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Welcome to *Hersheypark*, a proud supporter of STEM education initiatives. *Hersheypark* offers laboratory manuals focusing on Math, Physics, and Science in addition to the Advanced Physics Workbook. All of the manuals are designed to give students the opportunity to apply their content knowledge in a hands-on environment while enjoying the day at one of the country's favorite amusement parks.

NEW for 2012, *Hersheypark* has an updated Physics Lab Manual. We have incorporated STEM focus, open-ended, and conservation of energy activities that will challenge your thinking.

Our educational guides are designed to be a resource as you and your students plan your *Hersheypark* adventure. Feel free to choose the activities that best fit your students and reproduce the worksheets as needed. You will find activities that are appropriate for a variety of ages, grade levels, and curriculums. *Hersheypark* would like to recognize several individuals who have contributed their time and talents to updating the current Physics Lab Manual. These individuals are continuing the tradition of educational enrichment within *Hersheypark*.

- Pete Vreeland, Upper Merion High School
- Dave McCachren, Mifflin County High School
- Jim Delaney, Manheim Township High School
- Missy Doll, Manheim Township High School
- Chris Manning, Manheim Township High School

Hersheypark would like to extend a Thank You to the following individual for his continued support of our Education Programs.

- Dr. Geno Torri, Consultant

Hersheypark will gladly accept any recommendations, experiments, or corrections to our education guides. Please feel free to email your comments or questions to HersheyparkGroups@HersheyPA.com.

A Message to Educators from Authors

Hersheypark Physics Day offers students a unique opportunity to experience first-hand the physics concepts learned in the classroom. Over the years, many teachers have, through trial and error, developed ideas and procedures that make the Physics Day experience one of the most significant learning events of the year for their students. The authors would like to offer the following suggestions and advice:

Prior to the trip - administrative preparation:

_____ a. Plan financing of trip.

_____ b. Present proposal to administration for approval.

_____ c. Determine procedures to be used at the Park, like check-in locations and what to do in the event of an emergency situation.

_____ d. Obtain permission slips from students. NOTE: Be sure that students indicate any medical concerns (like allergies to bee stings) on their permission slips.

_____ e. Line up transportation.

_____ f. Provide maps of *Hersheypark* to the students. Discuss locations of emergency facilities and check-in points.

_____ g. Establish itinerary to maximize educational opportunities.

Typical time schedule:

9:30 AM	*Hersheypark* gates will open ½ hour early on Physics Day.
10 AM	Rides open. Begin lab activities. Activities typically take between three and four hours to complete with good reliability. Lunch-time check-in is a good time to assess how activities are going.
2:30 PM	Experimenting is typically completed by this time making it a good time for a check-in. Materials can be collected. Some groups leave at this time in order to arrive at their school at the end of the school day. Other schools give students free time to enjoy the Park until it closes.

Educational preparation:

_____ a. Establish and review safety requirements and emergency procedures.
_____ b. Pretest students on concepts to be reinforced by the field trip.
_____ c. Teach/review concepts that will be dealt with during the trip.
_____ d. Construct accelerometers.
_____ e. Assemble together all materials (lab sheets, pencils, calculators, stop watches, accelerometers, and plastic bags to carry everything in).
_____ f. Determine number of students per lab group and assign lab group members (groups of 3 or 4 seem to work best).
_____ g. Set clear objectives and requirements for students (number of rides to analyze, evaluation procedures that will be applied, follow-up assignments, etc.).

Example: All students must complete worksheet packets on four to five rides of which at least two must be coasters and two must be non-coasters.

Day of the trip:

_____ 1. Remind students of safety requirements and emergency procedures.
_____ 2. Remind students of check in times and locations.
_____ 3. Students should be prepared for sun or rain (sunscreen is highly recommended).
_____ 4. Students should bring money for food, phone, and storage locker.

After the trip:

_____ 1. Schedule class time for follow-up discussion of concepts experienced.
_____ 2. Evaluate student work.
_____ 3. Post-test students on concepts.
_____ 4. Put up bulletin board (it’s great motivation for future classes).

We hope that your educational experience goes smoothly and that your students walk away with a deeper understanding of physics principles.

Concepts Covered

RIDE	Linear Speed	Linear Acceleration	Circular Speed	Centripetal Acceleration	Linear Forces	Centripetal Forces	Horizontal Forces	Vertical Circles	Kinetic Energy	Potential Energy
Pirate Ship	X			X		X			X	X
Carrousel			X	X		X	X			
Wave Swinger			X	X		X	X			
Tidal Force	X	X			X				X	X
Comet	X			X		X			X	X
sooperdooperLooper	X			X		X		X	X	X
Trailblazer	X		X	X		X		X	X	X
Sidewinder	X		X	X				X	X	X
Wildcat	X	X			X					
Wild Mouse	X		X	X		X			X	X
The Claw			X	X		X			X	X
Storm Runner	X	X							X	X
Fahrenheit	X	X							X	X

Video Analysis Guidelines

Digital cameras have become a less expensive but powerful tool for the analysis of motion that is now available to high school Physics students. Three video analysis software packages available are: Videopoint from PASCO[1], Logger Pro from Vernier[2] Software & Technology, and Tracker from Open Source Physics[3]. Each of these allows the motion of an object to be followed frame by frame in a video permitting motion that occurs too quickly or is more complex than is easy to analyze using traditional means.

A digital video that can be imported into a computer is what is needed. Many cell phones can take short video segments. Most digital cameras can also record video. Many students have these devices and could record a video to be analyzed after returning to school. Many schools also have digital video cameras that are available for student use as well and could be a valuable part of your *Hersheypark* experience.

There are some general guidelines that should be followed so that the video can give you the best and most valuable data to analyze. Practicing in advance of the trip would be useful.

1. The camera should be stationary. A tripod would be nice since it is very difficult to hold a camera still as you are recording the video. Or at least brace your arms so that the camera is as still as possible. If you pan the camera to follow an object you lose the stationary reference frame needed to judge motion.

2. The camera line of sight should be perpendicular to the plane in which the motion occurs. This would allow your data to be better in that the object you are recording is the same distance from the camera for the entire video.

3. An object with known length must be in the video. This way, the video can be scaled so that your measurements are in real units – not just relative to pixels on the video. Often this is a meter stick. It could also be a person that you know or a part of the ride that you know its length from the *Hersheypark* ride specifications.

4. Most of the motion that you are interested in measuring takes place in a few seconds. It is convenient if your video is just long enough to see your motion. This is particularly important if the memory in your device is limited. Practice to make sure that the motion in which you are interested is part of your video. There may be a delay between when you press record and when the camera actually records. Be careful that you don't miss the start of the motion in which you are interested. If the time that you can record video is not limited, take several videos so that you have sufficient data to analyze.

[1] PASCO
10101 Foothills Blvd
Roseville, CA 95747
800-772-8700
www.pasco.com

[2] Vernier Software & Technology
13979 SW Millikan Way
Beaverton, OR 97005
888-837-6437
www.vernier.com

[3] Open Source Physics
www.opensourcephysics.org

STEM Focus Questions

Science:

1. As a general rule, a roller coaster reaches its maximum speed at the bottom of the first hill. Using the information about the specifications of the Park's rides, devise a method for calculating the speed of a roller coaster at the bottom of the first hill and complete the calculation for one of the roller coasters at the Park.

2. Of all of the rides at the Park, which ride produces the greatest gravitational potential energy in a passenger on that ride? Explain how you would calculate the energy of this ride.

Technology:

1. What technologies are used to control the potential and kinetic energy of the roller coaster cars as it moves from the station, through the ride, and back to the station?

2. Some of the roller coasters in the Park are constructed primarily out of wood while others are constructed primarily out of steel. How has the use of these two different technologies influenced the designs of the classic wooden roller coaster and the modern steel roller coaster?

Engineering:

1. Look at several different roller coasters in the Park and find the ones that have vertical loops. Where in these rides are the loops located (towards the beginning, middle, or end)? Why are they placed there? Are there any roller coasters that are different from the rest in terms of the placement of the vertical loop?

2. The track for a roller coaster is often built with banked turns at the bottom of hills. Why do the roller coaster engineers place these bank turns at the bottom of the hills and why are these turns banked?

Mathematics:

1. Every ride at the amusement park has a ride capacity. The ride capacity is the number of people who can ride each hour. Devise and explain a method for calculating the ride capacity for a ride at the Park and then complete that calculation. What are the characteristics of rides with a low ride capacity? What are the characteristics of a ride with a high ride capacity?

2. The amount of time that you wait in a line for a ride can be used to determine how many people were in front of you in the line when you joined it. Devise and explain a method for determining how many people were in front of you in line.

Open-ended Physics Day Questions

Note: These questions are designed to engage students in some qualitative and quantitative analysis of the application of physics concepts at an amusement park. Since each question requires them to essentially design a methodology for developing a solution to the question, students may approach any particular question differently. As a result, there may be several different solutions to the same question and there may be more than one right answer.

What if?

The log flume is a ride that sends riders down a long slope into a pond, producing a rather large wave. Does the size of the wave depend on the number of people in the car? What happens to the size of the wave if someone large is in the front of the flume? What if someone large is in the back of the flume? What if you wanted to ride the flume and not get wet, where would you sit?

Why do they do that?

Look at several different roller coasters in the Park and find the ones that have vertical loops. Where in these rides are the loops located (towards the beginning, middle, or end)? Why are they placed there? Are there any roller coasters that are different from the rest in terms of the placement of the vertical loop?

When a roller coaster enters a turn, it follows a track that is banked. Why do they bank turns for roller coasters? You may notice that some turns are banked at larger angles than other turns. Why do those turns require a larger angle?

How much is that?

As a general rule, a roller coaster reaches its maximum speed at the bottom of the first hill. Using the information about the specifications of the Park's rides, devise a method for calculating the speed of a roller coaster at the bottom of the first hill and complete the calculation for one of the roller coasters at the Park.

Compare all of the rides at *Hersheypark*. Which ride produces the greatest gravitational potential energy in a passenger on that ride? Explain how you would calculate the energy of this ride.

Every ride at the amusement park has a ride capacity. The ride capacity is the number of people who can ride each hour. Devise and explain a method for calculating the ride capacity for a ride at the Park and then complete that calculation. What are the characteristics of rides with a low ride capacity? What are the characteristics of a ride with a high ride capacity?

Where in the Park would you be moving with the greatest velocity? Support your answer with data. Where in the Park would you have the greatest acceleration? Support your answer data.

The Conservation of Energy

In this activity, you need to identify *three* different rides at *Hersheypark* (selecting one ride from each category listed below; two rides from the same category are not permitted) and describe the similarities in how each ride demonstrates the key concepts of the conservation of energy. Where appropriate, incorporate calculations with your explanation.

Conservation of energy key concepts:

- Potential energy
- Kinetic energy
- Thermal energy
- Work
- Energy transformation

Ride Categories:

- Roller coasters
- Water rides
- Free-fall rides
- Vertical circle rides
- Horizontal circle rides

Your analysis can include data from:

- Ride technical specifications located at the back of this Physics Guide
- Stop watches
- Video of the rides
- Sensor data from passengers who rode the rides

Your analysis should address the following points:

- How the rides provide passengers with potential energy
- How the passengers' potential energy is transformed into kinetic energy
- How some of the passengers' potential and kinetic energy is transformed into thermal energy
- How work is done on the passengers to give them potential energy or change kinetic energy
- How friction works to transform kinetic energy into thermal energy

Note: In this type of assignment, students may start this activity as a pre-trip pre-lab, spend a majority of their time at *Hersheypark* collecting data to answer the questions, and finish their write-up back at the school. The format of their write-up can take any form - lab report, class presentation, podcast, movie, wikispace website, etc.

The Pirate

As you can tell, the *Hersheypark* Pirate is a very large pendulum. In an ideal situation, the potential energy, E_P, at the top of the swing should equal the kinetic energy, E_K, at the bottom of the swing. However, this is NOT an ideal situation. (Why?)

Question 1: How does the E_P at the top of the ride compare to the E_K at the bottom of the ride?

Prediction 1: The E_K at the bottom of the ride will be:

(Choose one)
(a) Equal to the E_P at the top
(b) About 70% of the E_P at the top
(c) About 50% of the E_P at the top
(d) About 30% of the E_P at the top

Try It: We can answer the question in the following manner:

I) Find the E_P at the top using the height at the center of the boat and the mass of the boat. (See Engineering Specifications on the next page)

$E_P = m \bullet g \bullet \Delta h$ = _____________ Joules

II) We can find the E_K in two different ways (please do **both** ways).

(A) From the ground: Find the speed of the boat at the bottom by timing how long it takes for the complete length of the boat (from tip to stern) to pass the lowest point of the swing. Calculate the speed. Then calculate the E_K.

t = _____ s v = length/time = ______ m/s $E_K = .5\ m \bullet v^2$ = __________ Joules

(B) From the ride: Use the vertical accelerometer to measure the maximum acceleration (in g's) at the bottom of the ride.

Maximum acceleration = ________ g's • 9.8 m/s2 = ___________ m/s^2

We can use the centripetal acceleration equation to find the speed, v, and then calculate the E_K at the bottom of the ride. The <u>centripetal acceleration</u>, a_c, caused by the motion of the boat will be 1 g <u>less</u> than the maximum acceleration found above (since gravity causes a 1 g reading on the accelerometer when the boat is stopped at the bottom).

a_c = _____ g's • 9.8 m/s2 = __________ m/s^2

$v = \sqrt{(ac \bullet r)}$ = ______ m/s $E_K = .5\ m \bullet v^2$ = _________ Joules

Observations/Conclusions:

(1) How do the E_K from parts IIA and IIB compare?

(2) How does the E_K at the bottom compare to the E_P at the top? What percentage did you calculate (100 % • E_K/E_P)?

(3) Which prediction was the closest? Was yours?

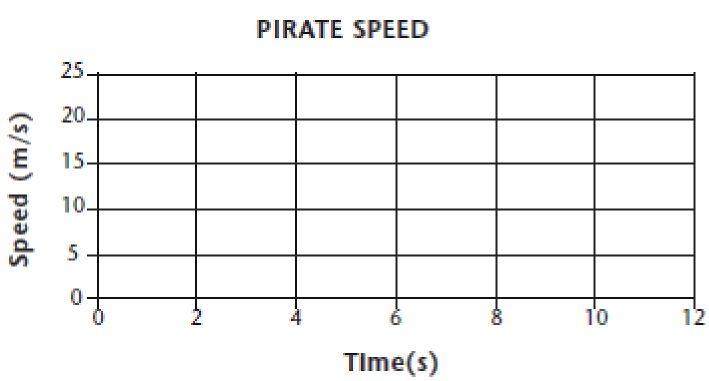
Question 2: How many g's of acceleration will you feel at the highest points on the ride?

Prediction 2: Choose one - Closer to (a) 0 g's (b) .5 g's (c) 1 g (d) 2 g's

Try It: Use the vertical accelerometer to find out!

Observations/Conclusions: Acceleration at the highest point on the ride is _____ g's.

Graph It: Draw a Speed-Time graph representing the motion of the Pirate (consider the center post) during at least one complete cycle of the ride.



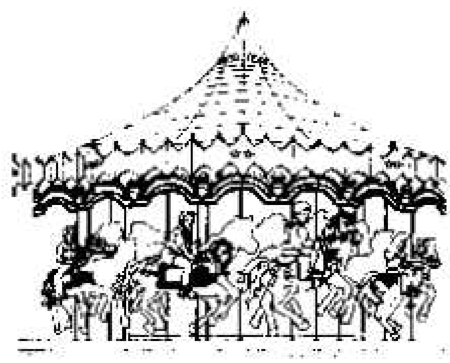
Engineering Specifications:

Mass of Boat:	9500 kilograms	g = 9.8 m/s2
Maximum height of center of Boat:	13.6 meters	
Length of Boat:	13.1 meters	
Radius of Pendulum:	13.6 meters	

The Carrousel

A mild ride for winding down or just taking it easy after some challenging rides.

Questions:
Where does a rider experience the greatest centripetal acceleration on this ride: on the horses closest to the center or the ones farthest out? What are the speeds and accelerations of a rider at each position?



Predictions:

(1) A rider experiences the greatest acceleration on the (inner ring, outer ring). [Circle one.]

(2) I estimate the acceleration of a rider on the inner ring to be __________ g's and the acceleration of a rider on the outer ring to be __________ g's.

Try It: You can answer the Questions in two ways. Please use both methods.

From the ground: Using the data in the Engineering Specifications on the next page, calculate the speeds and accelerations of a rider for both the inner ring and the outer ring of horses. To do this, first measure the period (time it takes for one revolution), T. Then use the following equations to calculate v and a_c for each ring.

T = __________ s

Inner Ring:

$v = 2 \bullet \pi \bullet r / T$ = ___________ m/s $ac = v^2 / r$ = ____________ m/s^2

Outer Ring:

$v = 2 \bullet \pi \bullet r / T$ = ___________ m/s $ac = v^2 / r$ = ____________ m/s^2

On the ride: Use the horizontal accelerometer to measure the centripetal acceleration at each position. Be sure the accelerometer is horizontal - you can hold it against the post you hold on to - and aim it toward the center of the circle. Remember: The tangent of the angle gives the number of g's of acceleration.

a_c for the inner ring = _____________ g's • 9.8 m/s^2 = ___________ m/s^2

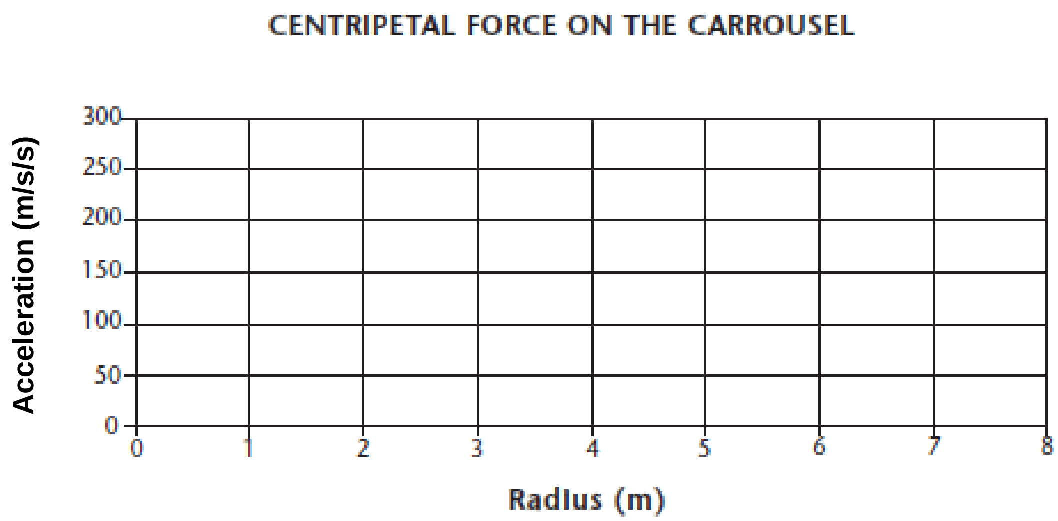
a_c for the outer ring = _____________ g's • 9.8 m/s^2 = ___________ m/s^2

Observations/Conclusions:

Where did your measurements show the greatest acceleration?

Graph It:

As you ride further out from the center of the CARROUSEL, the centripetal acceleration, a_c, changes. Sketch the graph that shows how the centripetal acceleration varies with the distance from the center of the ride, r.



Engineering Specifications:

Inner Radius = 5.3 meters $\pi = 3.14$
Outer Radius = 7.2 meters

The Wave Swinger

Questions:

(1) What is the speed of a rider on the Wave Swinger?

(2) What amount of centripetal acceleration does the rider experience?

Predictions/Estimations: Choose one ring of swings (inner, middle, or outer) on which to base your predictions.

(1) Watch the ride then estimate the speed of a rider in that ring.

Speed of rider = _____________ m/s

(2) Estimate the centripetal acceleration of a rider (in g's).

Centripetal Acceleration = _______________ m/s2

Try It:

(I) From the ground: Find the average time for one rotation of the swings (when at <u>full speed</u>). Then, using the data in the Engineering Specifications at the bottom of the next page, calculate the circumference, the speed of a rider, and the rider's acceleration.

Time for 1 revolution = ______ s   Circumference = 2 • π • r = ___________ m

Speed of a rider = v = circumference/time for 1 revolution = _____________ m/s

Now, calculate the centripetal acceleration of the rider:

ac = v^2 / r = ______________ m/s^2

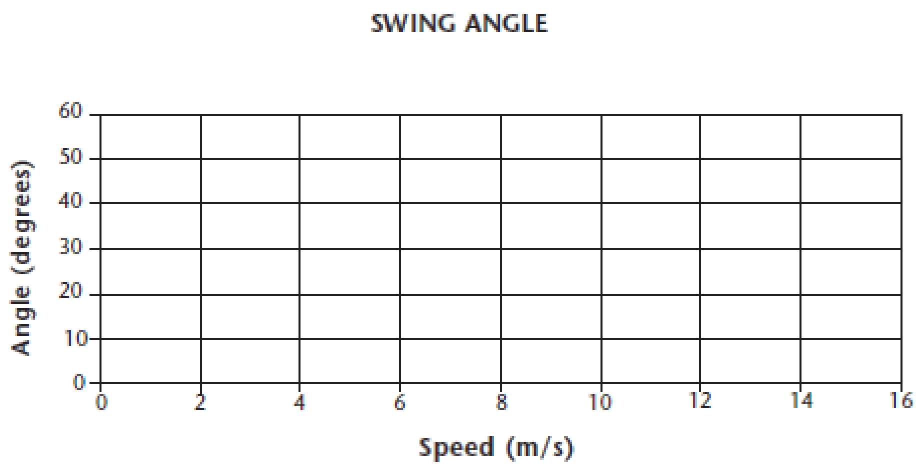
(II) On the ride: When the ride is at full speed, use the <u>horizontal</u> accelerometer to measure the centripetal acceleration. Hold the top of the accelerometer parallel to the chains holding the swings. Record the angle measurement below. [To find the acceleration, the angle □□ equals 90°- your angle measurement.]

Angle measurement = __________° Acceleration = tan Θ = missing?_g's

Observations/Conclusions:

Were your predictions correct? Is the acceleration a relatively large or small one? How do you decide?

Graph It: Draw a rough sketch of the graph that represents how the angle of the swing (from vertical) varies with respect to the speed of the swing around the circle.



Engineering Specifications:
Inner radius = 6.9 meters
Middle radius = 8.1 meters
Outer radius = 9.3 meters

TIDAL FORCE

Have fun riding, but, this is one ride where all measurements are taken from the ground! Please be sure the accelerometers don't get wet on this ride. Let someone else hold your equipment while you ride.

Question: What is the acceleration of the boat as it is brought to a stop by the water and what is the stopping force applied by the water?

Prediction: Take a guess at how many g's of acceleration the riders undergo as the boat is brought to a stop.

Acceleration at the bottom = ____________ g's

Try It: Use the following calculations.

(I) For simplicity, let's assume that the kinetic energy, E_K, of the boat at the bottom of the run is equal to the potential energy, E_P, of the boat at the top of the hill. Calculate how fast the boat is moving at the bottom of the hill.

E_K at the bottom = E_P at the top = $m \bullet g \bullet \Delta h$ = _____________________ J

v (at the bottom) = $\sqrt{(2 \bullet E_K / \text{mass})}$ = _________________ m/s

(II) Now, we need to time how long it takes for the water to bring the boat to a slow constant velocity. Use the stopwatch to see how long it is from the time the boat just enters the water until the time the boat stops making its big splash.

time = ____________ s

(III) We'll estimate the speed of the boat when it stops splashing to be about 3 m/s. The acceleration of the boat (and its passengers) will be:

$$a = \frac{3\text{ m/s} - v\text{ (at the bottom of the hill)}}{\text{time to stop}}$$ = _________ m/s2 [÷9.8 m/s^2 = ______ g's]

(IV) Using the mass of the full boat given in the specs and the acceleration (in m/s^2) from #III above, the stopping force of the water will be:

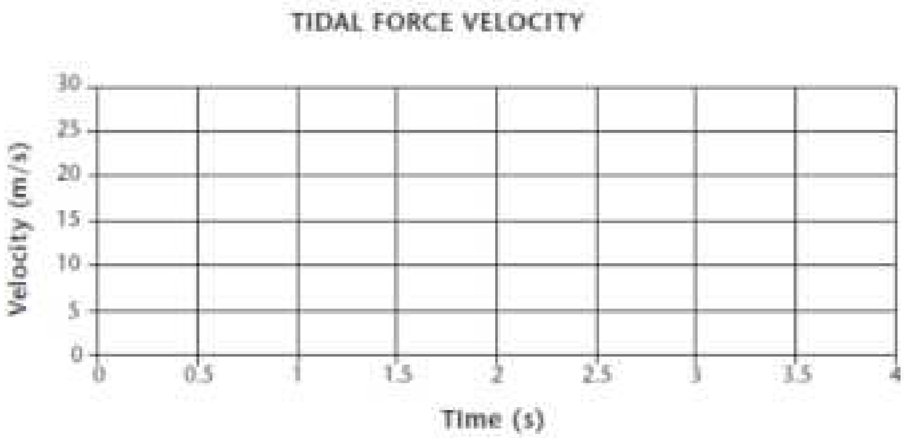
$\Sigma F = m \bullet a$ = _____________________

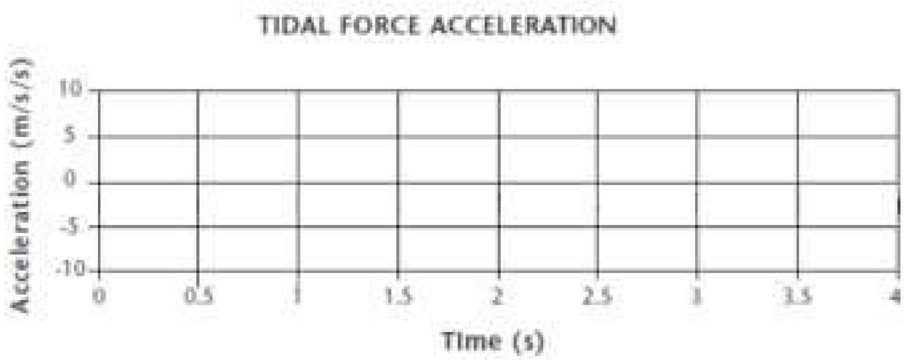
Observations/Conclusions:

How many g's of acceleration does the boat undergo? How does the stopping force compare to your weight in N (your weight in pounds x 4.45)?

Graph It:

Draw the Velocity-Time graph and the Acceleration-Time graph that represents the motion of the boat from the time the splash starts till the time the splash ends. Assume that 'forward' is the (+) direction and the acceleration is uniform.





Engineering Specifications:

Mass of the full boat = 4100 kg

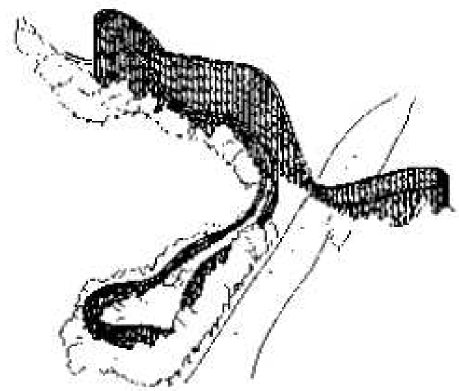
$g = 9.8\ m/s^2$

Height of the hill = 30 meters

Comet

We know that, under ideal circumstances, the potential plus kinetic energies of a coaster at the top of a hill (using the bottom of the hill as the reference level) will equal the kinetic energy of the coaster at the bottom of that hill. But, again, this is NOT an ideal situation!

Question 1: How does the kinetic energy, E_K, of the Comet at the bottom of the first hill compare to its total energy, E_T, at the top of the first hill? (The kinetic energy at the top of the hill is not zero, so it must be considered!)



Prediction 1: The E_K at the bottom of the ride will be:

(Choose one)

(a) Equal to the E_T at the top

(b) About 90% of the E_T at the top

(c) About 60% of the E_T at the top

(d) About 40% of the E_T at the top

Try It: We can answer the question as follows.

(I) Total Energy at the top:

(a) First, find the E_P of the coaster at the top of the first hill using the data given in the Engineering Specifications. We're choosing the bottom of the hill to be the reference level where $E_P = 0$ Joules.

$E_P = m \bullet g \bullet \Delta h =$ ___________________ Joules

(b) Then, find the kinetic energy, E_K, at the top. Determine the speed at the top of the hill by timing how long it takes for the complete length of the coaster train to pass the highest point of the hill then calculate the kinetic energy.

t = ______ s v = length of the train / time = _____________ m/s

$E_K = .5 \bullet m \bullet v^2 =$ _________________ Joules

(c) The total energy at the top of the hill, E_T, is the sum of the potential and kinetic energies:

$E_T = E_P + E_K =$ _____________________ Joules

(II) Kinetic energy at the bottom:

Determine the speed at the bottom of the hill by timing how long it takes for the complete length of the coaster train to pass the lowest point at the bottom of the hill then calculate the kinetic energy.

t = ______ s

v = train length / time = __________ m/s $E_K = .5 \bullet m \bullet v^2 =$ ______Joules

Observations/Conclusions: (1) Calculate the percentage (100% • $_K/E_T$)? How does the E_K at the bottom compare to the E_T at the top?

(2) Which prediction was the closest? Was yours?

Question 2: How does the vertical acceleration at the bottom of the second hill compare to the vertical acceleration at the bottom of the first hill?

Prediction 2: The acceleration at the bottom of the second hill will be:

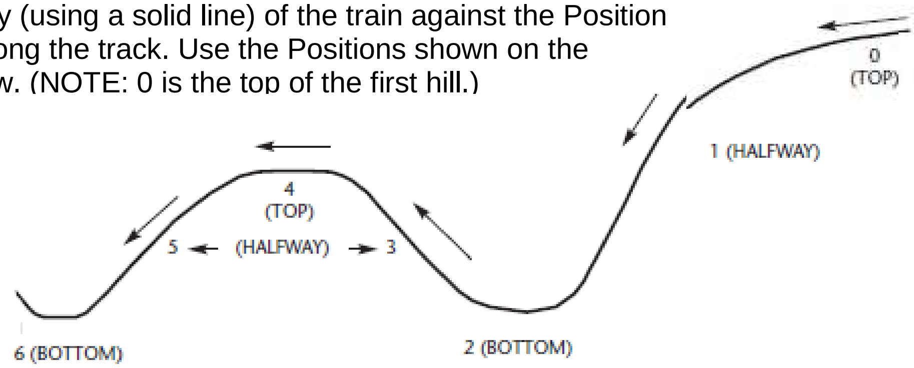
(a) About the same as the acceleration at the bottom of the first hill
(b) Much less than the acceleration at the bottom of the first hill
(c) Much greater than the acceleration at the bottom of the first hill
(d) A little less than the acceleration at the bottom of the first hill
(e) A little more than the acceleration at the bottom of the first hill

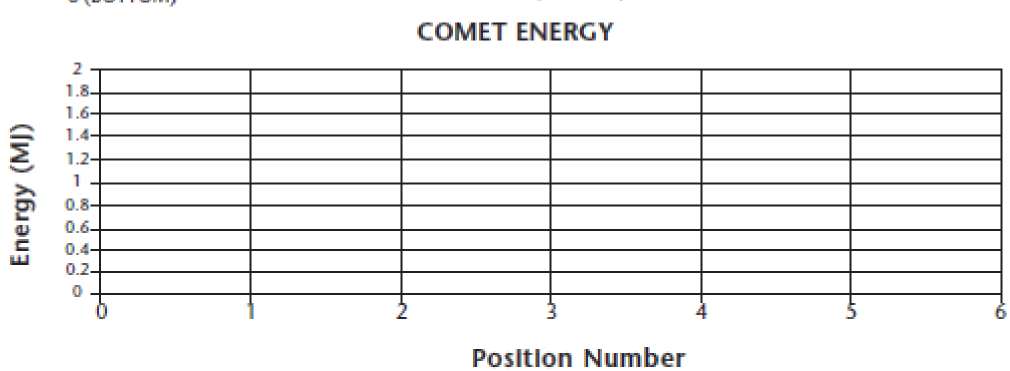
Try It: Use the vertical accelerometer to find out!

Acceleration at bottom of first hill = _____________ g's
Acceleration at bottom of second hill = _____________ g's

Observations/Conclusions: Which hill had the greater acceleration at the bottom? Why is this true?

Graph It: Sketch a rough graph of the Potential Energy (using a dotted line) <u>and</u> the Kinetic Energy (using a solid line) of the train against the Position of the train along the track. Use the Positions shown on the diagram below. (NOTE: 0 is the top of the first hill.)



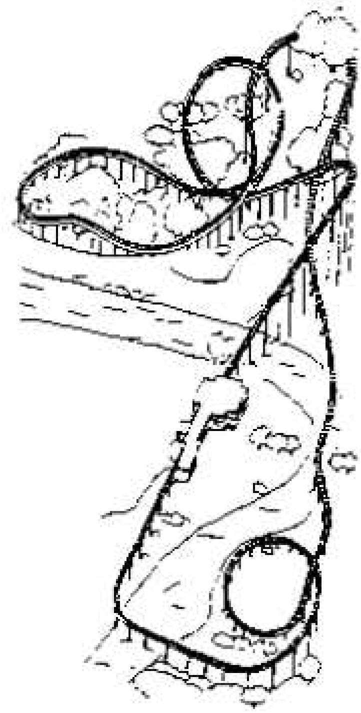


Engineering Specifications:

Mass of train (full) = 4300 kg
Length of train = 12.2 meters
Vertical drop for the first hill = 24.4 meters
$g = 9.8\ m/s^2$

sooperdooperLooper

We know that, under ideal circumstances, the potential plus kinetic energies of a coaster at the top of a hill (using the bottom of the hill as the reference level) will equal the kinetic energy of the coaster at the bottom of that hill. But, again, this is NOT an ideal situation!



Question 1: How does the kinetic energy, E_K, of the Looper at the bottom of the first hill compare to its total energy, E_T, at the top of the first hill? (The kinetic energy at the top of the hill is not zero, so it must be considered!)

Prediction 1: The E_K at the bottom of the ride will be:
(Choose one)

(a) Equal to the E_T at the top
(b) About 90% of the E_T at the top
(c) About 60% of the E_T at the top
(d) About 40% of the E_T at the top

Try It: We can answer the question as follows.

(I) Total Energy at the top:

(a) First, find the E_P of the coaster at the top of the first hill using the data given in the Engineering Specifications. We're choosing the bottom of the hill to be the reference level where E_P = 0 Joules.

$E_P = m \bullet g \bullet \Delta h$ = ____________________ Joules

(b) Then, find the kinetic energy, E_K, at the top. Determine the speed at the top of the hill by timing how long it takes for the complete length of the coaster train to pass the highest point of the hill then calculate the kinetic energy.

t = ______ s v = length of the train / time = ______________ m/s

$E_K = .5 \bullet m \bullet v^2$ = __________________ Joules

(c) The total energy at the top of the hill, ET, is the sum of the potential and kinetic energies:

$E_T = E_P + E_K$ = ______________________ Joules

(II) Kinetic energy at the bottom:

Determine the speed at the bottom of the hill by timing how long it takes for the complete length of the coaster train to pass the lowest point at the bottom of the hill then calculate the kinetic energy.

t = ______ s v = length of the train / time = ______________ m/s

$E_K = .5 \bullet m \bullet v^2$ = __________________ Joules

Observations/Conclusions: (1) Calculate the percentage (100 % • E_K/E_T)? How does the E_K at the bottom compare to the E_T at the top?

(2) Which prediction was the closest? Was yours?

Question 2: How many g's of acceleration will you feel

(a) at the bottom of the loop?

(b) at the top of the loop?

Prediction 2: What do you think?

(a) Acceleration at the bottom will be closer to (.5, 1, 2, 3) g's. (Choose one)

(b) Acceleration at the top will be closer to (.5, 1, 2, 3) g's. (Choose one)

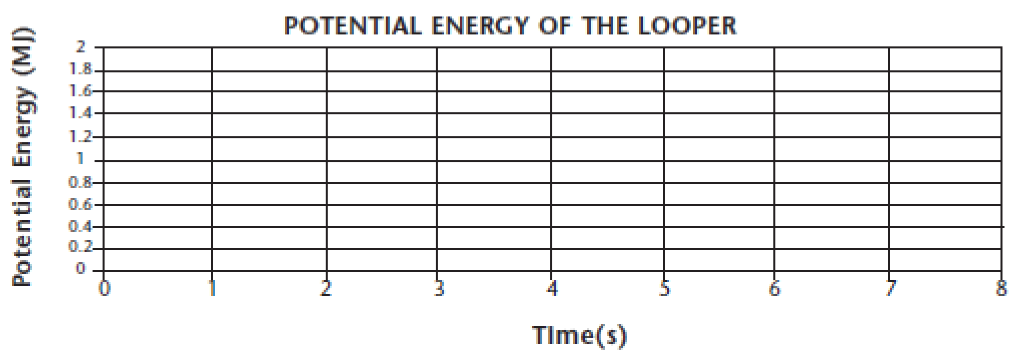
Try It: Use the vertical accelerometer to answer the question. Record your readings below. (HINT: Have your partner yell "NOW" when you are at the bottom and again when you are at the top - it's hard to tell when reading the accelerometer!)

(a) Accelerometer reading at the bottom = ___________ g's

(b) Accelerometer reading at the top = ____________ g's

Observations/Conclusions: Were the readings what you expected? Why or why not?

Graph It: Graph the Potential Energy of the coaster against Time from the top of the first hill through the loop to the end of the loop.



Engineering Specifications:

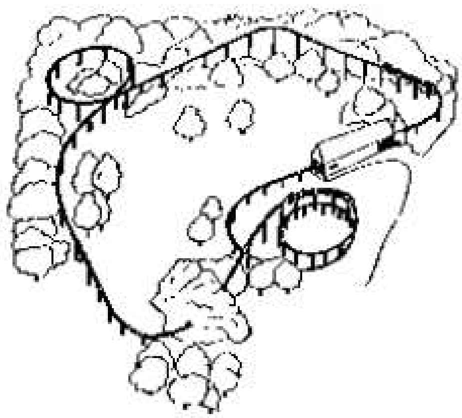
Mass of train (full) = 4300 kg

Length of train = 13 meters

Height of first hill = 25 meters $g = 9.8\ m/s^2$

The Trailblazer

Question: What is the radius of curvature of the final horizontal loop of this coaster ride?



Prediction: Take a look at the final loop and estimate its radius.

Radius = _____________ meters

Try It: To answer this question you'll need to take measurements both on and off the ride. We're going to use the centripetal acceleration equation to find the radius.

(I) From the ground, determine the speed of the coaster as it moves around the final horizontal loop. To do this, pick a point on the loop and measure how long it takes for the full length of the coaster to pass that point. Then, calculate the speed.

t = _______ s

v = length of the train / time = _____________ m/s

(II) Next, use the vertical accelerometer, holding it perpendicular to the safety bar with the bottom of the tube pointing to the floor, to measure the centripetal acceleration, a_c, of the coaster while you are in the final loop.

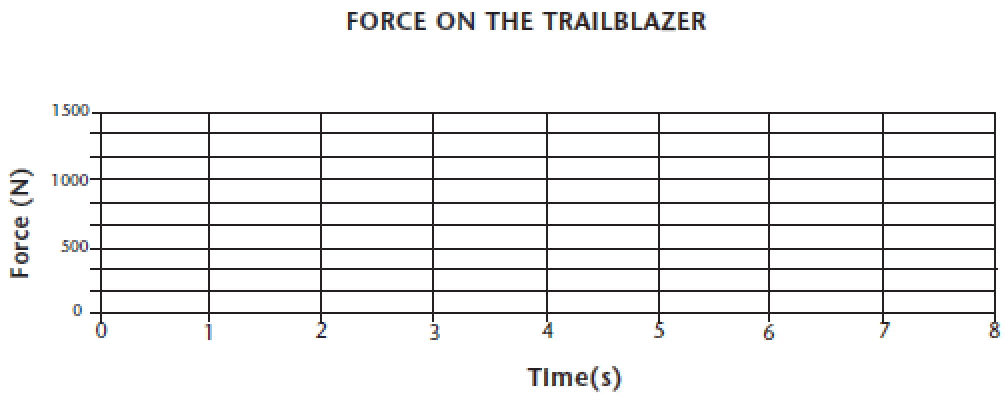
a_c = ___________ g's $\cdot$ 9.8 m/s^2 = ____________ m/s^2

(III) The radius of the loop, r, can then be found by

$r = v^2 / a_c$ = ______________ meters

Observations/Conclusions: How close was your prediction to the measured value? Which one do you think is right?

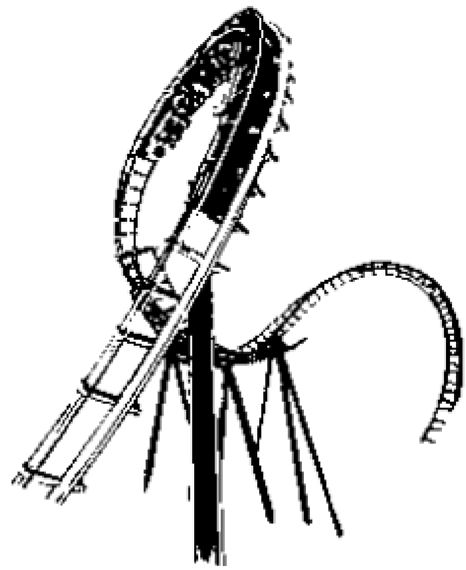
Graph It: Sketch the graph of the Force on your seat against the Time you are in the horizontal loop at the end of the ride.



Engineering Specifications:
Length of the coaster = 14.6 meters

The Sidewinder

We know that, under ideal circumstances, the potential plus kinetic energies of a coaster at the top of a hill (using the bottom of the hill as the reference level) will equal the kinetic energy of the coaster at the bottom of that hill. But, again, this is NOT an ideal situation!



Question 1: How does the kinetic energy, E_K, of the Sidewinder at the bottom of the starting hill compare to its potential energy, E_P, at the top of the starting hill? (Since the Sidewinder begins its run at rest, it has only potential energy at the top.)

Prediction 1: The E_K at the bottom of the ride will be:
(Choose one)
(a) Equal to the E_P at the top
(b) About 70% of the E_P at the top
(c) About 50% of the E_P at the top
(d) About 30% of the E_P at the top

Try It: We can answer the question as follows.

(I) Find the E_P of the coaster at the top of the starting hill using the data given in the Engineering Specifications. We're choosing the bottom of the hill to be the reference level where EP = 0 J.

$E_P = m \bullet g \bullet \Delta h =$ ___________________ Joules

(II) First, determine the speed at the bottom of the hill by timing how long it takes for the complete length of the coaster train to pass a point at the bottom of the hill (just where the track begins to level off) then calculate the kinetic energy.

t = _______ s v = length of the train / time = _____________ m/s
$E_K = .5 \bullet m \bullet v^2 =$ _________________ Joules

Observations/Conclusions: (1) Calculate the percentage. ($100\ \% \bullet E_K/E_P$)? How does the E_K at the bottom compare to the E_P at the top?

(2) Which prediction was the closest? Was yours?

Question 2: The critical speed for an object moving in a vertical loop is the slowest speed the object can be moving at the top of the loop and not fall out. At this speed, the rider would feel weightless (no pressure on your seat). When in the loop of the Sidewinder, is the coaster moving at the critical speed or higher? If higher, how many g's of acceleration do you think the rider is experiencing?

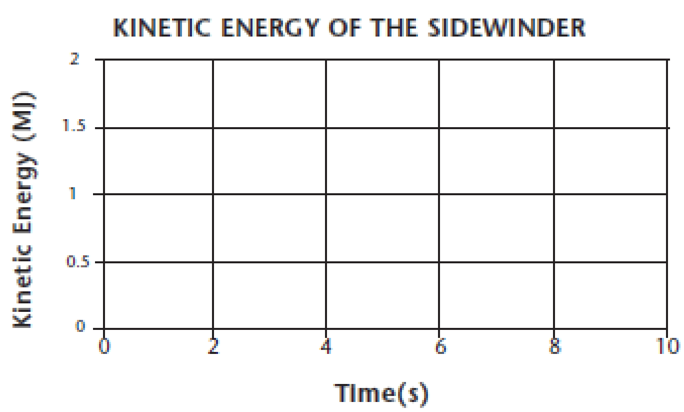
Prediction 2: The coaster is moving (at, faster than) the critical speed. (Choose one.)

If 'faster than' how many g's do you think you'll experience? _____________ g's

Try It: The easiest way to check this out is to measure it using the vertical accelerometer. (HINT: Have your partner yell 'NOW' when you are at the top of the ride - it's hard to tell when reading the accelerometer!)

Observation/Conclusion: What did you find out?

Graph It: Sketch a graph below that shows the Kinetic Energy of the coaster as it travels backwards from the high point of the second lift through the loop to the end of the loop.



Engineering Specifications:
Height of the second hill: 35.5 meters
Mass of the full train: 8260 kg
Length of train: 18.3 meters $g = 9.8\ m/s^2$

The Wildcat

Named after the first roller coaster at *Hersheypark*, this wooden coaster twists its way through or over itself 20 times during the ride.

Question 1: What is the average speed of the Wildcat from the time the coaster starts down the first hill until the time when the brakes are first applied at the end of the ride?

Prediction 1: NOTE - MAKE THIS PREDICTION AFTER YOU HAVE RIDDEN THE COASTER! THEN TAKE YOUR MEASUREMENTS FROM THE GROUND JUST TO SEE HOW WELL YOUR PERCEPTIONS COMPARE TO THE ACTUAL SPEED.

The average speed of the ride seems to be about:

(a) 10 miles/hour (almost 5 m/s)
(b) 20 miles/hour (about 9 m/s)
(c) 40 miles/hour (about 18 m/s)
(d) 60 miles/hour (about 27 m/s)
(e) 80 miles/hour (about 36 m/s)

Try It: : From the ground, use a stopwatch to measure the time of the ride **from the time the coaster starts down the first hill** until the **time when the brakes are first applied at the end of the ride.** Find the average speed of the ride using the equation below. (See the Engineering Specifications.)

Time = ___________________________

Average Speed = Distance traveled / Time = ______________ = ___________ m/s

Observations/Conclusions: How did your prediction compare to the actual measurement of the ride's average speed? If there was a difference between the two, explain why you think this might happen.

Question 2: While standing in line, you'll notice that the coaster stops at the end of the ride by applying the brakes a number of times. What is the maximum stopping acceleration (in g's) that the coaster undergoes during braking?

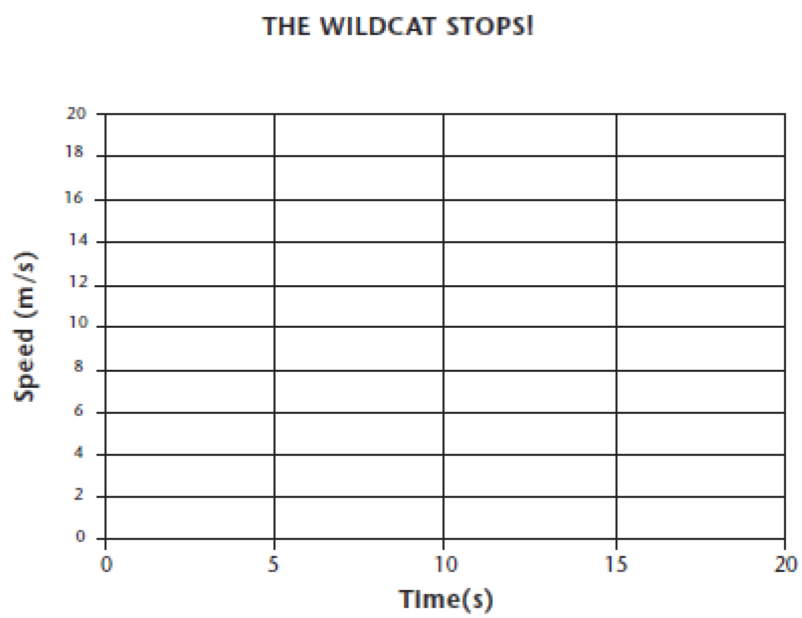
Prediction 2: You can make your estimate by comparing what you see while standing in line to what you've experienced in a car that comes to a quick normal stop which is about 0.7 (g's). The maximum stopping acceleration for the coaster is about ______ g's.

Try It: Before reaching the end of the ride, set the horizontal accelerometer **<u>firmly and horizontally on the lap bar with the 80° facing forward.</u>** As the car goes through the braking process, note the maximum angle to which the beads rise. The tangent of this angle is the acceleration (in g's).

The maximum stopping acceleration on the ride is _______________ g's.

Observations/Conclusions: How did your prediction compare to the actual meter reading? Explain any differences.

Graph It: Sketch a Speed-Time graph that shows how the speed of the coaster varies during the braking process.



Engineering Specification:
Ride length from top of 1st hill to where brakes first applied = 775 meters

GREAT BEAR

The constellation, Ursa Major (the Great Bear), can be identified in the night sky by the seven bright stars which most of us know as the Big Dipper. *Great Bear* the ride, is also characterized by seven major features along with an awesome growl that adds to the excitement of the ride. Two of these features, the 360° rolls, will be focus of this activity.

As you stand on the ground by the Wave Swinger, you can observe the first roll that *Great Bear* undergoes. Walk over by the *sooperdooperLooper* to see the second roll the riders experience on *Great Bear*. In both cases, the riders' bodies move in a circular path around the track as they move forward. The seat of the ride provides a centripetal force to keep the rider moving in the circular path.

Questions: 1. What is the maximum amount of centripetal acceleration the rider experiences within the rolls?
2. Will the centripetal acceleration in the first roll be greater than, less than, or equal to the acceleration in the second roll?

Prediction: 1. The maximum amount of centripetal acceleration the rider feels will be: (choose one) 1 g 2 g's 3 g's 4 g's 2. The centripetal acceleration in the first roll will be (choose one), Greater Than Less Than Equal To the acceleration in the second roll.

Try It: We'll answer both questions at the same time, first by doing calculations from the ground, and then, by using the accelerometer while on the ride.

From the ground: Stand in a position where you can observe the first roll of *Great Bear*. Measure the time it takes for the front seats to make the complete roll (from the time it is hanging straight down as it starts the roll until it is hanging straight down again at the end of the roll). Take this reading at least five times and record the average of your measurements below. Follow the same procedure for the second roll and record your results below.

Time interval for the first roll:_________s Time interval for the second roll:_________s
Next we'll calculate the tangential speed, v, and centripetal acceleration, a_c, for the two rolls.

NOTE: Use the Radius of Roll 1 (2.1 meters)

First Roll: $v = 2 \bullet \pi r_1/T =$ ____________ m/s

$a_c = v^2/r_1 =$ ____________ $m/s^2 \div 9.8\ m/s^2 =$ ____________ g's

NOTE: Use the Radius of Roll 2 (2.1 meters)

Second Roll: $v = 2 \bullet \pi r_2/T =$ ____________ m/s

$a_c = v2/r_2 =$ ____________ $m/s^2 \div 9.8\ m/s^2 =$ ____________ g's

On the Ride: Use the vertical accelerometer to measure the maximum acceleration you feel while in the two rolls. Remember to place the rubber band restraint around your wrist to keep the accelerometer from falling - it could be very dangerous to others on the ride! Have your partner yell "NOW!" just before you are starting each roll so you can keep your eyes on the accelerometer. You may have to do this activity more than once! Record your maximum readings for the rolls below.

Maximum Acceleration for Roll 1:____________ g's

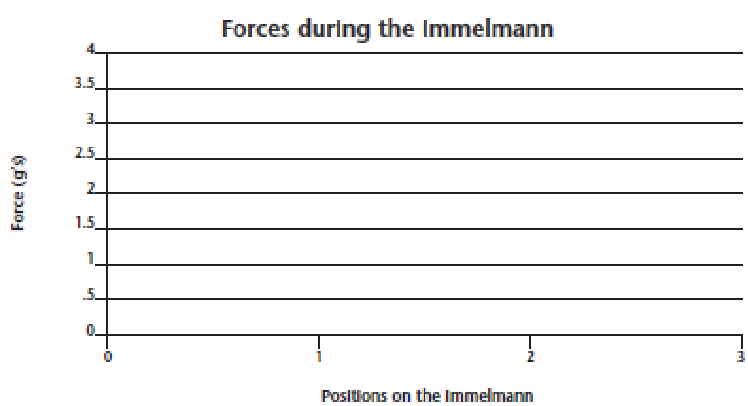
Maximum Acceleration for Roll 2:____________ g's

Observations/Conclusions:

1. How do the accelerations for the two rolls compare? Use your calculations and the accelerometer readings to back up your answers.

2. How do the calculations for Roll 1 compare to the maximum accelerometer readings for Roll 1? Should they be equal? If not, why? (HINT: Check part II B for the Pirate activity.)

Graph It: Just after going through the *Great Bear* loop, you travel around a structure called an Immelmann. Draw a rough **bar graph** that represents the vertical forces (with respect to your seat) that you feel as you move upward (Position 1 on the graph), across the top (Position 2), then downward (Position 3) in the Immelmann.



Engineering Specifications:

Radius of the first roll (Roll 1): 2.1 m

Radius of the second roll (Roll 2): 2.1 m

Wild Mouse

The Wild Mouse is a deceptively exciting ride! From the ground the car seems to be moving at a relatively slow speed - and it is, compared to the speeds of most coasters. But, the screaming of the passengers as they progress through the ride provides a clue to the thrills that you'll experience. For this activity, we'll concentrate on the series of switchbacks at the top of the ride.

NOTE: FOR COMFORT (AND SAFETY) YOU MAY WANT TO TAKE A TEST RIDE TO SEE WHAT CHALLENGES YOU'LL HAVE IN MAKING THESE MEASUREMENTS.

Question: When moving along the curves at the top of The Wild Mouse (the switchbacks), the riders feel as if they are going to fall over the edge. How many "g's" of centripetal acceleration are the riders experiencing as they make these turns?

Prediction: The riders will be feeling (0.5, 1.0, 1.5, 2.0, greater than 2.0) g's of acceleration as they whip around the switchback curves. (Choose one).

Try It: We'll determine the centripetal acceleration in two different manners.

A. On the ride: place the horizontal accelerometer on a level surface (maybe, on the lap bar?) with the **80°** mark facing toward the **right** side of the car. Before reaching the turns, note which of the three BB's is on the 0° mark when the accelerometer is level. As you go around each **left-hand** curve at the top of the ride (the switchback sections), note the maximum angle reading that the BB reaches. Record these measurements below and determine the centripetal acceleration in g's.

1st left-hand turn reading: Θ = _____________°
Centripetal Acceleration, $a_c = \tan \Theta$ = _____________ g's

2nd left-hand turn reading: Θ = _____________°
Centripetal Acceleration, $a_c = \tan \Theta$ = _____________ g's

3rd left-hand turn reading: Θ = _____________°
Centripetal Acceleration, $a_c = \tan \Theta$ = _____________ g's

B. From the ground: Determine the beginning and end of the half-circle that the car makes as it goes around a turn. Using the radius given in the Engineering Specifications below, calculate the distance traveled by the car for the half-circle.

Distance around the half-circle = π r = _________ meters note erased 2 since half circle

Use the stop watch to determine the time it takes for the car to traverse the half-circle. Take at least three trials. Record the average reading below and calculate the speed of the car for the turn. Then calculate the centripetal acceleration.

Time to travel the half-circle (t) = _______ seconds

Speed of the car (v) = Distance around the half-circle ÷ Time = _______ m/s

Centripetal Acceleration (a_c) = v^2 / r = _______ m/s_2

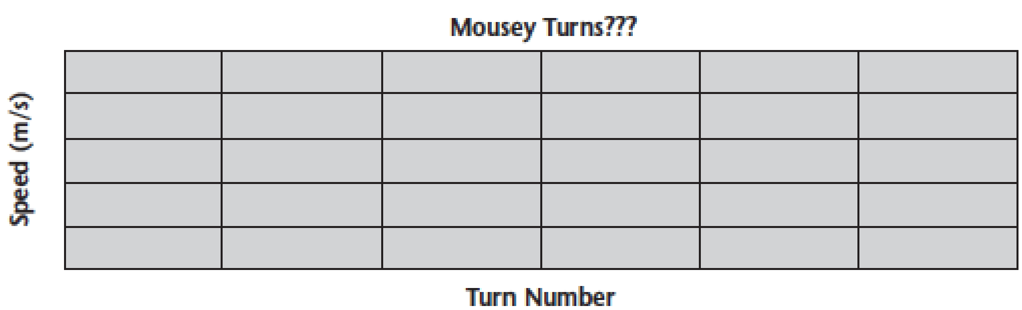
Observations/Conclusions:

(a) How do the centripetal accelerations in parts (A) and (B) compare?

(b) Do all three turns create the same accelerations?

(c) How does the numerical result compare to how you feel on the ride?

Graph It: Draw a rough graph below showing the **actual** speeds (with a solid line) for each of the turns of the switchback section AND the speeds you **think** you are going (with a dotted line).



Engineering Specifications:
Radius of turns =2.74 meters

The Claw

Combine the slowly rotating platform of the Carrousel with the pendulum motion of the Pirate ship and you have *The Claw*. The interplay of motions on this ride provides a unique combination of sensations.

Questions: (1) At what point (or points) in the ride will your seat apply the greatest "upward" force against your bottom? How many g's of acceleration will you feel when this happens?

(2) Knowing where the greatest upward force occurs, in what direction are you moving and in what direction is the centerpost of *The Claw* moving?

(3) How does the potential energy of *The Claw* at the top of the swing, compare to its kinetic energy at the bottom of the swing?

(4) What is the centripetal acceleration of *The Claw* (as a whole) when it is at the bottom of its swing? How does this compare with your accelerometer readings from Question 1?

Predictions: (1) I will feel the greatest "upward" force when the ride is (at its highest point in the swing, at its lowest point in the swing, at the halfway points) and the acceleration at this time will be closer to (.5 g's - I'll feel as if I weigh less than may normal weight; 1.0 g - I'll feel as if I weigh my normal weight; 2 g's, 3 g's - I'll feel as if I weigh 2 or 3 times my normal weight). Write your two choices on the line below.

(2) The greatest "upward" force occurs when the rotation of the ride (makes me move in the same direction as the centerpost is swinging, makes me move opposite to the direction that the centerpost is swinging). Write your choice below.

(3) The potential energy of *The Claw*, at the top of the swing is (less than, greater than, equal to) its kinetic energy at the bottom of the swing. Write your choice below.

(4) The calculated accelerations will be (>, <, =) the actual readings from the accelerometer.

Try It: (1) and (2) You'll have to answer Questions 1 and 2 while on the ride. You'll need the vertical accelerometer to take measurements and a partner. Before the ride begins, hold the accelerometer vertically (with both hands, if you can). Hold it this way for the duration of the ride. After *The Claw* has begun its swinging motion, watch the accelerometer to see when it reaches its greatest reading. You will have to let your partner know when the greatest readings occur, so that your partner can watch to see where, in the swing, that this is happening.

(1) Maximum Acceleration:______________________ g's occurs as_____________________

(2) Direction you are moving during maximum acceleration: ____________________________

(3) Determine the potential energy (E_P) at the top:

$E_P = m\,g\,h =$ __________________ J (Use the average height of the ride below)

(4) Determine the average speed of the ride at the bottom by timing how long it takes for the carrousel to cross the imaginary center line of the ride at the bottom of the swing and dividing the diameter of the carrousel by the time. (See specifications on next page.)

Average speed = Diameter / Time to pass = ___________________________ m/s

Calculate the average kinetic energy, E_K, from the average speed calculated above:

$E_K = 1/2\ m\ v^2 =$ ___________________________J

(5) Calculate the centripetal acceleration of a rider at the bottom of the swing using the average speed calculated above:

$ac - v^2/r =$ _________________ m/s^2 (“r” is the swing radius - see below.)

The accelerometer readings will be 1 g greater than the centripetal acceleration because the accelerometer will read 1 g when the ride is stopped. So how does the maximum acceleration measured in #1 compare to the calculated value above?

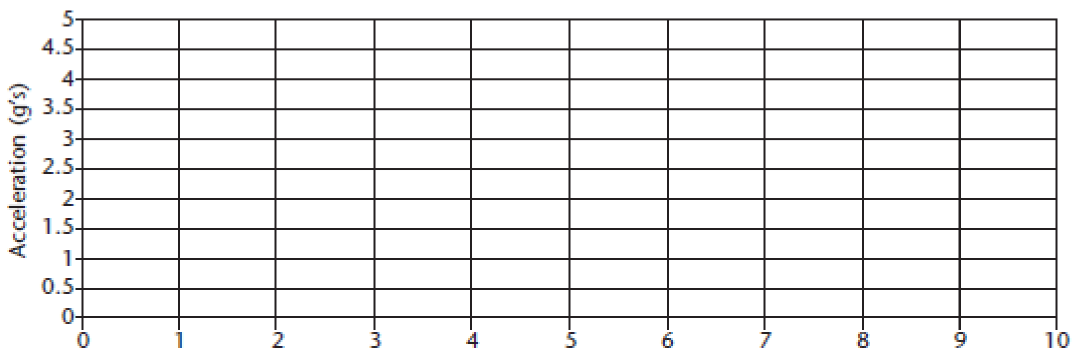
Observations/Conclusions:

(1) Why did you feel the maximum acceleration where you did? Your explanation MUST be supported by your findings in #1 and 2.

(2) Give your best guess as to why the E_P at the top of the swing and the E_K at the bottom of the ride compared as they did.

(3) Give your best guess as to why the calculated centripetal acceleration and the measured accelerometer readings compared as they did.

Graph It: Roughly sketch the accelerations that you undergo during a full period of the ride at maximum swing.



Specifications:

Mass of ride (loaded): 20,6011 kg

Diameter of Carrousel: 8.229 m

Average max. height of Carrousel: 19.507 m

Swing Radius: 11.277 m

Storm Runner

For safety reasons, no data collection devices will be allowed on this ride.

Two of the most impressive aspects of *Storm Runner* are its takeoff and the 46 meter (150 foot) vertical ride to the peak of the "top hat".

Questions:

(1) What is the initial acceleration of the ride?

(2) What is the minimum power the launching mechanism must expend? ("Minimum" because, due to friction, the motors must expend even more power!)

(3) How does the total energy of the coaster at the top of the "top hat" compare to its total energy at the end of the initial acceleration?

Predictions:

(1) The rider will feel an acceleration closest to ____________.

(a) .5 g's (b) 1.0 g's (c) 1.5 g's (d) 2.0 g's (e) 2.5 g's

(2) The minimum power expended by the launcher is ____________.

(a) 1 000 000 J (b) 2 000 000 J (c) 3 000 000 J (d) 10 000 000 J.

(3) The ETOTAL at the peak of the "top hat" should be (>, <, or =) the ETOTAL at the bottom of the "top hat". (Choose one)

(4) The calculated accelerations will be (>, <, =) the actual readings from the accelerometer.

Try It:

(1) You will have to find a place where you can watch the train's initial acceleration from rest to its maximum speed (maybe while in line?). Use a stopwatch to measure the time for this acceleration from the start to the bottom of the "top hat" (just before it starts its upward climb).

Make 5 measurements - average the best three (the most consistent ones).

Time for the acceleration: t = __________s

Find the average velocity for the train. The train's displacement, Δx, along the horizontal part of the track is given in the specifications at the end.

$\bar{v} = \frac{\Delta x}{t} =$ = ____________m/s

The initial velocity is 0 m/s. So, we can find the velocity by using another average velocity equation, assuming <u>uniform acceleration</u>:

$$\bar{v} = \frac{v_i + v_f}{2}$$

Determining v_f. v_f = ______________ m/s.

Finally, we can find the acceleration: a = $v_f + v_i$. Calculate the acceleration.

a = ______________ m/s^2.

Divide the acceleration by 9.8 m/s^2 to put this number into "g's"

a = ______________ g's

(2) First, we have to figure out the kinetic energy (E_K) gained by the coaster during takeoff. Since the power used is equal to the rate at which the Work is done by the motors, and the gain in kinetic energy is equal to the amount of Work done by the motors, we can calculate the Power used by dividing the change in E_K by the time during which the work occurred. We measured this time in the previous section.

The change in $E_K = 0.5\ m\ v^2$ = _______________ (since E_K is initially zero.)

Power = Work/time = _______________ watts

Convert the power to horsepower. There are 746 watts in 1 horsepower.

______________ watts = _______________ hp

(3) Since you already know the velocity of the coaster at the bottom of the "top hat", you can calculate the kinetic energy. The potential energy will be 0 J if we consider the starting height to be 0 m. So, the total energy at the bottom is

EK = $0.5\ m\ v^2$ = __________________ J E_{TOTAL} AT BOTTOM

At the top, you'll have to calculate both the potential and kinetic energies (since the coaster is moving at the top).

EP = m g h = ____________________ J

To get the speed of the coaster at the top, we can time how long it takes for the coaster to pass the peak of the "top hat".

v = length of the coaster/time to pass = _____________________ m/s

EK = $0.5\ m\ v^2$ = _____________________ J

ETOTAL = E_P (at the top) + E_K (at the top) = ___________________ J E_{TOTAL} AT THE TOP

Observations/Conclusions:
(1) Some of the best standard automobiles can reach accelerations of about .8 g's to .9 g's. How does *Storm Runner* compare?

(2) Most of our cars have power ratings in the neighborhood of 90 to 200 horsepower. How many cars could be powered during one of the launches of *Storm Runner*?

(3) How do the total energies at the bottom and the peak of the "top hat" compare? Explain these results.

Specifications:
Horizontal Run during Takeoff (just before release): 45 m
Length of Train: 11,984 millimeters   Height of "Top Hat": 45.7 m

Fahrenheit

The main feature of *Fahrenheit* is its first hill: a 97° drop – a fall that doesn't go just straight down, but curves inward by 7° !

Question 1: If we fell straight downward, unhampered by air resistance, we'd accelerate at 9.8 m/s^2 downward. Will the design of this coaster cause our maximum acceleration (at the bottom of the first hill) to be equal to, less than, or greater than 9.8 m/s^2?

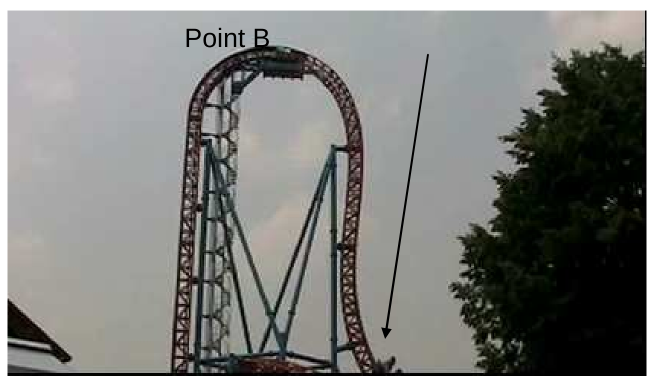
Prediction 1: The rider's maximum acceleration will be closest to ________ .
(a) 2.45 m/s^2 (.25 g) (b) 4.9 m/s^2 (.5 g) (c) 9.8 m/s^2 (1 g)
(d) 14.7 m/s^2 (1.5 g) (e) 19.6 m/s^2 (2 g)

Try It: Let's assume that the coaster's acceleration at the top of the first hill is 0 m/s^2 (point A on the picture below) and that it reaches maximum acceleration near the bottom of the hill (point B on the picture below). You will have to find a place where you can watch the coaster's acceleration from top to bottom of the hill (maybe while waiting in line?).

We'll calculate the coaster's average acceleration during this time using the kinematics equation:

$$\Delta x = \frac{1}{2}\bar{a}t^2 + v_i t$$

To save you some time, we'll tell you that the initial speed of the coaster at the top point is 4.3 m/s and the distance traveled by the train between pictures is about 28.5 meters.



So, your mission is to determine the time it takes for the coaster to go **from point A to point B.**

Take at least 5 measurements and average the most consistent ones.

Average Time for the acceleration: t = _______________ s

Rearrange the equation to calculate the average acceleration. Show your calculations below:

Average Acceleration =___________m/s^2

We'll assume that the acceleration is increasing uniformly from point A to point B to make the maximum acceleration calculation easier – this should give us a roughly correct reading. Similar to the average velocity equation, the average acceleration equation would be:

$$\overline{a} = \frac{a_i + a_f}{2}$$

where $a_i = 0$ m/s^2. Record your calculated value for a_{MAX} below.

Conclusion:

$a_{MAX} = a_f = 2 \cdot a_{AVG} =$ _______ m/s^2 which is closest to prediction choice ________.

Question 2: Many people think that the lift to the top of the first hill is more nerve-wracking than the rest of the ride. It takes a lot of power to pull the coaster up the hill. We'll compare this power to that used by a typical automobile. (See Question 2 on *Storm Runner* for the calculations). While the chain is lifting the coaster, how many cars could be powered with the same amount of energy?

Prediction 2: While the chain is lifting the coaster, the power used by the ride is equivalent to the power used by a <u>minimum</u> of ______ cars.

(a) 2 (b) 30 (c) 100 (d) 150 (e) 1000

Try It: Using the Engineering specs below, determine the Power used by calculating the Work done on the coaster during the lift. Then, time how long it takes to get the train to the top – <u>*just as it starts up the hill until the middle of the train is at the top*</u>.

$$Work = mgh = \underline{\qquad\qquad\qquad} J$$

$$LiftTime = \underline{\qquad\qquad\qquad} s$$

Final Answer/Conclusion
See *Storm Runner* Question 2 for calculations)

$$Power = \frac{Work}{time} = \frac{\underline{\qquad\quad} J}{\underline{\qquad} s} = \underline{\qquad\qquad} W = \underline{\qquad\qquad\qquad}$$ cars

Graph It: Draw a rough graph showing the velocity of the coaster as it descends the first hill from point A to point B. (Be careful: Re-read the assumptions of the first part!)

VELOCITY (M/S)

TIME (SECONDS)

Engineering Specifications:

Height of 1st Hill: 36.9 m Mass of Train: 5443 kg Train Length: 8.2 m

Ride Measurements

CARROUSEL	ENGLISH	METRIC
Radii	25′	7.62 m
Inner horse	17′5″	5.31 m
Middle horse	20′5″	6.22 m
Outer	23′6″	7.16 m
Total ride time	2 minutes	2 minutes
Single rotation time	11 seconds	11 seconds

COMET	ENGLISH	METRIC
Height of first hill	84′2″	25.65 m
Height of valley	4′0″	1.22 m
Height of second hill	70′-6 1/2″	21.5 m
Horsepower of chain motor	75	55950 watts
Area of front of car	8.6 sq. ft.	.80 m^2
Length of coaster train	40′0″	12.19 m
Riders each hour	1,100	1,100
Average speed	27 ft./sec.	8.23 m/s
Minimum speed	66 ft./sec.	20.12 m/s
SECOND MAJOR CURVE: Radius	35′	10.67 m
Degrees	87 degrees	87 degrees
Entering height	54′2″	16.51 m
Exit height	50′11″	15.52 m
Minimum ride height	42″	1.07 m
Ride capacity	24 a train/2 trains	24 a train/2 trains
Round trip distance	2,950′	899.1 m
Round trip time	1 min. 49 sec.	1 min. 49 sec.
Mass of train	6,200 lbs. empty/9,500 lbs. full	2812 kg/4309 kg

NOTE: Average weight is 150 lbs. (68.04 kg) per rider.

GREAT BEAR	ENGLISH	METRIC
Mass of train	22,400 lbs.	10 ton
Length of train	39′ 2″	11.937999 m
Distance from wheels to bottom of seat	6.5 ft.	1.9812 m
Distance of track	2,800′	853.44 m
Height of loop (Top of Loop)	106′	32.3088 m
Height of loop (Bottom of Loop)	31′	9.4488 m
Height of first hill	11′ 6″	36.500652 m
Height at the bottom of first hill	10′ 4″	3.1490917 m
Distance around loop - beginning and ending at the same point	187′ 6″	57.15 m

PIRATE	ENGLISH	METRIC
Horsepower of swing engine	100 hp	74600 watts
Riders each hour	1,200	1,200
Maximum swing angle	75 degrees	75 degrees
Ride capacity	54 adults	54 adults
Round trip time	1 1/2-3 min. a ride	1 1/2-3 min. ride
Mass of boat	14,300 lbs. empty/21,050 lbs. full	6486 kg/9548 kg
Length of boat from tip of needle to stern	43′0″	13.1 m
Maximum height of center of boat	44′6″	13.6 m
Radius swing (center fulcrum down center of boat)	44′6″	13.6 m

NOTE: Average weight is 150 lbs. (68.04 kg) per rider.

SIDEWINDER	ENGLISH	METRIC
Height of hill (is it the same on both ends?)	121′1″: Lift 1 116′5″: Lift 2	36.90 m / 35.48 m
Vertical drop of first hill	121′1″	36.90 m
Vertical drop of second hill	116′5″	35.48 m
Mass of train	14,000 lbs. empty/18,200 lbs. full	6350 kg/8255 kg
Length of train	60′	18.29 m
Total ride time	1 min. 40 sec.	1 min. 40 sec.

SOOPERDOOPERLOOPER	ENGLISH	METRIC
Height of first hill	81′0″	24.69 m
Angle of first drop - steepest	varies-38 degrees	varies-38 degrees
Height of loop	53′	16.15 m
Height of second hill	64′0″	19.51 m
Horsepower of chain motor	100 hp	74600 watts
Weight of coaster loaded	9,400 lbs.	4264 kg
Weight of coaster empty	8,000 lbs.	3629 kg
Chain speed	6-8 ft./sec.	2.07 m/s
Length of train	42′6″	12.95 m
Round trip time	1 min. 57 sec.	1 min. 57 sec.
Frontal area of train	9.3 sq. ft.	.86 m/s
Riders each hour	850	850
Average speed	22.34 ft./sec.	6.81 m/s
Minimum speed	0-2 ft./sec.	0-.61 m/s
Minimum rider height	54″	1.37 m
Rider capacity	24 a train/2 trains	24 a train/2 trains
Round trip distance	2614.8′	797 m

TIDAL FORCE	ENGLISH	METRIC
Mass of boat	6,000 lbs. empty/9,000 lbs. loaded	2722 kg/4082 kg
Number of riders	20/boat - 3 boats	20/boat - 3 boats
Length of boat	18′9″	5.71 m
Height of lift	100′	30.5 m
Vertical drop	100′	30.5 m

TRAILBLAZER	ENGLISH	METRIC
Height of hill	52′0″	15.85 m
Height of valley	18′0″	5.49 m
Height of loading aea	10′0″	3.05 m
Horsepower of chain motors	50 hp	37300 watts
Weight of coaster	4,000 lbs. empty/8,500 lbs. loaded	1814 kg/3856 kg
Areas of front of car	10.3 sq. ft.	.96 m^2
Riders each hour	1400	1400
Average speed	175 ft./sec.	53.34 m/s
Ride capacity	30 per train	30 per train
Round trip distance	1890′	576 m
Length of coaster	48′0″	14.63 m
Measured radius of horizontal loop	36′0″	10.97 m

NOTE: Average weight is 150 lbs. (68.04 kg) per rider.

WILDCAT	ENGLISH	METRIC
Mass of train	11,400 lbs.	5171 kg
Length of train	42′6″	12.95 m
Radius of first turn (the one you can see best)	43′6″ (Turn 3)	13.26 m
Round trip distance	3100′	944.8 m
Radius of horizontal circle (in the cylcone somewhere?)	61′ (Turn 9)	18.59 m
Number of riders per train	24	24
Vertical drop of first hill(?)	85′	25.91 m

The Physics of Roller Coasters

SCIENTIFIC AMERICAN FRONTIERS

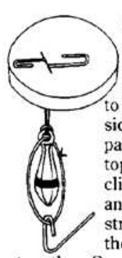
Building a Force Meter

On SCIENTIFIC AMERICAN FRONTIERS, high school students measure the G-forces they experience while riding a roller coaster. The device they use is a simple force meter they built themselves. In this activity, you will build your own force meter to measure the G-forces you feel during a ride on a roller coaster, swing or even a trip in an elevator.

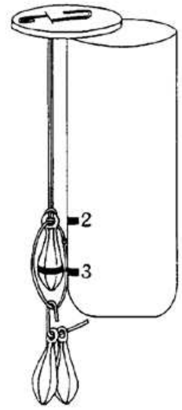
PROCEDURE

Step 1. Make a thick line across the widest part of one sinker. Push a rubber band through the eye of the sinker and loop one end of the rubber band through the other and pull tight.

Step 2. Unbend a paper clip to create a U. Hold the free end of the rubber band behind the U. Loop the other end with the sinker around the paper clip and through the top loop and pull it tight.

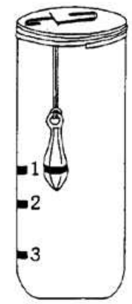


Step 3. Poke the ends of the U through the can lid so that the weight will hang close to but not touching one side of the can. Push the paper clip flush against the top; bend the ends of the clip back across the top and tape down. Slide the string through the eye of the sinker and tie the ends together. Connect the small paper clip to the string loop.



Step 4. Hang 2 more sinkers on the small clip. Hold the lid against the edge of the can with the weights hanging outside. Mark a heavy line where the permanent sinker hangs against the can as "3 G." Remove one extra sinker and mark the "2 G" level. Remove everything but the permanent sinker.

Step 5. Insert the suspended sinker into the can and tape the lid on securely. Mark the level of the sinker as "1 G" or normal. (Note: the marks are not evenly spaced because rubber bands are not linear. Double the force does not give double the stretch.)



Materials:

clear tennis ball container
(2) #1 (small) paper clips
(3) 2-oz. fishing sinkers with eye holes
several #18 rubber bands
indelible marker
8" piece of string

Step 6. Estimate the 0 G or "weightless" position. Turn the can on its side; jiggle the rubber band so it is in a resting, unextended position and mark "0 G" on the can. Tape a 3-rubber band chain onto the meter as a wrist strap. (It will hold the meter on an exciting ride but will break in an emergency.) Hold the meter inside the roller coaster car. *Remember, always follow the rules on amusement park rides.*

Calculations

Calculate the force you experience on a roller coaster ride by multiplying your body weight by the number of Gs noted on the force meter. At what point in the ride do you feel the heaviest? The lightest? When and why do you feel weightless?

Measuring G Forces on a Swing

You can also use your force meter to measure G-forces on a swing. When you are sitting still on a swing, it pushes up against your body with a force equal to your weight, and the rubber band pulls up with a force equal to the weight of the sinker. As the swing moves along its curved path, **centripetal force** pulls you in toward the center of the curve. Once the swing is moving, you and the sinker need additional centripetal force to pull you in toward the center of the curve. The faster the swing goes through its bottom curve, the more extra force is needed and the heavier you feel.

1. Hold the force meter along the chain of the swing and describe what happens to the meter as the swing goes all the way forward and back again. Where are the forces largest? You may need a partner to push you to keep the amplitude (size) of the swing's motion constant.

2. Repeat your readings with the swing going much higher. What happens to your speed? What happens to the forces registered?

3. Concentrate on your seat while you are watching the meter. Do you actually feel heavier and lighter when the meter indicates you should?

4. Compare your readings with your classmates, using the same swing going to the same height. Be sure the meter is at the same spot on the swing chain. Does body weight make a difference?

SCIENTIFIC AMERICAN FRONTIERS is made possible by an underwriting grant from GTE Corporation. Presented in association with *Scientific American* magazine.