom is shown below.



Six Flags America Tower of Doom

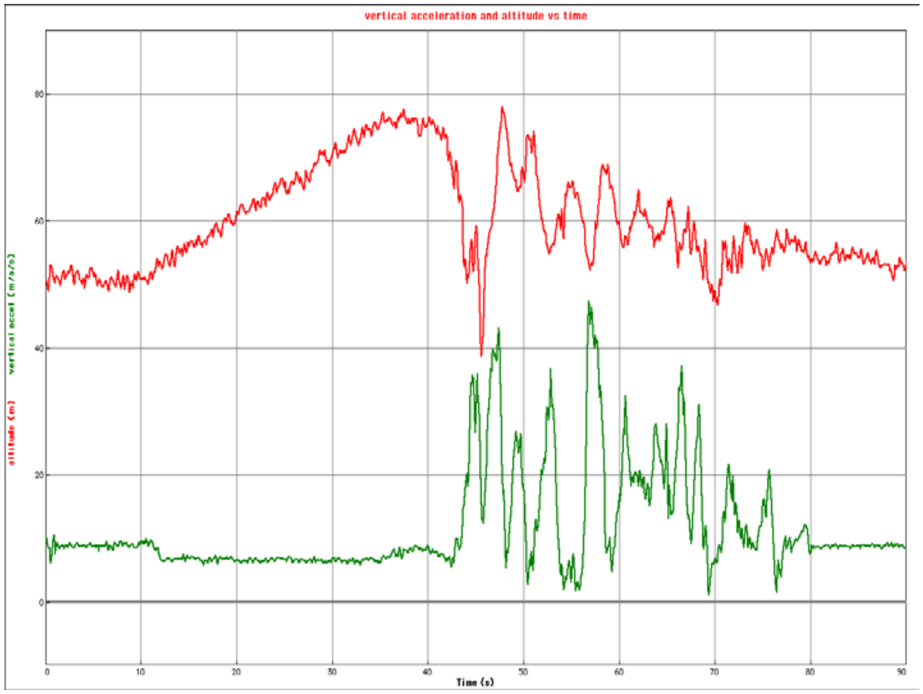
Features on this graph are very easy to identify. A more difficult graph to analyze is the following graph taken on Superman Ride of Steel. Only the vertical acceleration is shown. It is easy to distinguish the lift hill where the vertical acceleration is .
Other acceleration features can be identified by comparing the ride altitude profile with the vertical acceleration.



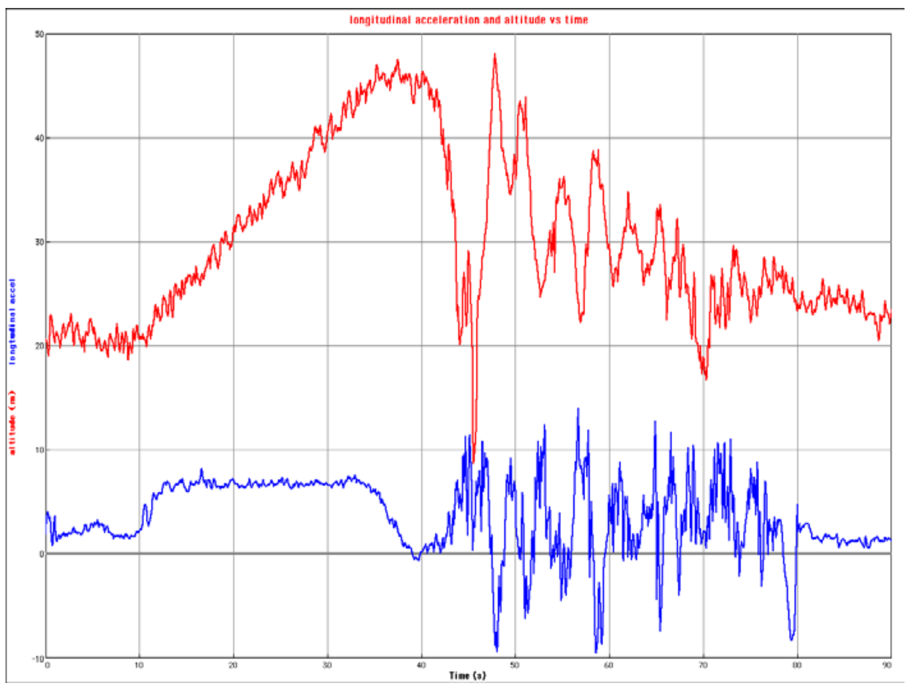
Six Flags America Superman Ride of Steel

A final example that shows all three accelerations is taken from Six Flags America's Mind Eraser, an example of a looping coaster. The three accelerations are shown in separate graphs for ease of interpretation.

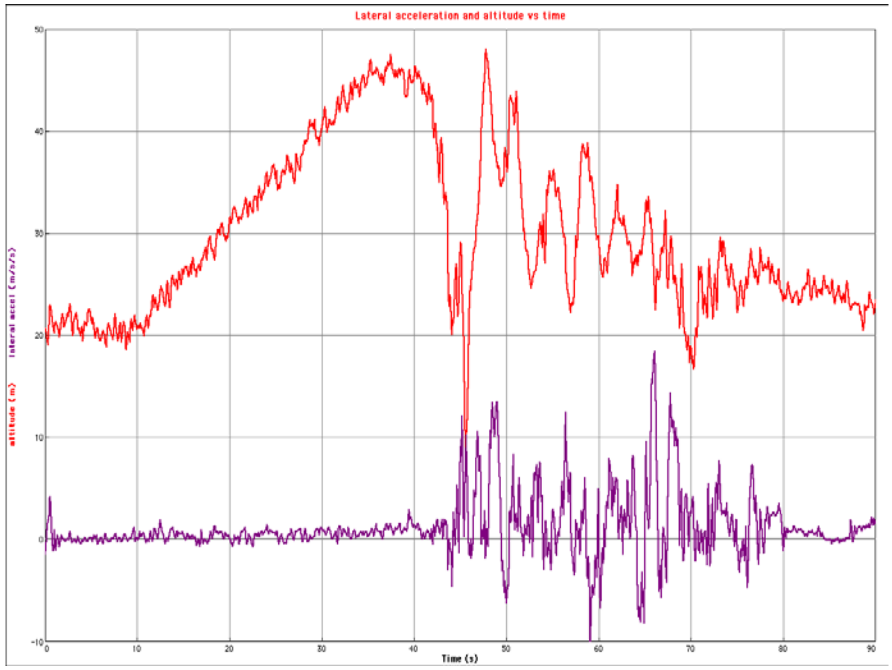
Mind Eraser Altitude and Vertical Acceleration



Mind Bender Altitude and Longitudinal Acceleration



Mind Eraser Altitude and Lateral Acceleration



A manual that discusses data collection at the Amusement Park can be downloaded free from Vernier's website at http://www.vernier.com/cmat/datapark.html

USEFUL RELATIONS

Distance, Velocity and Acceleration:

$v = \Delta d / \Delta t$
$a = \Delta v / \Delta t$

For Circular Motion:

$C = \pi D = 2 \pi R$ $v = C / T = 2 \pi R / T$

At the surface of the earth:

$g = 9.8 \text{ m/s}^2$ $10 \text{ m/s}^2 = 32 \text{ ft/s}^2$

If acceleration is constant:

$d = (v_f - v_o)\, t / 2$
$d = v_o\, t + 1/2\, a\, t^2$
$v_f = v_o + a\, t$
$v_f^2 = v_o^2 + 2\, a\, d$

Potential and Kinetic Energy:

Gravitational Potential Energy:

$GPE = E_P = Ug = m\, g\, h$

Kinetic Energy:

$KE = 1/2\, m\, v^2$

Force:

$F_{net} = m\, a$

Centripetal Force:

$F_c = m\, v^2 / R = 4\, \pi^2\, m\, R / T^2$

Conversions:

88 ft/s = 60 mph
1.5 ft/s = 1 mph
1 m/s = 2 mph
1 ft/s = 0.30 m/s
1 mph = 1.60 km/h

SIX FLAGS AMERICA
RIDE SPECIFICATIONS

The Wild One	• Height of the first hill ***29.9 m*** • Track height at bottom of first hill ***5.2 m*** • Track height at top of second hill ***20.4 m*** • Height of hill before the horizontal loop ***11.6 m*** • Exit height of the horizontal loop ***4.6 m*** • Radius of the horizontal loop ***12.2 m*** • Length of passenger train ***14.5 m*** • Angle of lift incline ***19.5 degrees*** • Length of lift incline ***89.6 m***
Jokers Jinx	• Length of acceleration phase ***61.0 m*** • Time of acceleration phase ***3 seconds*** • Length of train ***14.6 m*** • Speed at end of acceleration phase ***26.7 m/s*** • Difference in height from acceleration phase to bottom of first loop ***1.1 m*** • Radius of curvature of bottom of vertical loop ***21 m*** • Radius of curvature of top of vertical loop 6.0 m • Height at top of first loop ***28.3 m***
Superman Ride of Steel	• Height of the first hill ***61.0 m*** • Track height at bottom of first hill ***1.2 m*** • Track height at top of second hill ***52.1 m*** • Radius of curvature at top of second hill ***25m*** • Height at entrance of first horizontal loop ***4.9 m*** • Radius of first horizontal loop ***30.5 m*** • Height at exit of first horizontal loop ***6.1 m*** • Height at entrance of second horizontal loop ***5.5 m*** • Radius of second horizontal loop ***22.9 m*** • Height at exit of second horizontal loop ***9.4 m*** • Angle of lift incline ***30.0degrees*** • Length of lift incline ***122 m*** • Length of train ***16.2 m***
Roar	• Height of the first hill ***27.4 m*** • Track height at bottom of first hill ***3.4 m*** • Track height at top of second hill ***21.0 m*** • Angle of lift incline ***25.0 degrees*** • Length of lift incline ***64.8 m*** • Length of train ***18.1 m***
Batwing	• Height at top of first hill ***35.1 m*** • Height of the bottom of the vertical loop ***1.2 m*** • Height of the top of the vertical loop ***22.6 m*** • Radius of curvature of the bottom the vertical loop ***20.0 m*** • Radius of curvature of the top of the vertical loop ***6.0 m*** • Angle of lift incline ***32.0 degrees*** • Length of lift incline ***66.2 m*** • Length of train ***15.3 m***

The Mind Eraser	• Height of the first hill ***30.5 m*** • Height at bottom of first hill ***4.6 m*** • Radius of curvature at bottom first hill ***15m*** • Radius of curvature at bottom of vertical loop ***17.0 m*** • Radius of curvature at top of vertical loop ***6.0m*** • Height at bottom of vertical loop ***5.5 m*** • Height at top of vertical loop ***21.6 m*** • Angle of lift incline ***32.0 degrees*** • Length of lift incline ***57.6 m*** • Radius of helix ***8.2 m*** • Length of train ***15.0 m***
Tower of Doom	• Length of free fall ***21.6 m*** • Total height ***42.7 m*** • Time of free fall ***2.1sec*** • Maximum speed ***24.9 m/s***
Riddle Me This	• Radius of ride ***4.2 m*** • Maximum angle of tilt ***48 degrees***
Pirate's Flight	• Radius of rotation ***10.4 m*** • Length of chains suspending the gondola ***6.2 m***
High Seas	• Length of boat ***14.5 m*** • Distance from pivot to center of boat ***12.2 m*** • Maximum angle ***75 degrees***
Carousel	• Radius of inner circle of horses ***4.4 m*** • Radius of outer circle of horses ***7.2 m***
Flying Carousel	• Radius for inner chairs at maximum angular velocity ***8.5 m*** • Radius for outer chairs at maximum angular velocity ***9.9 m***

SAMPLE CALCULATIONS

Throughout these sample calculations, it will be assumed that the mass of the rider is 55.0 kg and the acceleration of gravity is 9.80 m/s^2. Calculations will be made to 3 significant figures, even though some measurements will only be made to 2 significant figures.

<u>Superman-Ride of Steel (Non-looping coaster)</u>
The calculations for Roar, Superman, and Wild One are all very similar. Data used in the calculations is given in the Resource Manual.

1. Find the potential energy at top of the first hill:

2. Need the measured time to calculate power. Assume the time is 20.0 s.

3. Length of the lift hill can be calculated from the given height and angle of the hill.

4. The force to move the rider up the first incline is the component of the weight along the incline or,

5. An approximate value for the speed at C can be found from the measured time for the train to pass point C and the given length of the train. Assuming a time of 0.500s for this sample calculation:

$$v_{ave} = \frac{length}{time} = \frac{16.2m}{0.500s} = 32.4m/s$$

6. The kinetic energy at the bottom of the hill using this speed is

$$E_{KC} = \frac{1}{2}mv_C^2 = \frac{1}{2}(55.0kg)(32.4m/s)^2 = 28,900J$$

8. If there was no friction, the kinetic energy at the bottom of the hill can be found from the change in potential energy since the kinetic energy at the top of the hill is approximately zero. Setting the change in potential energy equal to the change in kinetic energy

$$\Delta E_P = \Delta E_K$$

$$E_K = mgh_A - mgh_C = (55.0kg)(9.80m/s^2)(61.0m - 1.2m) = 32,200J$$

If friction is neglected, the speed at the bottom of the incline can be found from this kinetic energy

$$E_{KC} = \frac{1}{2} m v_C^2$$
$$v_C = \sqrt{\frac{2E_{KC}}{m}} = \sqrt{\frac{2(32,200J)}{55.0kg}} = 34.2m/s$$

9. The upward force applied by track at the bottom of the incline is
$$F_{track} = \frac{mv_C^2}{R} + mg = \frac{2E_{KC}}{R} + mg = \frac{2(32,200J)}{30.0m} + (55.0kg)(9.80m/s^2) =$$
$$= 2,150N + 539N = 2,690N$$

10. $$ForceFactor = \frac{ForceApplied}{Weight} = \frac{2690N}{539N} = 4.99$$

12. Assuming no energy loss due to friction, the speed at the top of the second hill can be found using conservation of energy again.
$$\Delta E_P = \Delta E_K$$
$$E_{KD} = \frac{1}{2} m v_D^2 = mg(h_A - h_D)$$
$$v_D = \sqrt{2(9.80m/s^2)(8.9m)} = 13.2m/s$$

13. The force exerted by the track point D with a radius of curvature 25.0 m is found similarly to step 9:
$$F_{track} = mg - \frac{mv_D^2}{R} = (55.0kg)(9.80m/s^2) - \frac{(55.0kg)(13.2m/s)^2}{25.0m}$$
$$= 539N - 383N = 156N$$

14. The resulting force factor is
$$ForceFactor = \frac{ForceApplied}{Weight} = \frac{156N}{539N} = .289$$

<u>Mind Eraser-Looping Coaster</u>

The calculations for Mind Eraser, Batwing, and Two-Face: The Flip Side are very similar and only the calculations for Mind Eraser will be shown here.

1. The potential energy at point A (note that the speed at A is approximately zero)

2. Need the measured time to get to point A so assume a time of 10.0 s

3. Length of lift hill can be found from the height and the angle of rise

4. The force to move the rider up the first incline is the component of the weight along the incline or,

5. An approximate value for the speed at C can be found from the measured time for the train to pass point C and the given length of the train. Assuming a time of 0.700s for this sample calculation:

6. The kinetic energy at the bottom of the hill using this speed is

7. The potential energy at the bottom of the vertical loop

9. Using conservation of energy and assuming no losses due to friction (also the kinetic energy at A is approximately zero),

10. The upward force applied by track at the bottom of the incline is

11. The force factor can be found as before

13. The potential energy at the top of the vertical loop (point D) is given by

14. Using conservation of energy with the kinetic energy at point A negligible

15. Solving this equation for the speed at point D

$$v_D = \sqrt{\frac{2E_{KD}}{m}} = \sqrt{\frac{2(4,800J)}{55.0kg}} = 13.2m/s$$

16. At the top of the vertical loop the rider is upside down and the track exerts a force downward to keep the rider moving along the circular arc. The force of the track on the rider is given by

18. And the resulting force factor is

Joker's Jinx-an induction coaster

Joker's Jinx is not a gravity coaster, unlike all the other coasters at Six Flags America. There is no other similar coaster at Six Flags America.

1. The kinetic energy at point B for a speed of 27 m/s is

2. The work done is the average force exerted through this distance which is equal to the change in kinetic energy. Since the ride started from rest, the change in kinetic energy is just the final kinetic energy found in step 1. Equating and solving for the average force

3. Calculate the potential energy at point B relative to point C, the lowest point in the ride.

4. The total energy at B is the sum of the kinetic plus the potential energy or

5. The kinetic energy at C (assuming no energy loss) is just the total energy at B. This can be solved to get the speed at C

6. The force exerted at the bottom of the loop is

7. The resulting force factor at point C is

$$ForceFactor = \frac{ForceApplied}{Weight} = \frac{2,460N}{539N} = 4.56$$

9. Relative to point C, the potential energy at point D is

$$E_{PD} = mgh_D - mgh_C = (55.0kg)(9.80m/s^2)(28.3m) = 15,300J$$

10. Applying conservation of energy to point D

$$E_{KD} + E_{PD} = E_{KC} + E_{PC}$$

$$E_{KD} = E_{KC} + E_{PC} - E_{PD} = 20,200J + 0J - 15,300J = 4,900J$$

11. Solving for the speed at point D

$$E_{KD} = \frac{1}{2}mv_D^2 = 4,900J$$

$$v_D = \sqrt{\frac{2E_{KD}}{m}} = \sqrt{\frac{2(4,900J)}{55.0kg}} = 13.3m/s$$

12. The force exerted at the top of the loop is in the downward direction and is given by

14. The force factor at D is then given by

Amusement Park Web Sites

National Amusement Park Historical Association
http://www.napha.org/

America Coaster Enthusiasts
http://www.aceonline.org/

Amusement Park Physics
http://www.vernier.com/cmat/amusementparkphysics.html

Clarence Bakken's Physics Day Website
http://homepage.mac.com/cbakken/pga/

Roller Coaster Physics
http://www.vast.org/vip/book/home.htm
This is an excellent resource written by Tony Wayne. There are over 150 pages available in pdf format.

Virtual Roller Coaster-Annenberg/CPB Project
http://www.learner.org/exhibits/parkphysics/

Roller Coaster G-Forces Applet
http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/circmot/rcd.html

Quick Time Roller Coaster Movies from CNN
http://www.cnn.com/TRAVEL/DESTINATIONS/9706/roller.coasters/coasters.html

Six Flags America
http://www.sixflags.com/parks/america/home.asp