SIX FLAGS FIESTA TEXAS

Physics & Mathematics Day

IPC Physics & Mathematics Activities

For High School
Grades 9-12

Instructions For Using This Document

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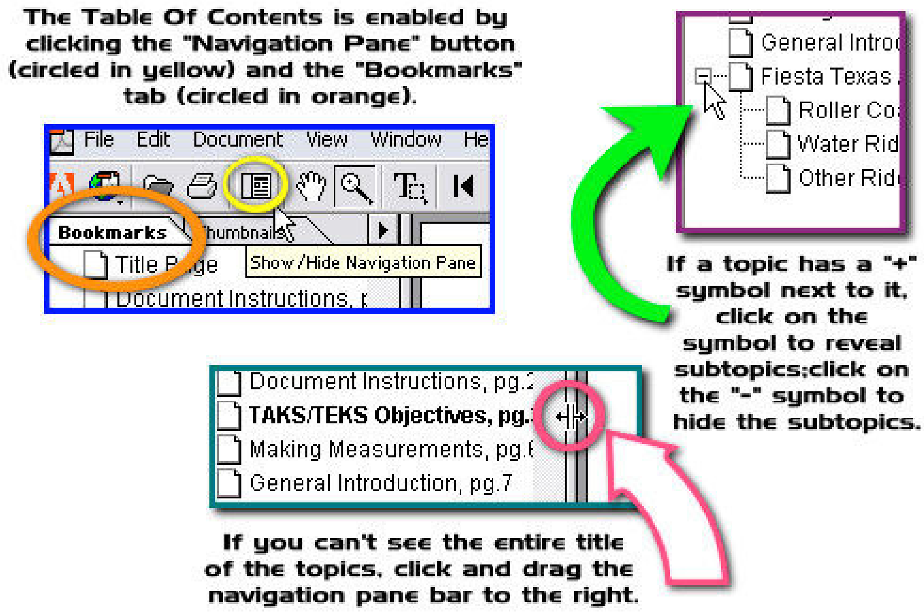

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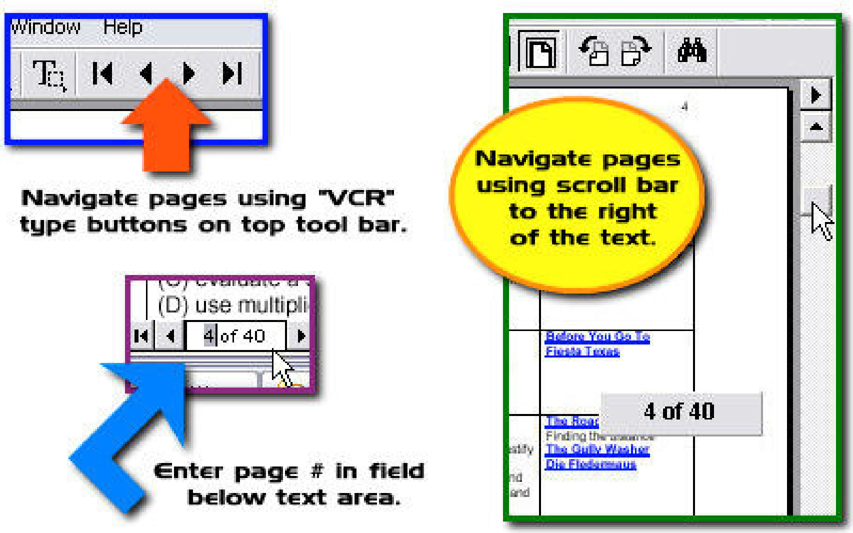

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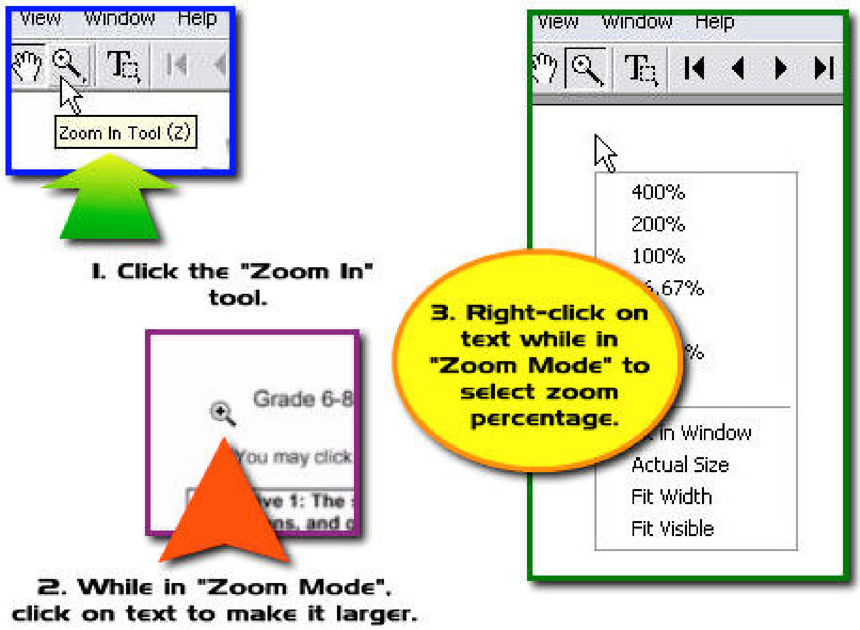

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Physics & Mathematics Day at Six Flags Fiesta Texas

To the Teacher:

These activities were written to focus on specific and interesting questions about the rides and activities at *Six Flags Fiesta Texas*. Our activities incorporate mathematics and physics concepts for various levels from IPC to Physics and from Algebra I through Precalculus. There are many books and web sites that have been written about the mathematics and physics of amusement parks which could serve as good references for extending the instructions given here. We recommend that you take the time to carefully look at these activities to choose which ones are appropriate for your students. We believe that students should be given a reasonable set of well-defined lesson goals to accomplish at the park.

Students will have a more enjoyable and successful day at the park if they have had practice with a variety of measuring devices (technological and non-technological) before visiting *Fiesta Texas*. It is suggested that teachers construct non-technological devices, discuss measurement and data-gathering tools, strategies, and concepts before coming to the park. Instructions are included in the guide for constructing inexpensive measuring devices. A list of resource web sites has also been included to provide additional ideas.

At the end of the students' hands-on experiences at *Six Flags Fiesta Texas*, students' understanding of the following physical and mathematical concepts will be strengthened.

Physics concepts:

Kinematics: Linear and Rotational
Laws of Conservation of Energy and Momentum
Measurement of Qualitative and Quantitative Data
Newton's Laws of Motion
Work, Power, and Energy

Mathematics concepts:

Data Collection and Analysis
Linear, Quadratic, Trigonometric, Rational and Polynomial Functions
Mathematical Modeling
Measurement and Estimation
Triangulation

In preparing this packet, we have used several resources. We would especially like to thank and acknowledge the ***Fiesta Texas Physics Workbook*** (1997) by Wesley Hausenfluke and Jeff Kurth, the ***Roller Coaster Physics*** (1998) by Tony Wayne, and ***Physics Day*** Handbook by Michigan's Adventure from which instructions and activities were taken and adapted to construct this guide.

We hope you enjoy your day of discovery at Fiesta Texas!

We welcome any questions, comments, and/ or suggestions for improving these instructions and ensuring a successful learning experience for all students.

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TAKS/TEKS Physics

List of Relevant TAKS, IPC, and Physics Objectives

TAKS Objective 5: The student will demonstrate an understanding of motion, forces and energy.

IPC (4) The student knows concepts of force and motion evident in everyday life.

(A) Calculate speed, momentum, acceleration, work and power in systems such as in the human body, moving toys, and machines

Physics

4A: generate and interpret graphs describing motion including the use of real time technology
4B: analyze examples of uniform and accelerated motion including linear, projectile, and circular
4C: demonstrate the effects of forces on the motion of objects
4E: identify and describe motion relative to different frames of reference
5C: calculate the mechanical energy and momentum in a physical system such as billiards, cars, and trains

(B) Investigate and describe applications of Newton's laws such as in vehicle restraints, sports activities, geological processes, and satellite orbits.

Physics

4B: analyze examples of uniform and accelerated motion including linear, projectile, and circular
4C: demonstrate the effects of forces on the motion of objects

(D) Investigate and demonstrate mechanical advantages and efficiency of various machines such as levers, motors, wheels and axles, pulleys and ramps.

Physics

5A: interprets evidence for the work-energy theorem

IPC (5) The student knows the effects of waves on everyday life.

(A) Demonstrate wave types and their characteristics through a variety of activities such as modeling with ropes and coils, activating tuning forks and interpreting data on seismic waves.

Physics

8A: examine and describe a variety of waves propagated in various types of media and describe wave characteristics such as velocity, frequency, amplitude, and behaviors such as reflection, refraction, and interference.
8B: identify the characteristics and behaviors of sound and electromagnetic waves
8C: interpret the role of wave characteristics and behaviors found in medicinal and industrial applications

(B) Demonstrate wave interactions including interference, polarization, reflection, refraction, resonance within various materials.

Physics

8A: examine and describe a variety of waves propagated in various types of media and describe wave characteristics such as velocity, frequency, amplitude, and behaviors such as reflection, refraction, and interference.
8B: identify the characteristics and behaviors of sound and electromagnetic waves
8C: interpret the role of wave characteristics and behaviors found in medicinal and industrial applications

IPC (6) The student knows the impact of energy transformations in everyday life.

(A) Describe the law of conservation of energy

Physics **5D:** demonstrate the conservation of energy and momentum
7A: analyze and explain everyday examples that illustrate the laws of thermodynamics

(B) Investigate and demonstrate the movement of heat through solids, liquids, and gases by convection, conduction, and radiation,

Physics **7A:** analyze and explain everyday examples that illustrate the laws of thermodynamics
7B: evaluate different methods of heat energy transfer that result in an increasing amount of disorder

(D) Investigate and compare economic and environmental impacts of using various energy sources such as rechargeable or disposable batteries and solar cells.

Physics **7B:** evaluate different methods of heat energy transfer that result in an increasing amount of disorder

(F) Investigate and compare series and parallel circuits.

Physics **6C:** identify and analyze the influences of charge and distance on electrical forces

TAKS/TEKS Physics

Objectives by Activity

Activity	TAKS Objectives	IPC Objectives	Physics Objectives
Roller Coaster (no instruments)	5	4A, 4B	
Roller Coaster	5	4A, 4B, 4D, 6A	4A, 4B, 4C, 5A, 5C, 5D
Looping Roller Coasters	5	4A, 6A	4B, 4E, 5D
Wave Runner	5	4A	4B, 4C, 4E
S.S. Overboard	5	4A, 4D, 5B, 5A, 6A	4A, 4B, 4C, 4E, 5A, 5C, 7A, 8A
Circular Rides	5	4A	4B, 4E
Dornröschen (Carousel)	5	4A, 4B, 4D	4B, 4C, 4E, 5A, 5C, 7A
Die Fledermaus (Swings)	5	4A, 4B, 5A, 6A	4B, 4C, 4E, 5C, 8A
Water Rides	5	4A, 4B, 5A	4B, 4C, 4E, 8A, 8C
Pilger Banhof (Train)	5	4A, 4B	4A, 4B
Steingasse (Bumper Cars)	5	4A, 4B, 4D, 6A, 6F	4B, 4C, 4E, 5A, 5C, 6C, 6E

Activities by Objective

Objective	Roller Coaster (no inst.)	Roller Coaster	Looping Roller Coasters	Wave Runner	S.S. Over-board	Circular Rides	Dorn-roschen (Carou-sel)	Die Fleder-maus (Swings)	Water Rides	Pilger Bahnhof (Train)	Steingasse (Bumper Cars)
TAKS 5	X	X	X	X	X	X	X	X	X	X	X
IPC 4A	X	X	X	X	X	X	X	X	X	X	X
IPC 4B	X	X					X	X	X	X	X
IPC 4D		X			X		X				X
IPC 5A					X			X	X		
IPC 5B					X						
IPC 6A					X			X			X
IPC 6F											X
PHYS 4A	X			X	X					X	
PHYS 4B	X	X	X	X	X	X	X	X	X	X	X
PHYS 4C			X	X	X		X	X	X		X
PHYS 4E		X	X	X	X	X	X	X	X		X
PHYS 5A	X			X	X		X				X
PHYS 5C	X			X	X		X	X			X
PHYS 5D	X	X									
PHYS 6C											X
PHYS 6E											X
PHYS 7A				X	X		X				
PHYS 8A				X	X			X	X		
PHYS 8C									X		

TAKS/TEKS Mathematics

Exit Level Mathematics TAKS with TEKS correlation

(click the underlined text to go to that section of the workbook)

Objective 1: The student will describe functional relationships in a variety of ways.	
Algebra 1 (b) (1) (B) The student [gathers and records data, or] uses data sets to determine functional (systematic) relationships between quantities.	**Waiting Times**
Algebra 1 (b) (1) (D) The student represents relationships among quantities using [concrete] models, tables graphs, diagrams, verbal descriptions, equations, and inequalities.	All
Objective 2: The student will demonstrate an understanding of the properties and attributes of functions.	
Algebra 1 (b) (2) (D) In solving problems, the student [collects and] organizes data, [makes and] interprets scatter plots, and models, predicts, and makes decisions and critical judgements.	**Roller Coasters (with no instruments)**; **The Wave Runner** ; **S.S. Overboard**; **Circular Rides**, **Der Pilger Bahnhof**
Algebra 1 (b) (3) (A) The student uses symbols to represent unknowns and variables.	All
Algebra 1 (b) (4**) Foundations For Functions**. The student understands the importance of the skills required to manipulate symbols in order to solve problems and uses the necessary algebraic skills required to simplify algebraic expressions and solve equations and inequalities in problem situations. (A) The student finds specific function values, simplifies polynomial expressions, transforms and solves equations, and factors as necessary in problem situations.	**Roller Coasters**; **Looping Roller Coasters**
Objective 3: The student will demonstrate an understanding of linear functions.	
Objective 4: The student will formulate and use linear equations and inequalities.	
Objective 5: The student will demonstrate an understanding of quadratic and other nonlinear functions.	
Objective 6: The student will demonstrate an understanding of geometric relationships and spatial reasoning.	

Geometry (b) (4) (A) The student selects an appropriate representation ([concrete,] pictorial, graphical, verbal, or symbolic) in order to solve problems.	All
Objective 7: The student will demonstrate an understanding of two -and three- dimensional representations of geometric relationships and shapes.	
Geometry (d) (1) **Dimensionality and the geometry of location**. The student analyzes the relationship between three-dimensional objects and related two-dimensional representations and uses these representations to solve problems. (C) The student uses top, front, side, and corner views of three-dimensional objects to create accurate and complete representations and solve problems.	Roller Coasters; The Wave Runner
Objective 8: The student will demonstrate an understanding of the concepts and uses of measurement and similarity.	
Geometry (e) (1) **Congruence and the geometry of size**. The student extends measurement concepts to find area, perimeter, and volume in problem situations. (B) The student finds area of sectors and arc lengths of circles using proportional reasoning.	Looping Roller Coasters
Geometry (f) (1) **Similarity and the geometry of shape.** The student applies the concepts of similarity to justify properties of figures and solve problems. (A) The student uses similarity properties and transformations to [explore and] justify conjectures about geometric figures. (B) The student uses ratios to solve problems involving similar figures (C) In a variety of ways, the student [develops], applies, and justifies triangle similarity relationships, such as right triangle ratios, [trigonometric ratios,] and Pythagorean triples.	Roller Coasters (with no instruments); S.S. Overboard
Objective 9: The student will demonstrate an understanding of percents, proportional relationships, probability, and statistics in application problems.	
Objective 10: The student will demonstrate an understanding of the mathematical processes and tools used in problem solving.	

Pre-Calculus TEKS

(c) (3) (D) Solve problems from physical situations using trigonometry, including the use of Law of Sines, Law of Cosines, and area formulas.	**Law of Sines**
(c) (5) The student uses conic sections, their properties, and parametric representations to model physical situations. The student is expected to: (A) use conic sections to model motion, such as the graph of velocity vs. position of a pendulum and motions of planets.	**S.S. Overboard**
(c) (6) The student uses vectors to model physical situations. The student is expected to: (A) use the concept of vectors to model situations defined by magnitude and direction; and (B) analyze and solve vector problems generated by real-life situations.	**The Wave Runner** **Die Fledermaus**

TEKS by Problem

Law of Sines	Pre-calculus c6A, c6B
Roller Coasters (with no instruments)	Algebra 1 b1D, b2D Geometry d1C, f1B, f1C
Roller Coasters	Algebra 1 b2D, b3A Geometry d1C
Looping Roller Coasters	Algebra 1 b4A Geometry e1B Algebra 2 d4D, d4E
The Wave Runner	Geometry d1C Pre-calculus 6A, 6B
S.S. Overboard	Geometry f1C Algebra 2 d4D, d4E Pre-calculus c3D
Circular Rides	Algebra 1 b2D
Dornröschen	Pre-calculus c3D
Die Fledermaus	Pre-calculus c6A, c6B
Water Rides	
Der Pilger Bahnhof	Algebra 1 b2D
Steingasse	Pre-calculus c6A, c6B
Waiting Times	Algebra 1 b1B

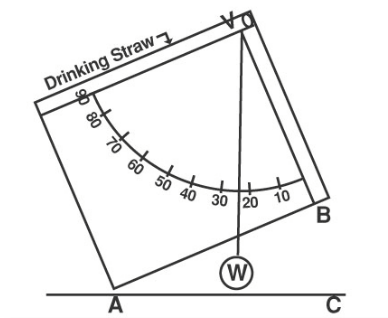
Preparation for IPC • Physics • Mathematics Day

List of equipment needed:

1 . Watch - At least one member of each group should have some kind of timing device that can measure fractions of a second.

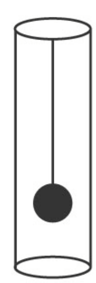
2 . Protractor-sextant - This device is a protractor with a weight hanging from a string that passes through the vertex. The kit from *Central Scientific Company* includes a horizontal accelerometer with a protractor printed on foam board and a straw mounted on the top so it can also be used to determine angles of elevation.

http://tqjunior.thinkquest.org/6169/sextant.htm



3 . Spring accelerometer - There are several designs available to measure the acceleration of the rider in units of "g". *Central Scientific Company* sells an accelerometer made with a weight hanging on a spring inside a plastic tube. Other accelerometers replace the spring with an elastic band.

http://library.thinkquest.org/2745/data/meter.htm



4 . Measuring tape - A thick string or cord of length 2-3 meters with a mark every 10 cm could be substituted for the tape.

5. Graphing calculator and data collection device (CBL EA-100) or Calculator and pencil - The calculator should have trigonometric functions.

6. Plastic bag - A one gallon *Zip Lock* bag will keep the workbook, calculator, and all other materials together.

7 . Safety cords or fanny pack - Must be used to attach or hold measurement instruments to the wrist or waist of the rider.

Making Measurements

Time

The times that are required to work out the problems can easily be measured using a watch with a second hand or a digital watch with a stopwatch mode. When measuring the period of a ride that involves harmonic or circular motion, measure the time for several repetitions of the motion, then divide by the number of repetitions. This will give a better estimate of the period of motion than just measuring one repetition. You may want to measure the time two or three times and then average them. A digital watch will be required for timing certain rides.

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 the following methods. They will give you a reasonable estimate. Try to keep consistent units, i.e. meters, centimeters, etc., to make calculations easier.

Pacing

Determine the length of your stride by walking at your normal rate over a measured distance. Divide the distance by the number of steps and you can get an average distance per step. Knowing this, you can pace off horizontal distances.

Ride Structure

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 by counting the number of cross members. This method can be used for both vertical and horizontal distances.

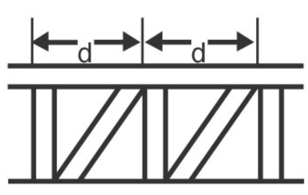


figure a

Triangulation

For measuring height by triangulation, a protractor sextant can be constructed following the directions from the following web site:

http://tqjunior.thinkquest.org/6169/sextant.htm

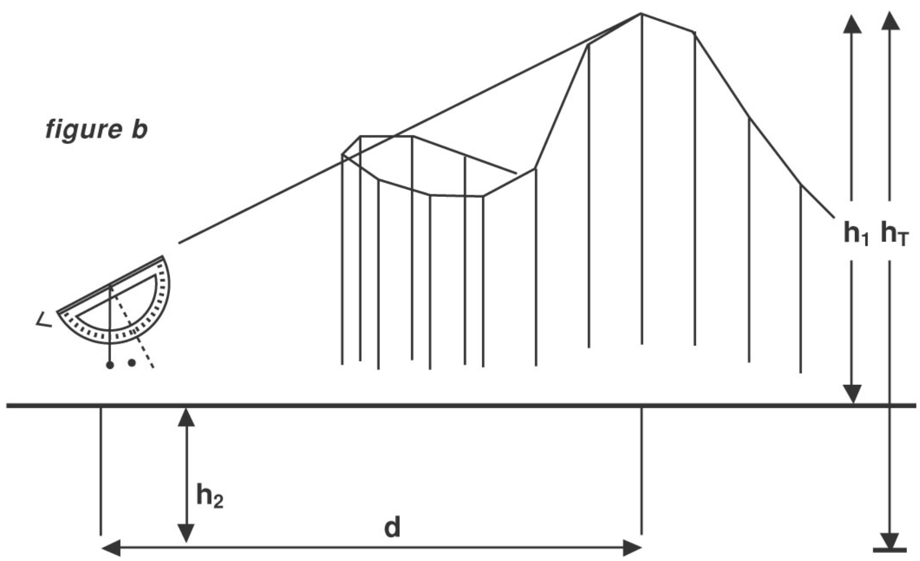
or a kit can be purchased from *Central Scientific Company* (Amusement Park Physics).

1. Measure the distance between you and the ride by using a measuring tape or pre-measured string. d:_________m

2. Measure the height from the observer's eye to the ground.

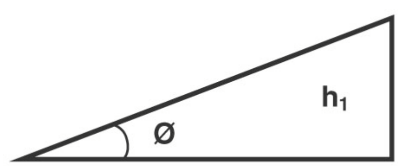
h_2=________m

3. Take a sighting at the highest point of the ride. Read off the angle of elevation. ø =______________



$h_1/d = \tan Ø$

$h_1 = d(\tan Ø)$



5. Multiply the tangent value by the distance from the ride: $h_1 =$ __________m

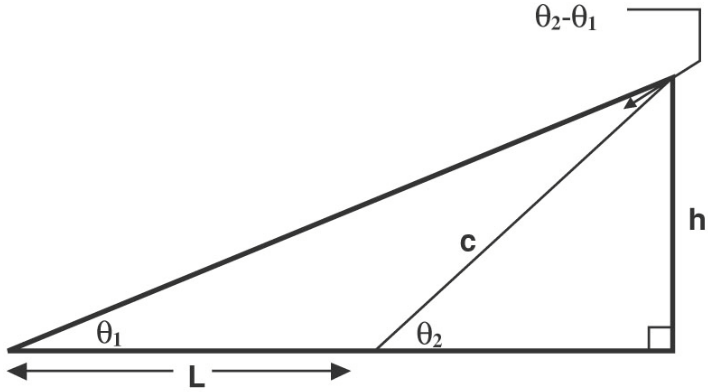
6. Add this to the height of the observer's eye to the ground:

$h_2 =$ _________m

7. This number is the height of the ride:

$h_T =$ _________m

Law of Sines



If you can't measure all the way to the base of the structure, you may use the law of sines to find its height.

1. Using a tape measure or pre-measured string, find the length L of the baseline. The baseline should be laid out radially from the object.

L=___m

2. Measure the height from the observer's eye to the ground.

Observer's height =______m

3. Take a sighting from the ends of the baseline to the highest point of the ride. Call the angles of elevation $ø_1$ and $ø_2$.

$\Theta_1 =$ ______ ^{o} __ $\Theta_2 =$ ______ ^{o} __

From the definition of sine, $h = c \sin ø_2$, Unfortunately, we can not measure c directly.

However, from the Law of Sines,

$$\frac{c}{\sin \Theta_1} = \frac{L}{\sin (\Theta_2 - \Theta_1)}$$

4. Substituting, we obtain: $h = \dfrac{L \sin \Theta_1 \sin \Theta_2}{\sin (\Theta_2 - \Theta_1)}$

h = ______m

5. Finally, add the observer's height to obtain the actual height of the ride:

Height of ride = ___________m

Acceleration

Accelerometers are designed to record the *g forces* felt by a passenger. Accelerometers are calibrated in *g's*. A reading of *1 g* equals an acceleration of 9.8 m/s^2. As you live on Earth, you normally experience 1 g of acceleration vertically (no g's laterally or longitudinally). Accelerometers are usually oriented to provide force data perpendicular to the track, longitudinally along the track, or laterally to the right or left of the track. The acceleration is always in the direction of the net force. However, the acceleration is not always in the same direction that the object is moving. The following statements should be made clear to students:

1. When an object traveling in a straight line speeds up, the direction of its acceleration is the same as its direction of motion.
2. When an object traveling in a straight line slows down, the direction of its acceleration is opposite its direction of motion.
3. When an object moves in a circle at a constant speed, the direction of its acceleration is toward the center of the circle.
4. When an object moves in a parabola (like those in a roller coaster ride), the direction of acceleration is along the axis of the parabola.

Listed below are the sensations of various g forces. These are rough estimates, but may be helpful in estimating accelerations on the various rides.

Accelerometer Reading	Sensation
+3.0 g	3 times heavier than normal
+2.0 g	Twice normal weight
+1.0 g	Normal weight
+0.5 g	½ Normal weight
+0.0 g	W
-0.5 g	½ Normal weight, but directed away from the coaster seat

Construction of Spring Accelerometers:

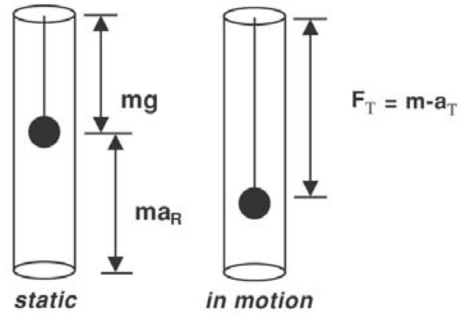
1. **A spring accelerometer -** Hang one weight from the spring and mark the position. This represents *1g*; *g* is the new unit of weight. Suspend 2 weights and mark this the *2g* position. Continue this procedure up to 5 weights. Since the stretch of the spring should be linear, all the markings will be equally spaced. Because the spring's force is sometimes less than *1g*, also mark the *zero g* position. The *zero g* position occurs where the spring is not stretched at all. Additional direction for a spring accelerometer can be found at:

http://library.thinkquest.org/2745/data/meter.htm

or one can be purchased from *Central Scientific Company* (Amusement Park Physics).

2. **A spring scale and fishing weight**· A weight is taped securely to the end of the spring scale. The weight should be about 1/6 of the full scale reading. For example, if you have a 20 N scale (2000 grams), the weight would need to be approximately 3 N (300 grams).

Vertical Acceleration
A simple device for measuring vertical accelerations is a 0-5 Newton spring scale with a 100g mass attached. The plastic tube with elastic and fishing weight approximate this equipment. The forces on the mass are drawn where F_T is the reading on the scale. The forces on the masses are shown in the diagram.



This **force device** can be calibrated to read in multiples of an object's weight. While a person is holding the device in an upright position, the mass is held up by the force of the spring. The length of the spring's stretch is directly related to this force. The ratio of this force to the weight of the object is called ***g force***.

If the person is holding the scale right side up, then:

$$F_T = mg + ma_{(Ride)} \text{ or } ma_{(Total)} = mg + ma_{(Ride)}$$

Since m is constant

$$a_T = g + a_R \text{ or } a_T - g$$

If the person is holding the scale upside down against gravity as might be found at the top of a loop, then

$$a_R = -(a_T + g) \text{ ie. Acceleration is upwards}$$

In either situation, the acceleration can be calculated by knowing F_T (or a_T).

Longitudinal Acceleration

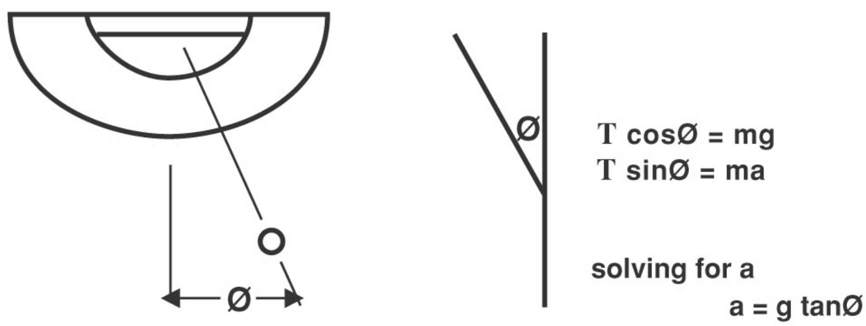
Acceleration of a person on a ride can also be determined by direct calculation. Down an incline, the average acceleration of an object is defined as:

$$a_{ave} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\text{change in speed}}{\text{change in time}}$$

Using methods previously discussed, it is possible to estimate speeds at both the top and bottom of the hill and the time it takes for the coaster to make the trip. Thus average acceleration can be found during that portion of the ride.

Lateral Acceleration

The protractor sextant discussed earlier as a triangulation instrument may also be used to measure lateral accelerations. The device is held with the sighting tube horizontal, and weight swings to one side as you round a curve. By measuring the angle, acceleration can be determined. See the drawing below:



Centripetal Acceleration

With uniform circular motion, remember that:

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

and the centripetal acceleration is given by:

$$a_C = \frac{v^2}{r} = \frac{4\pi^2 r}{t^2}$$

Or,

$F_c = ma_c = mv_c/ r = 4P^2r/T^2$

where $\mathbf{a_c}$ is *centripetal acceleration*, **r** is *radius of path*, **T** is the *period*, **V** is *tangential speed*, $\mathbf{F_c}$ is *centripetal force*, and **m** is *mass*.

Speed / Velocity

Speed and velocity are used interchangeably here because we are working with forward motion only. When an object is moving at a constant speed, the speed is calculated by measuring the distance traveled in a certain amount of time.

If you know the length of a train, for example, you can determine the time it takes for the train to pass a selected point on the track and then calculate the speed as follows:

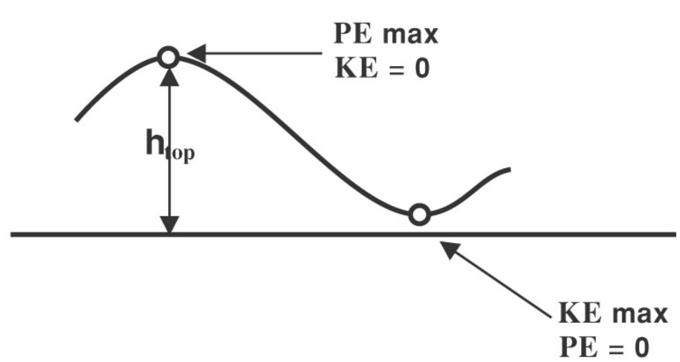
$$\text{Average velocity} = \frac{\text{length of train}}{\text{time to pass a fixed point}}$$

In most situations, we assume that total mechanical energy is conserved. As Potential Energy increases, Kinetic Energy decreases and vice versa. If you know the height of a hill on a roller coaster, you can calculate the approximate Potential Energy at the top and use Conservation of Energy to calculate the approximate speed at the bottom of the hill. You could also use the speed of an object to calculate the Kinetic Energy and then predict the height to which it would rise. We ignore friction in these situations, and usually assume that the speed at the top of the hill is 0.

$PE = mgh$ and $KE = ½ mv^2$

change in PE = change in KE or in most cases ***the PE at the top = the KE at the bottom***

So according to Conservation of Energy: $mgh_{top} = 1/2mv^2_{bottom}$



Resource Web Links

(If you are connected to the internet, clicking on these URLs will open the page in your browser)

Classroom Implementation of Amusement Park Physics:
http://www.newton.dep.anl.gov/app/nau_links.htm

Internet Project Resource Page Amusement Park Rides (Roller Coasters):
http://k12science.ati.stevens-tech.edu/ike/summer99/resourcerc.html

Amuse me Theme Park Physics:
http://library.thinkquest.org/C005075F/

Physics of Roller Coaster Project:
http://www.glenbrook.k12.il.us/gbssci/phys/projects/yep/coasters/rcstupa.html

The Physics of Amusement Parks:
http://library.thinkquest.org/2745/

Hockaday Physics
http://home.hockaday.org/HockadayNet/academic/physics/SixFlags/sixflags.htm

The Physics of Rides:
http://themeparks.miningco.com/travel/themeparks/cs/physicsofrides/index.htm

Roller Coaster Designers:
http://www.coasters.net/designers/

Ride Safety:
http://themeparks.miningco.com/travel/themeparks/cs/ridesafety/index.htm

Annenberg: Amusement Park Physics:
http://www.learner.org/exhibits/parkphysics/coaster.html

Interactive Roller Coaster:
http://www.funderstanding.com/k12/coaster/

Fiesta Texas Approximate Data

Roller Coasters

Superman Krypton Coaster:

Height 170 ft
Max. Speed 66 mph
length of train 45ft
weight empty train 16000 lbs; 36 seats
height of loop 120 ft

Rattler:

Height 186 ft
Max. Speed 55 mph
length of train 5 ft
weight empty train 14000 lbs; 20 seats
uses 250 hp, 480V 3 phase motor

Road Runner Express:

Height 85 ft
Max. Speed 42 mph
length of train 52 ft
weight of empty train 17000 lbs; 28 seats
climb up first hill varies from 2 to 8 ft/sec. It accelerates up the first hill.

Boomerang:

Height 125 ft
Max. Speed 45-48 mph
length of train 48 ft
weight of empty train 14000 lbs; 32 seats
height of loop 43 ft
uses hydraulic motor

Park power comes in at 34500 volts; peak usage 7 Megawatts

Water Rides

Power Surge:

Height 55 ft
length of boat 16 ft
weight of empty boat 1700 lbs
100hp pump; about 320000 gallons

Bugs' White Water Rapids:

conveyor belt travels at 1 ft/sec
main drop 40 ft
370000 gallons

Gully Washer:

3 pumps; 240 hp, 18ft of head each
375000 gallons

Others

Bumper Cars:

480 volt 3 phase rectified to 90Volts DC; 1 hp motor
300 lbs empty car

Train:

length of track 0.9 miles
average speed 3-5 mph

Data from Roller Coaster Database

www.rcdb.com

Fiesta Texas

Boomerang:

Length 266.7m
Height 38.1m
Inversions 3
Speed 77.2 km/hr
Duration 1 min:48 s
Capacity 750 riders/hr

Rattler:

Length 1548.4m
Height 54.7m
Drop 37.87m
Inversions 0
Speed 104.6 Km/hr
Duration 2 min: 26 s
Angle of Descent 61.4^{o}

Road Runner Express:

Length 731.5m
Height 22.3m
Inversions 0
Duration 2 min: 24 s
Capacity 1800 riders/hr

Superman Krypton Coaster:

Length 1226.8m
Height 51.2m
Inversions 6
Speed 112.7Km/hr
Duration 2 min: 35 s
Capacity 1600 riders/hr

Roller Coasters (with no instruments)

adapted from: ***Roller Coaster Physics*** by Tony Wayne

1. Determine the length of the coaster train.

2. What is the published length of the track?

3. Estimate the mass of the loaded train.

4. Determine the vertical height of the first hill.

5. How fast is the train traveling over the top of the first hill?

6. How much time does it take for the middle of the train to be lifted to the top of the first hill?

7. What is the velocity of the train at the bottom of the dip after the first hill?

8. Use conservation of energy and calculate the height of the drop from the first hill.

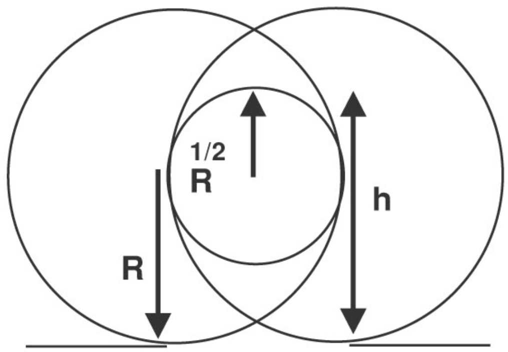
For looping coasters answer questions 9-13

9. What is the velocity of the train as it enters the bottom of the first loop?

10. What is the velocity of the train as it passes the top of the loop?

11. Calculate the height of the loop.

Suppose the loop was designed using very simple geometry. Below is a loop that is designed from splicing together two large circles with a smaller circle. Outline the loop on the diagram below. The smaller circle's radius is half the radius of the larger circles. Use information calculated above to determine the radii of the two circles.



12. Large circle radius ______ Small circle radius ______

13. Use information calculated above to calculate the g's felt by the rider:

Entering the bottom of the loop ____ At the top of the loop_____

14. Calculate the velocity of the train as it travels over the 2nd hill.

15. What is the velocity of the train at the bottom of the dip after the 2nd hill?

16. Assuming the initial total mechanical energy of the train is ZERO, how much total mechanical energy is gained by lifting the train to the top of the first hill?

17. The train has to lose its total mechanical energy by the time it reaches the end of the ride. Assuming that 2/3 of the initial energy at the top of the first hill is lost due to friction during the ***length of the entire ride***, what is the average force of friction opposing the train's motion as it travels along the entire length of the track? (HINT: Use energy and work)

18. Compute the power needed to raise the train to the top of the first hill.

19. If electricity costs \$0.40 / (kW•hr), how much does it cost to raise the train to the top of the first hill?

20. Estimate how many runs the train makes in one hour.

21. How much does it cost to run the coaster for a 14 hour day?

Roller Coasters

Road Runner Express

Rattler

Boomerang

Superman Krypton Coaster

Observe the roller coasters in the park. Do the trains use motors for the entire trip or only part of it? From where do the trains get the energy to complete the course? Explain your reasoning.

Observe the wheel assembly on the trains. Draw a sketch and describe why you think the wheels are made that way.

Coasters typically wind around and around to conserve space. Draw a sketch of what the coaster would look like if it were straightened out. Do not take out the loops and curves, just draw it as if it were laid out in a straight line. If the coaster is extremely long just draw the first 5 or 6 hills and drops.

Draw a graph of **(vertical distance from the ground vs. time)** for this ride.

Where is the highest point of the ride? Why do you think so?

Label your previous sketch with the following points: maximum Potential Energy, minimum Potential Energy, maximum Kinetic Energy, minimum Kinetic Energy, maximum velocity .

Have some of your group be brave and ride the coaster. Describe your feelings at different points of the ride. Label the sketch where you feel the heaviest and where the lightest (or weightless).

Where was your acceleration the greatest? What caused this large acceleration? (Remember that acceleration is a vector quantity and depends on two things)

Compare the second highest point with the highest point. Discuss the height of the hill, velocity of the train, Potential Energy and Kinetic Energy.

Some coaster enthusiasts say that passengers in the first car, middle car and last car experience the ride differently. What do you think? Use your observations of the ride, your gut feeling while riding the ride and your measuring device to support your conclusion.

If you look carefully at the first hill of the Rattler, you can see where modifications were made. What modifications do you think were made and why do you think they were done?

Making Measurements:

Before:

Determine the length of the train:	**L_{train} = _______m**
Determine the height of the first hill:	**h_{hill} =_______m**
Estimate the mass of a full train of passengers:	**m_{train} =_______kg**
Time required to lift a loaded train up to the top of the first hill:	**t =______sec**
Time for train to pass a point at the bottom of the first hill:	**t =______sec**

During:

If you have an instrument (Spring Accelerometer or CBI), measure the acceleration component perpendicular to the track. Record where this reading is greatest during the ride (Do this later).

a = ____m/S² = _____g's

Calculations:

Calculate the Potential Energy of the loaded train at the highest point. Assume that velocity is essentially zero.

PE = mgh   PE =____J

Calculate the velocity of the train at the bottom of the first drop using Conservation of Energy. (assume PE = 0)

PE= mgh, KE = 1/2 mv^2 v =_____m/s

Measure the velocity of the train at the bottom of the first drop by timing the train past a fixed point.

v = d/ t   v = ______m/s

Compare your answers for velocity of the train. Do they agree? Should they? Explain.

Measure the velocity of the train at the second highest point by timing the train past a fixed point. Calculate the height of the second highest point using Conservation of Energy.

PE= mgh, KE = 1/2 mv^2 h =_____m

Calculate how much work is done to lift the train to the highest point.

W=Fd   W= _____J

Calculate the power of the lift system.

P = W/t   P = _______watts

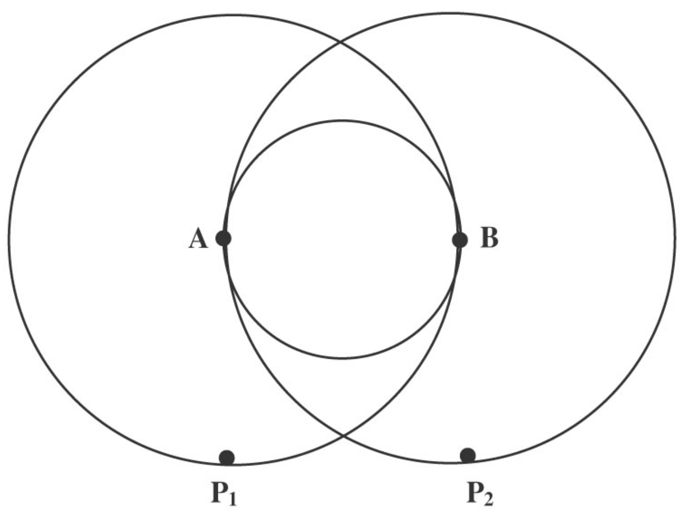
Looping Roller Coasters

Boomerang

Superman Krypton Coaster

Several of the coasters have vertical loops. Sketch the shape of these loops and discuss what you notice about the shape.

A simple irregular loop can be simulated using the combination of parts of circles of different radii. Can you see an irregular loop in the following regular circles that is similar to the ones in the roller coasters? Outline it.



Suppose points A and B are centers of the two larger circles and endpoints of a diameter of the smaller circle. What is the height of the loop in terms of the length AB? Approximately what is the length of the loop from point P1 to point P2 in terms of the length AB?

Other irregular loops can be formed similarly, but using circles of varying radii. Can you sketch such an irregular loop?

The irregular loop you've been describing is the ***Clothoid (Klothoid)*** or ***Spiral of Archimedes*** loop. Research the Clothoid loop and describe how it is formed.

Making Measurements:

Before:

Determine the length of the train: **L_{train} = _____m**

Determine the height of the loop: **h_{loop} = _____m**

During:

If you have an instrument (Spring Accelerometer or CBL) measure the radial acceleration just before entering the loop.

a_b = _____g's = _____m/s^2

Use your instrument to measure the radial acceleration at the top of the loop.

a_t = _____g's = _____m/s^2

Calculations:

Calculate the speed of the train just before it enters the loop.

$v = \Delta d / \Delta t$ v = ______m/s

Calculate the speed of the train at the top of the loop.

$v = \Delta d / \Delta t$ v = ______m/s

Using the acceleration you measured, calculate a radius of curvature for the track where the train enters the loop.

$a_b = v_b^2/r$, $r_b = v_b^2/a_b$ r = _______m

Using the acceleration you measured, calculate a radius of curvature for the track at the top of the loop.

$a_t = v_t^2/r$, $r_t = v_t^2/a_t$ r =_______m

Compare the radii that you calculated.

Using the radius of curvature that you determined, calculate the minimum velocity required for the train to make it around the top of the loop (without restraining devices). This is known as ***critical velocity***.

$$g = v_c^2/r_t \quad , \quad v_c = \sqrt{gr} \qquad\qquad v_c = \_\_\_\_\_\_\_\_ \text{m/s}$$

What would happen if the ride had been made with a circular loop instead of a clothoid loop? Assume a circular loop with a diameter equal to the height of the clothoid loop. The velocities calculated would be the same.

Calculate the radial acceleration at the bottom of the circular loop.

$$a_b = v_b^2/r_b \quad , \quad a_b = \_\_\_\_\_\_\_\_ \text{m/s}^2 = \_\_\_\_\_\_\_\_ \text{g's}$$

Calculate the radial acceleration at the top of the circular loop.

$$a_t = v_t^2/r_t \quad , \quad a_t = \_\_\_\_\_\_\_\_ \text{m/s}^2 = \_\_\_\_\_\_\_\_ \text{g's}$$

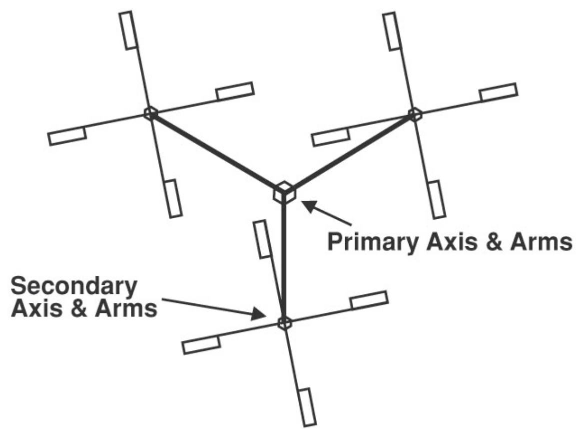
Calculate the minimum velocity required for the train to make it around the top of the circular loop (critical velocity.)

$$v_c = \sqrt{gr} \qquad\qquad v_c = \_\_\_\_\_\_\_ \text{m/s}^2$$

Compare the clothoid and circular loop data. Why do you think clothoid loops are used instead of circular ones?

The Wave Runner
(Scrambler)

The Wave Runner is a ride often called a scrambler. It is a dual-axis ride consisting of a primary axis and a secondary axis for each cluster of seats. Riders move much like the pen of a Spirograph and experience horizontal accelerations because of changes in speed and direction.



Making Measurements

1. Estimate the length of the primary arms and secondary arms.

Primary arms: ______m

Secondary arms: ______m

2. When viewed from above, which way do the primary arms rotate about the primary axis, clockwise or counter-clockwise?

3. When viewed from above, which way do the secondary arms rotate about the secondary axis, clockwise or counter-clockwise?

4. Use a watch to measure the time for one of the primary arms to make one revolution. Choose an object at rest on the ground as a reference point for making this measurement. This time is called the **period** for the primary arms.

______sec

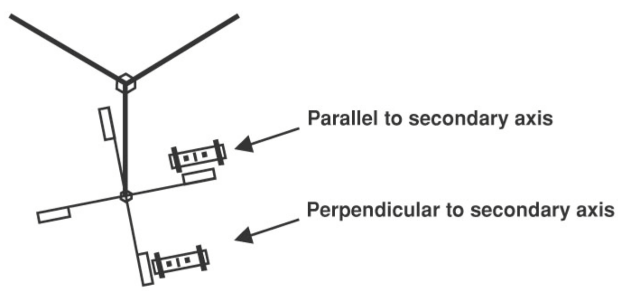
5. Use a watch to measure the time for one of the secondary arms to make one revolution about its axis. Use the Primary arm upon which it is

attached as your reference for making a revolution. Call this the secondary period.

_______sec

6. Observe and describe the motion of a rider. If a rider were able to hold a piece of chalk against the ground below his seat, what pattern would be drawn? Sketch this pattern .

7. While riding the ride, use an accelerometer to help you answer the following questions. The accelerometer can be held in two orientations, but always parallel to the ground.



a. Holding the accelerometer **parallel to the secondary arm** on which you are riding, note the changes in the acceleration. This gives you the radial (along the radius) acceleration. Where is this acceleration reading the greatest (near the center, midway, or near the outer edge)?

b. Holding the accelerometer perpendicular to the secondary arm on which you are riding, note the changes in the acceleration. This gives you the lateral (side to side) acceleration. Where is this acceleration reading the greatest (near the center, midway, or near the outer edge)?

8. Describe the speed of the ride when you are near the center, midway, and near the outer edge. Where is your speed the least? Where is your speed the greatest?

Questions

9. Does moving fast mean having a large acceleration? Explain.

10. Where in the ride did you feel the greatest force on your body? How would you describe your speed at this location?

11. Where in the ride did you feel the least force on your body? How would you describe your speed at this location?

12. Noting the periods of rotation, which axis has the greatest rate of rotation?

Calculations

13. Calculate the angular velocity and linear velocity of a point at the end of a primary arm about the primary axis.

14. Calculate the angular velocity and linear velocity of a point at the end of a secondary arm about the secondary axis.

Extensions

- Discuss the linear velocity, linear acceleration, angular velocity and angular acceleration of a rider at a specific point on the ride. Sketch the different forces acting on the rider at that point.

- What path would a rider follow if the rate of rotation of the secondary arms was much greater, suppose three times greater than the actual rate? Make a sketch of the path.

- Create a mechanical model of the ride to show how the rotation about the two axes affects the path of a rider.

- Create a simulation or mathematical model to investigate the effects of changes in the rotation speeds, rotation directions, and lengths of primary and secondary arms.

The S. S. Overboard

The *S.S. Overboard* is a ship that acts as a pendulum. While riding the *S.S. Overboard*, you will be experiencing free fall at times and a sensation of weightlessness at times.

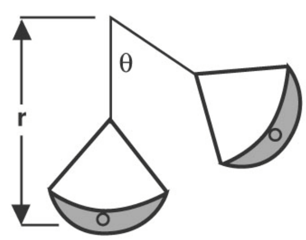
Making Measurements:

1. Observe the "propulsion system" underneath the ship. Describe how it works to power the ride.

2. Measure the time for the boat to make 3 to 5 complete oscillations while the propulsion system is disengaged.

# of oscillations _______ t = _______sec

3. Using triangulation, measure the radius of the boat's path (from pivot point to center of boat). This measurement corresponds to the length of the pendulum. Explain how you arrived at your measurement.



r = ______m

4. Using a protractor, measure the maximum angle that the boat swings from the vertical.

Θ = ______°

5. While riding the ride, use a spring accelerometer to measure the centripetal acceleration at your highest position (at) of the ride and at your lowest position (ab) of the ride.

a_t =_______g's =_______m/s^2

a_b =_______g's =_______m/s^2

6. Describe your sensations of weight:

a. at rest.

b. moving through the lowest point.

c. at the highest point.

7.Sketch a graph showing height above ground of the center of the boat vs. time.

8. Sketch a graph showing horizontal displacement of the center of the boat from rest vs. time.

Calculations

9. Calculate the period T for the boat.

$$T_{boat} = t\ /\ \#\ \text{of oscillations} = \_\_\_\_\_\_ \text{sec/oscillation}$$

10. Using the centripetal acceleration values and measured radius, calculate the velocity of the boat at its highest position (V_t) and at its lowest position (V_b).

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

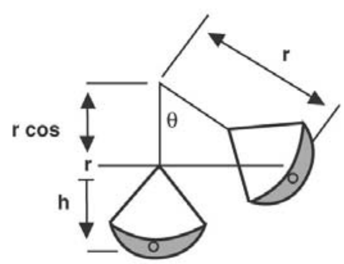
$$v_t = \sqrt{a_t r} \quad \text{and} \quad v_b = \sqrt{a_b r}$$

$$v_t = \_\_\_\_\_\_ \text{ and } v_b = \_\_\_\_\_\_$$

11. Calculate the period (T) of a simple pendulum with a length (L) equal to the radius (r) you obtained.

$$T = 2\pi\sqrt{\frac{L}{g}} \qquad T_{pendulum} = \_\_\_\_\_\_\_ \text{sec}$$

12. Using the angle Θ and radius r, calculate the maximum height (h) that the center of the boat rises.



$$h = r - r\cos\theta = r(1 - \cos\theta)$$

$$h_{boat} = \_\_\_\_\_\_\_\_\_ \text{m}$$

13. Since the total energy (potential and kinetic) is the same throughout the swing, the energy at the bottom (kinetic) equals the energy at the top (potential). Therefore the following equations can be used to calculate the maximum velocity of the pendulum as it swings through it's lowest position.

$$E_{bottom} = E_{top}$$

$$\frac{1}{2} m v_b^2 = mgh$$

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

v_b = _______m/s

Questions

14.In a simple pendulum, the mass is considered to be concentrated at the end of a weightless string. How does the S.S. Overboard differ in its construction?

15. Do you think that the S.S. Overboard acts like a simple pendulum? Why or why not? (Compare your calculations for the boat and the simple pendulum.)

Extension:

• Investigate the component of the acceleration tangent to the motion .
• Investigate properties of a *physical* pendulum.

Circular Rides

Die Fledermaus (Wave Swinger)

Dornröschen (Carousel)

Wagon Wheel

Crow's Nest Ferris Wheel

There are many circular rides throughout the park. Some examples are listed above. These rides offer opportunities to make comparisons and to calculate angular and linear velocities.

Making Measurements

1. Choose any five of the circular rides in the park. Measure the diameter of each by stepping off the distance from an area beside the ride. Estimate the maximum number of people who can ride at one time. Record the time it takes for the ride to complete one revolution. It will be best to take this time once the ride has reached its maximum speed. Also record the time the ride runs from start to finish. Complete the following table.

Ride	Diameter in Meters	Max. People at a Time	Time of One Revolution	Total Time for Ride
a.				
b.				
c.				
d.				
e.				

Calculations

2. *Angular velocity* is a useful way to describe circular motion. The angular velocity (ω), in radians per second, is determined by $\omega = 2\pi/t$, where t is the time in seconds it takes for the ride to make one revolution. Calculate the angular velocity of each of the circular rides you chose. Record the angular velocities in the table below.

3. Linear velocity can also be calculated for circular motion. The linear velocity (v) in meters per second is determined by $v=\omega r$, where r is the radius of the circle in meters. Calculate the linear velocity of each of the rides and record each in the table below.

Ride	Angular Velocity	Linear Velocity
a.		
b.		
c.		
d.		
e.		

Questions

4. In which of the rides you considered does the rider travel the greatest distance during one ride? What is the distance covered?

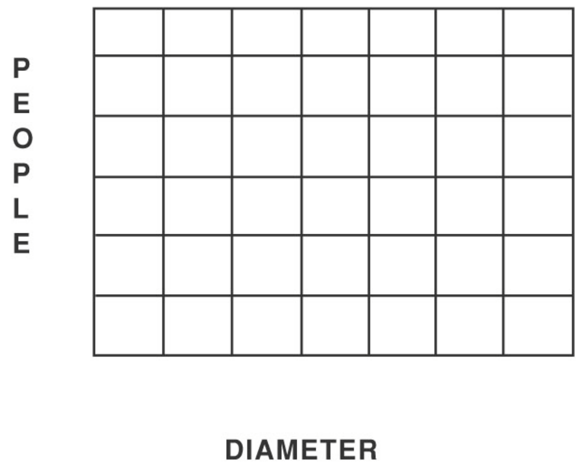
Ride: ________________ Distance: ________________m

5. Which ride has the greatest angular velocity? _____________________

Which has the greatest linear velocity? ____________________________

Would these have to be the same ride? Explain.

6. Look at the maximum number of people and the diameter of each ride. Make a scatter plot of the number of people vs. diameter on the graph below. Be sure to show the scales on both axes. Does there seem to be any correlation? If so, find an equation that models the correlation.



7. What differences can you describe between the rider's experience on circular rides that are horizontal circles (like the Carousel) and those that are vertical (like the Ferris Wheel)?

8. Why do you think the Wagon Wheel starts out as a horizontal circular motion and then moves to a vertical circular motion?

Dornröschen

(The Carousel)

The Dornröschen is a replica of a carousel that was first designed in the early part of this century. This carousel, containing hand-painted panels, animals, and chariots, sends riders back to the romantic times of carnivals and county fairs.

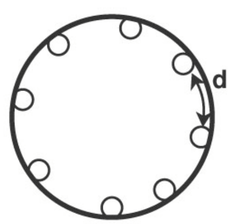
Making Measurements:

1. Determine the period of rotation by measuring the time for two rotations.

$t_{\text{two rotations}}$ = ________sec

t = t/2 = ________sec

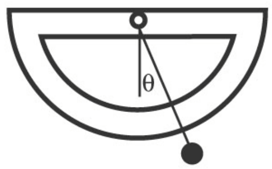
2. As soon as you get on the platform, determine the circumference of the inner ring of animals by measuring the distance between two adjacent animals and then counting the number of animals in one complete rotation. Do the same for the outer ring of animals.



(inner ring of animals) C_i = ________m

(outer ring of animals) C_o = _______m

3. Sit on an animal in the inner ring. Once the carousel reaches full speed, measure the centripetal acceleration using your protractor-sextant. Make sure the protractor is level and you are measuring the angle at which the weight is hanging from the vertical. Now measure the centripetal acceleration while riding one of the outer ring animals.



(inner circle of animals) Θ_i = _______ °

(outer circle of animals) Θ_o = ______ °

4. While the carousel is spinning at full speed, describe any forces that you 'feel' acting on you.

Calculations:

5. Using the measured circumference, calculate the radius for both the inner ring and outer ring of animals.

$$C = 2\pi r$$

(inner ring of animals) r_i = ______m

(outer ring of animals) r_o = ______m

6. Angular velocity is a useful way to describe circular motion. The angular velocity, ω, can be determined by the formula below. Calculate the angular velocity of the carousel in radians/sec.

$$\omega = \frac{2\pi}{t}$$

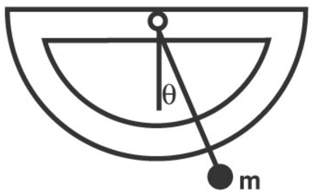
ω = _______radians/sec

7. Centripetal acceleration can be determined with $a_c = v^2/r$ and linear velocity can be found using $v = \omega r$. Combining these two equations we get $ac = \omega^2 r$. Calculate the centripetal accelerations for the inner and outer ring of animals.

a_c for inner ring = ______m/s^2 = ______g's

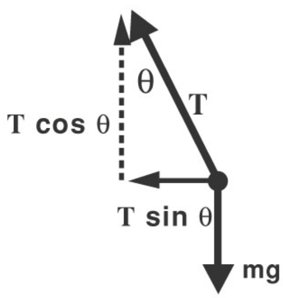
a_c for outer ring = ______m/s^2 = ______g's

8. While undergoing uniform circular motion, the forces on the suspended mass can be broken down into vertical and horizontal components. The sum of the vertical components should equal zero.



$$\Sigma F_y = 0$$
$$mg = T\cos\theta$$

The horizontal component of the string will equal the centripetal force.



$$\Sigma F_x = T\sin\theta = ma_c$$

Since the tangent of the angle is defined as opposite over adjacent, we can then write the equations.

$$\tan\Theta = \frac{T\sin\Theta}{T\cos\Theta} = \frac{ma_c}{mg} = \frac{a_c}{g}$$

$$ac = g\tan\Theta$$

Use this approach to calculate the centripetal acceleration from the angle Θ.

a_c for inner ring =______m/s2 = ______g's

a_c for outer ring =______m/s2 =______g's

Questions

9. At which location on the carousel do you experience the greatest centripetal acceleration? Why?

10. Compare your measured value for centripetal acceleration with that calculated from the angular velocity. Which method of finding centripetal acceleration is the least reliable? Give reasons for your answer.

11. While on the rotating carousel, what is the direction of the net force on you?

12. If you dropped a coin while standing on the outer edge of the carousel while it is spinning, describe the path the coin would move along.

Extension

• Describe the up and down motion of the animals.

• Investigate amplitude, frequency and harmonic motion.

Die Fledermaus

(Swings)

Predict what you think will happen before the ride starts. How will an empty swing behave compared to one with a rider? Draw a sketch.

Draw a diagram of the ride:

a.) at rest

b). rotating but not tilted

c). rotating and tilted

Is there a difference in the radius? Explain.

How did your prediction compare to what actually happened with an empty swing?

Describe your sensations when the ride is:

a). rotating but not tilted

b). rotating and tilted moving downward

c). rotating and tilted moving upward

Making Measurements:

Before:

Measure the period of the swing:

a). rotating but not tilted

b). rotating and tilted

Measure the angle when the ride is rotating but not tilted.

During:

If you have an instrument (horizontal accelerometer or CBL), determine the range of the radial accelerations.

If you have an instrument (spring accelerometer or CBL), determine the range of readings. (Hold it vertical to your frame of reference)

Calculations:

Calculate the centripetal force acting on you when the ride is rotating but not tilted.

$F_c = mv^2/r$ F=______N

Calculate the tension in the chain when the ride is rotating but not tilted.

Draw a vector diagram of the forces acting on you when the ride is rotating but not tilted.

Draw vector diagrams of the forces acting on you when the ride is rotating and tilted.

Draw diagrams when you are at the top of the swing and when you are at the bottom.

Water Rides

Power Surge

Bugs' White Water Rapids

During much of the ride the boats are free floating. Describe how you could estimate the flow rate of the water and determine the time to circulate all the water in the ride once.

Describe what happens to you at the bottom of the hill when the boat splashes. What causes this? (more than *you get wet!*)

If you have an instrument (horizontal accelerometer or CBL), determine your horizontal acceleration during the splash.

a = ______g's = ______m/s^2

Calculate the Potential Energy at the top of the hill.

PE = mgh PE =______J

Calculate the velocity at the bottom of the hill, before the splash.

v = d/ t v =______m/s

Calculate the velocity at the bottom of the hill, after the splash.

v = d/ t v =______m/s

Time how long the splash lasts.

t = ______sec

Calculate the force it takes to slow the boat during the splash. Use impulse.

$Ft = m v$ F=______N

Calculate the amount of work done on the boat while it is being slowed.

$W = Fd$ W =______J

Gully Washer

Describe your experience when you first step onto the boarding wheel.

You walk straight to a boat to board. Describe and sketch:

a). What your path feels like to you.

b). What your path looks like to an outside observer above.

Do you notice any difference in feeling as you walk outward on the wheel?
Take instrument (horizontal accelerometer or CBL) readings if possible.

Estimate the diameter of the wheel and the rate of rotation.

d=______m

rotation =______rpm

Compute your centripetal acceleration:

a). When you step on to the wheel

b). At the outer edge as you board the boat

Compute your angular and linear (tangential) velocity:

a). When you step on to the wheel

b). At the outer edge as you board the boat

Der Pilger Bahnhof

(The Train)

The train makes a circuit around the park. It offers several opportunities for measurement and estimation. For example, can you estimate the average speed of the train, the number of passengers who can ride at one time, and the length of the track?

Making Measurements

1. Estimate the length of the train engine and one of its passenger cars.

Engine:______m   Passenger car:______m

2. Find a railroad crossing and measure the width of the crossing. Then measure the time it takes for the engine to cross the crossing. Be precise; measure from the time the front of the engine enters the crossing to the time the front of the engine leaves the crossing.

Width of crossing:______m

Time for engine to cross:______sec

3. Estimate the length of the entire train and explain the method you used for your estimation.

Length of train: _____________

4. Estimate the number of people who can ride the train at one time and tell how you arrived at your estimation.

Maximum number of people on train: ____________

5. Time the train ride from beginning to end. Also time any stops the train makes during a complete circuit.

Time for one complete circuit: ______min.

Actual time the train is moving: ______min.

6. Describe the motion of the train. Does it seem to run at a uniform speed? If not, where does it run the fastest? Where does it run the slowest?

Calculations

7. Use the measurements you made for the time it took for the train engine to cross a crossing to calculate the speed of the train. After riding the train, do you think this is a good estimate of the average speed of the train? If not, estimate the average speed.

Crossing speed: _______m/sec

Average speed: _______m/sec

8. Use the average speed and the actual running time to estimate the length of one circuit of the track.

Length of track: _______m

Der Pilger Bahnhof

(The Train)

Open-ended Train Question: Assuming that the train moves at a constant speed. Devise a way to calculate the total length of track. **DO NOT DO ANYTHING DANGEROUS!** Draw sketches and show examples of all calculations that you used to solve this problem. Clearly explain your thinking.

Steingasse

(Bumper Cars)

Describe what happens in the following collisions: (assume equal masses)

a). you collide with a stationary car

b). you are rear-ended

c). you have a head-on

d). you collide with a solid object, such as the wall

e). you are sideswiped

The bumper cars have a rubber bumper filled with a large inflated inner tube. Compare what the collisions would be like if there were no bumper. (*Physics students: be sure and use the concept of impulse.)*

Draw vector diagrams showing the moment before and after the different collisions described above.

Calculate the momentum of your car at full speed. Estimate the values if you need to.

Do you think that the collisions are perfectly elastic? Justify your answer.

The bumper cars operate on 90volts DC and use a 1 hp motor.

Sketch what the circuit of one of the cars would look like.

Calculate how much current that a single car draws.

Assume that each car acts as a resistance in parallel. How much total current is drawn during the ride?

How much power is consumed during the ride by the cars?

Waiting Times

Many of the rides in the park have "mazes" in which people wait in line to ride the ride. Choose one such ride and analyze the waiting time.

Making Measurements

1. Choose a ride that has a potential for long lines of people waiting. Sketch the layout of the waiting area. Identify three places in the waiting line from which you will estimate waiting time. Label them ***A***, ***B***, and ***C*** on your diagram.

Ride: ____

Diagram of Waiting Area:

2. Count the number of people ahead of a person in line at each of your points, ***A***, ***B***, and ***C***.

A:______ B:______ C:______

3. How many people board the ride each time it loads? ________

4. What is the time interval between loading times? ______

Calculations

5. Estimate the waiting time from each of your points, ***A***, ***B***, and ***C***, and show how you arrived at your estimation.

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