

Physics Fun: THE INVESTIGATIONS!

The Study of Mechanics, Energy, Force & Motion



Investigations:

Your visit to Lake Compounce is an opportunity not only to have fun, but also to learn about science and the use of technology throughout the park. Use our education program and our exciting rides to broaden your appreciation of Science.



Investigation #1: Zoomerang Coaster

Mass of each car	= 1500 pounds or 680 kg
Number of cars	= 7
Maximum Height	= 36.91 meters Lift 1
35.5 meters Lift 2	
Top of Loop	= 19.325 meters
Total distance traveled	= 286 meters (1 way)
Diameter of loop = _____	



Ride the Zoomerang or watch from the upper midway. Match the statement with the letter from the photo above. Letters may be used more than once and there may be more than one answer for each statement. Keep in mind that the Coaster zooms both forward and backwards.

- _____ 1. Where do you have the greatest potential energy?
- _____ 2. Where do you have the greatest kinetic energy?
- _____ 3. This location is where you have the greatest velocity.
- _____ 4. This location is where you have the slowest velocity.
- _____ 5. This is where you feel almost weightless.
- _____ 6. This is where you feel very heavy.
- _____ 7. Where is work being done?
- _____ 8. Where do you feel the greatest deceleration?
- _____ 9. Where so you experience the greatest G-Force on you?
- _____ 10. This is where the greatest friction is produced.

Observations and Calculations:

1. How many riders are on the Zoomerang? Find the average number per ride from 3 runs of the coaster.

1st trip number
2nd trip number
3rd trip number
average number / trip

2. Use your watch or stopwatch to determine how long the ride lasts from loading people to unloading people.

time = _____ seconds = _____ minutes = _____ hours.

3. Based on the time for one ride, calculate how many rides could be run in an 8 hour day.

_____ rides

4. Using the average number of people per trip and the number of rides per day, how many people could ride the Zoomerang in:

One Day ? _____ One Season (85 days)? _____

5. Work is the force causing something to be displaced. $W = Fd$
 - a. Calculate the work needed to lift the Zoomerang to the top of the first lift hill. Note: For vertical work here, the force is the weight of the train and the riders and the distance is the height. Therefore, $W = mgh$. Use the max number of riders at 63.5 kg each.

- b. Power is the rate of doing work. Calculate the power needed to lift the train to the top of the first hill.

Power = _____ Watts = _____ horsepower

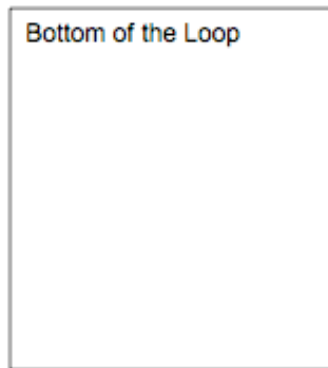
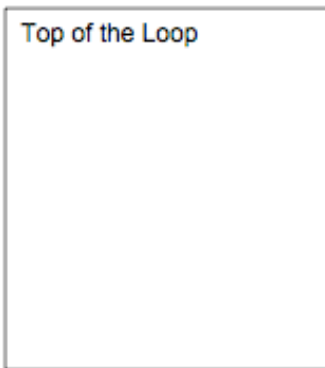
6. Explain qualitatively the energy transformation in one complete trip. Specifically, consider the energy change from the loading area to the first peak and then the change from this point to the end of the ride.

7. What measurements must be made to evaluate the maximum potential energy of the Zoomerang?

- a.
- b. Carefully make these measurements and record the results here.
- c. Calculate the maximum potential energy of the Zoomerang (include riders). Where is the Zoomerang located when it has potential energy? What is the speed at this point? (Label and explain your steps).
- d. What is the Zoomerang's maximum kinetic energy? Where is it located at this time? What is its speed at this point? (Show work)
- e. Compare the speed calculation obtained in (d) above with the speed calculation obtained in the next problem. Comment on any correlation.

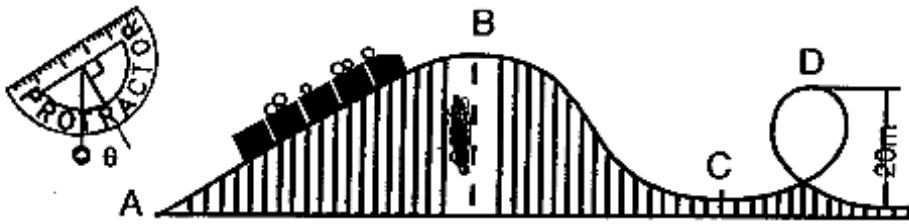
It is said that the speed of a roller coaster as it travels through a loop depends on the height of the hill from which the coaster has just descended. The equation $s = 8 \sqrt{h - 2r}$ gives the speed s in feet per second, where h is the height of the hill and r is the radius of the loop. Using the data assembled at the start of the lab, determine how fast the Zoomerang travels through its initial "loop."

8. a. What force or forces do you feel at the top of the loop?
- b. Draw a free body diagram representing the forces acting on you at:



9. What is the minimum speed you can have when upside down and not fall out? (assuming no restraints). Show your work!

Zoomerang! **Looping Coaster** *10/5*



Measurements

Your mass = __kg

Angle of rise, first hill $\theta =$ -o

Time for first car to reach top of first hill

Time for first car to travel down from B to C

Sensations (Normal, Heavier, Lighter):

At B, just before descending

At about halfway down

At C, bottom of the curve

At D, top of the loop

Observations

1. What is the advantage of a long, shallow first incline?
2. Why is the first hill always the highest?
3. Why is the track of the roller coaster banked?
4. Where does your meter read closest to zero?
5. How do you feel at this point?
6. What does the near zero reading tell you about the track at that point?
7. Where does the meter give a maximum reading? Why is it a maximum here?

Meter Readings:

- force meter =
- force meter =
- force meter =
- force meter =

Looping the Loop

$$\Delta E_p = \Delta E_k$$

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

$$F_{\text{bottom}} = \frac{mv^2}{r} + mg$$

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

$$E_p = mgh$$

$$E_k = E_{\text{total}} - E_p$$

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

$$F_{\text{track}} + mg = \frac{mv^2}{r}$$

$$\text{Force factor} = \frac{\text{track force (force felt)}}{\text{normal weight}}$$

- If there had been no friction, what would be the maximum speed at the bottom of the first drop?
- Going through the curve, the track must exert enough force to both hold you in a circle and counteract gravity. Calculate the force on you at the bottom of the loop.
- Calculate the force factor at the bottom of the first drop.
- Why is it important that the radius be large at point C?
- Calculate your potential energy at the top of the loop. (Point D)
- Assuming conservation of energy, calculate your kinetic energy at the top of the loop.
- What is your speed at the top of the loop?
- At the top of the loop, gravity works with the track to hold you in a circle. Calculate the force the track exerts on you.
- Why is it important that the top radius be small? _____
- What should the force meter read at the top?
- In the space to the right, draw a diagram showing the forces acting on you when you and the force meter are upside down at the top of the loop, and the meter reads zero.

$$\text{Speed} = \underline{\hspace{2cm}}$$

$$\text{Force}_{\text{bottom}} = \underline{\hspace{2cm}}$$

$$\text{Force factor} = \underline{\hspace{2cm}}$$

$$\text{Potential energy} = \underline{\hspace{2cm}}$$

$$\text{Kinetic energy} = \underline{\hspace{2cm}}$$

$$\text{Velocity}_{\text{top}} = \underline{\hspace{2cm}}$$

$$\text{Force}_{\text{track}} = \underline{\hspace{2cm}}$$

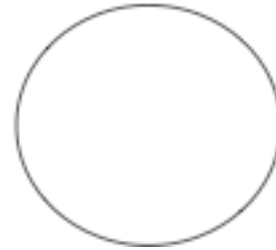
$$\text{Force factor} = \underline{\hspace{2cm}}$$

Investigation #2: The Rotor

1. Below are the measurements needed to determine the centripetal force on you or one of your lab partners. Show forces & velocity on the diagram. Fill in the values.

Measurement	Value
Your mass	
Radius	
Period	

Diagram (Top View)



2. From the radius, calculate the circumference of the Rotor.
3. Calculate the centripetal acceleration on you, and explain how this relates to centripetal force. ($a_c = v^2/r$; $v = \text{Circumference divided by the time for one trip around.}$)
4. G force is a comparison of the normal force of gravity on you to the force you experience in an accelerated frame of reference. A force of 1 g is equal to your normal weight in pounds or newtons.
 - a. What force holds you to the wall of the Rotor?
 - b. Explain in detail what this force is and how it is produced.
- c. Calculate this force on you. (Show your work.) $F_c = mv^2/r$
- d. Calculate the g force acting on you in the Rotor. (F_c divided by your weight.)

5. Draw a free body diagram of the forces acting on you while in the Rotor.
(Label all forces.)

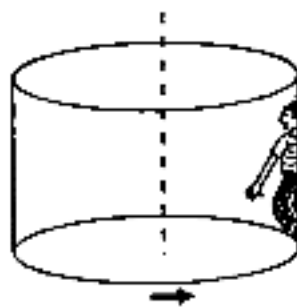


6. a. If you do not slide down the wall, what does this tell you about the force of friction?
- b. What is the normal force in this diagram equal to?
- c. Calculate the coefficient of friction (μ)

Rotor #2

Measurements

- Your mass = _____
Time for ten revolutions = _____
Period = _____
Radius = _____
Force meter reading at top speed = _____
(Hold tube horizontal, next to your eyes)



Observations

1. Describe how the wall feels and explain why it was constructed this way.

2. Describe how the force against your back changes as the speed increases.

3. Have someone on the ride hold an object hanging from a string. Sketch the angle that the string makes with the vertical and describe how the angle changes as the Rotor increases in speed.

4. Imagine a person throwing a ball at someone directly opposite on the ride. Describe the path the ball would follow:
 - a. As seen by other riders.

 - b. As seen by an observer above the ride.

Rotor

Calculations

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

$$F_c = \frac{mv^2}{r}$$

1. Calculate the maximum speed.

$$v_{\text{max}} = \underline{\hspace{2cm}}$$

2. Calculate the centripetal force. (Force exerted by the wall on your back at top speed.)

$$\text{Centripetal force} = \underline{\hspace{2cm}}$$



3. While you are spinning, three forces are acting on you: gravity, friction, and the push of the wall. Show the forces on the figure.

$$F_{\text{friction}} = mg$$

4. Since you do not slide down the wall at top speed, how great is the frictional force? (What is it balancing?)

$$\text{Force of friction} = \underline{\hspace{2cm}}$$

$$F_{\text{friction}} = \mu F_c$$

5. Compute the minimum coefficient of friction necessary for this ride to operate safely.

$$\text{Coefficient of friction } \mu = \underline{\hspace{2cm}}$$

$$\text{Force factor} = \frac{\text{force felt (centripetal)}}{\text{weight}}$$

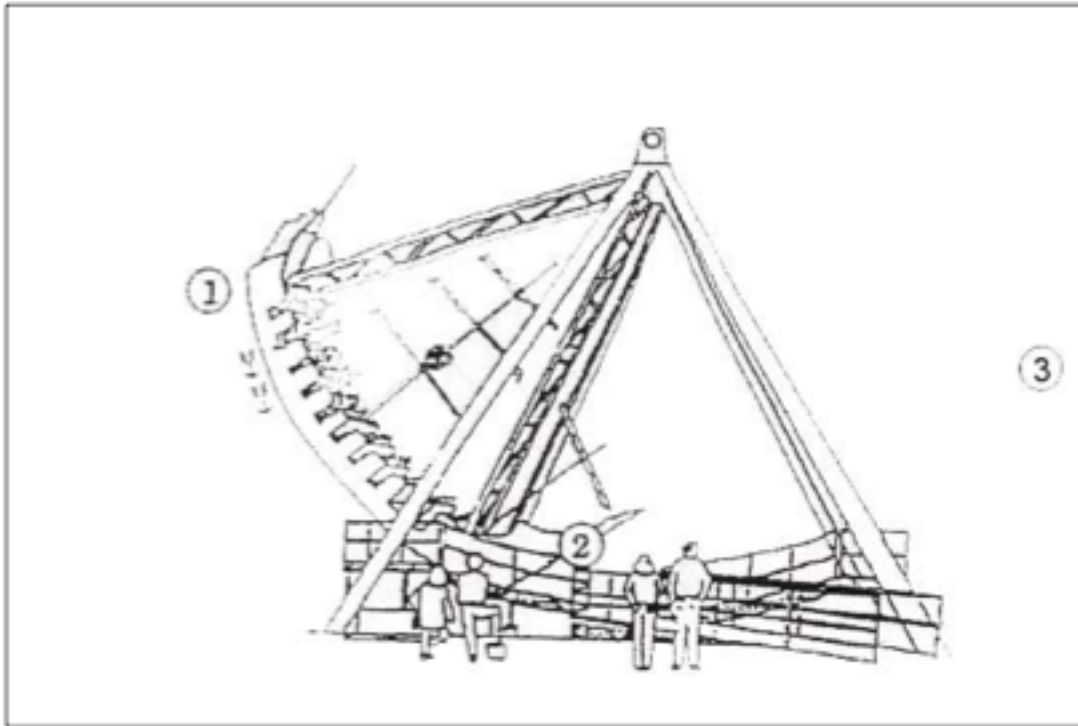
6. Use the centripetal force that you calculated to find the force factor. Compare it with the reading on the force meter.

$$\text{Force factor} = \underline{\hspace{2cm}}$$

Investigation #3: The Pirate

Ride capacity (number of Riders)
Approximate weight (full)
Maximum height of the Pirate
Radius of Swing

Weight of Pirate Empty = 14300 lbs or 6490 kg



1. Explain the energy transformation which occurs when the Pirate is in operational mode.
2. Calculate the maximum velocity of the Pirate and show where this occurs. (Show your work).

Answer _____

3. Measure the period of the Pirate (Use a stop watch and time several oscillations).

Period =

Calculate the frequency of the Pirate. (Show all work).

4. Draw a free body diagram of the forces acting on you when (a) you are at the bottom of the swing and (b) at the top of the swing.

Bottom	Top
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5. Using the Pirate as a pendulum, and the information from above, calculate the acceleration due to gravity at this park. (Show your work).

$g =$

Investigation #4: The Carousel

Note: Answer the questions based on your position on the Carousel. Use two different distances from the center.



Data:

Trial #1

Trial #2

1. Your distance from center
2. Your period of rotation
3. Your velocity
4. Centripetal force acting on you

Show your work here:

1. What effect on the centripetal force did changing your location produce?
2. If you are near the center of the Carousel, explain what strategy you would use to throw a ball to a partner on the outside edge.
3. If the output of the engine is 25 hp. Calculate the work required to turn the Carousel once.

(Note: 1 hp = 550 ft-lbs/sec or 746 watts).

Work _____

Carousel #4

Measurements

Period: _____

Number of horses in outer ring: _____

Space between horses: _____

Number of horses in inner ring: _____

Space between horses: _____

Hold the horizontal meter perpendicular to the horse at top speed and record the angle with the vertical:

Inner horse: _____

Outer horse: _____



Hold the force meter upright and record the meter readings as the horse goes up and down.

At bottom going up: _____ In middle going up: _____ Arriving at top: _____

At top starting down: _____ In middle going down: _____ Arriving at bottom: _____

Observations

1. Is the floor level? _____ If not, which way does it tilt? _____
Why? _____

2. How does the angular velocity of the outer horse compare with that of the inner horse? (Compare their revolution rates.) _____

3. Which horses appear to have the greatest linear speed, the inner or the outer? _____

4. How do the readings on the vertical force meter relate to the force sensations that you experienced? _____

5. How does the radial force meter reading on an inner horse compare with that on an outer horse? _____

Carousel # 4

Calculations (Show all substitutions)

$$C = 2\pi r$$

$$v = \frac{\text{Circumference}}{T}$$

$$F_c = \frac{mv^2}{R}$$

$$F_g = mg$$

$$F_c = \frac{mv^2}{R}$$

1. Calculate the circumference of the outer ring (distance between horses times number of horses) Circumference = _____
2. What is the radius of this ring? Radius = _____
3. Calculate the average maximum speed of an outer horse. Maximum speed = _____
4. Calculate the circumference of the inner ring and its radius. Circumference = _____
Radius = _____
5. What is the maximum average speed of an inner horse? Maximum Speed = _____
6. How do your calculations compare to the answer to observation #3? Explain.

7. Calculate the centripetal force acting on you when you ride on outer horses. Centripetal Force = _____
8. Give your weight in newtons. Weight = _____
9. In the space to the right diagram the forces on a rider. Show the angle β between the vertical and force applied by the plastic tubing. The centripetal force is the resultant force.
10. Compute the centripetal force on you as you ride an inner horse. Centripetal force = _____
11. Using your vector drawing, discuss what you expect to happen to β as you change from an inner to an outer horse. How do your measurements of β compare with your expectation?

Investigation #5: The Wildcat

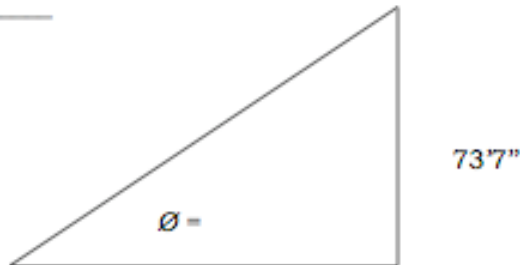


Data:

Your mass: _____ kg
Angle of the first hill: _____ °
Time for train to travel up the first hill: _____ sec.
Elevation of first hill = 73'7'' from grade level (_____ meters)

1. Calculate your average speed going up the first hill.

Distance = _____



Velocity Calculation Here

Distance Calculation Here

2. What is your potential energy at the top of the first hill? (Show work)
3. How much work was needed to get you to the first hill? (Show work)
4. What force was used to get you to the top of the hill? (Show work)

5. The Wildcat track at the bottom of the first hill is at an elevation of 5' 2'' from grade level or _____ meters. (Show all work)
- How much potential energy is remaining at the bottom of the first drop?
 - How much kinetic energy do you have at the bottom of the first drop?
- c. Calculate your velocity at the bottom of the first drop.

First Turn: Radius of curvature = _____ feet (_____ meters)
 Elevation = 57' 9'' or (_____ meters)

- What is your velocity in this turn? (Show your work)
- Calculate the centripetal force on you in this turn. (Show your work)
- Why is the track banked in the curve?
- What is the g force on you in the turn? (Show your work)

End of Ride: Time to stop: _____
 Braking point elevation = 21' 1'' (_____ meters)
 Braking distance = 250 feet (_____ meters)

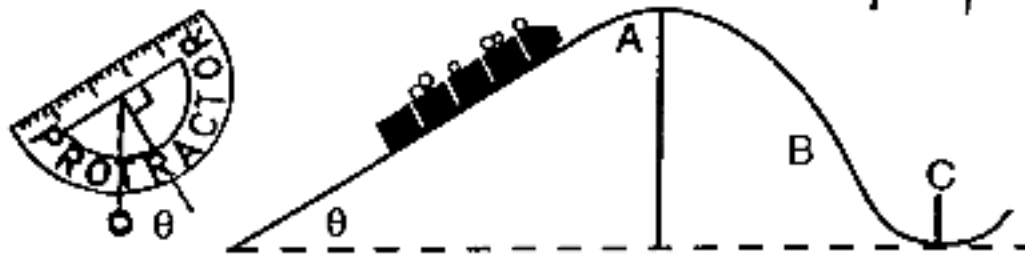
- What is your velocity at the braking point? (Show your work)
- What is your deceleration? (Show your work)



#5 Wildcat!

Roller Coaster

1 of 4



Measurements

Your mass = _____ kg Time for first car to reach top of first hill = _____ s
 Angle of rise, first hill, $\theta = 27^\circ$ Time for first car to travel down first incline = _____ s

Sensations (normal, heavier, lighter):

Meter readings:

At A, just before descending _____

Force meter = _____

At B, about half way down _____

Force meter = _____

At C, bottom of the curve _____

Force meter = _____

Observations

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

- Why is the first hill always the highest?

- Why is the track of the roller coaster banked?

- Where does your meter read closest to zero? _____
How do you feel at this point?

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

- Where does the meter give a maximum reading? _____
Why is it a maximum here?

Roller Coaster #5 Wildcat

Calculations (Show all substitutions)

$$E_p = mgh$$

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

$$F = mg \sin \theta$$

$$\text{work} = mgh$$

$$F \cdot l = \text{work}$$

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

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

$$v_{\text{final}} = 2(v_{\text{average}})$$

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

1. What is your potential energy at the top of the first hill? Potential energy at top = _____
2. What power is used to get you up the first hill? Power = _____
3. What is the length of the first hill? Length = _____
4. What force is used to get you up the first hill? Force = _____
5. How many times your normal weight is this? Force factor = _____
6. Calculate the average speed from A to C. Average speed = _____
7. What is your speed at the bottom of the first hill, based on the average speed from A to C? Final speed = _____
8. What kinetic energy does this speed give at the bottom of the first hill? Kinetic energy at bottom = _____
9. Within experimental error, was your energy conserved? Explain your answer. _____

4 of 1

Finding the force factor at the bottom of the first drop (Show all substitutions)

At the bottom of the first drop, the track makes an almost-circular arc, as if it were part of a circle of radius 50 m. Use the steps given below to find the force factor that you experience as you go through the low point on the track.

$$\Delta E_p = \Delta E_k$$

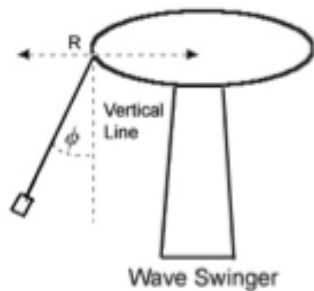
$$E_k = \frac{1}{2} mv^2$$

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

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

1. Assuming no friction, find the maximum speed at the bottom of the first drop. Speed = _____
2. In order to go through this curve, the track must exert enough force to both hold you in a circle and balance your weight. Calculate the force that the track exerts on you at the bottom of the loop. Force_{applied} = _____
3. Calculate the force factor at the bottom of the first valley. Force factor = _____
4. How did the force factor that you calculated compare with the meter reading at C?

Investigation #6A: Wave Swinger



1. Estimate the radius of the circle traveled by a chair in the outer ring as the ride operates
2. Using the above value, calculate the distance (circumference) traveled by the chair in one revolution.
3. Calculate the linear speed of the moving chair.
4. Estimate the mass of the chair and the average rider.
5. What is the centripetal force needed to keep the chair with rider moving in a circle? (Assume the swing chair has a mass of 9 kg.)
6. Measure or estimate the angle between the chair chains and the vertical.
7. What is the tension needed in the chain to supply the centripetal force in Question #5?
8. Diagram the ride at the following times:
 - a. at rest
 - b. when it is moving, but not tilted
 - c. when it is moving and tilted.

Is there any difference in the radius? Please explain.
9. Determine the length of the entire chain.
10. What causes the swings to move out as the wheel turns?

11. Where does “down” appear to the riders?
12. Describe the reasons for the different sensations on the ride at the following points:
 - a. when moving, but not tilted.
 - b. going down when tilted.
 - c. going up when tilted.
13. Measure the period of a swing when:
 - a. moving and not tilted.
 - b. moving and tilted.
14. How does the angle of an empty swing compare with the angle of an occupied one at the same radius? Does the mass of the rider seem to make any difference?
15. Although the hub is rotating at a constant rate, it does not seem that way when the ride is tilted. Indeed, your tangential velocity is NOT constant. Why?
16. Determine the tangential speed at which the outer swing is moving when the hub is moving and tilted. Give the answer for both the bottom and top of the orbit.
17. Determine the tangential acceleration of the outer swing when the hub is moving and tilted. Give the answer for both the bottom and top of the orbit.
18. Find the centripetal force of an empty swing when the hub is moving and tilted. Give the answer for both the bottom and top of the orbit.
19. The swing angle is the difference of the vector combination of the gravitational and centripetal forces. Calculate the theoretical angle the swing should have (when the ride is not tilted), and compare it with the measured value.
20. Calculate the gravitational, centripetal, and tensional forces acting on the swing when you are in it. Do this for the following four cases:
 - a. at rest
 - b. moving, but not tilted
 - c. moving, tilted, and at the top of the orbit.
 - d. moving, tilted, and at the bottom of the orbit.

How do these compare with the same quantities when the swing is empty?

Rotating Swings #10

1 of 4

Measurements

Time 2 revolutions at top speed

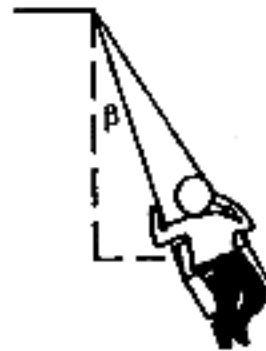
$t =$ _____

Period = _____

Radius of ride at top speed = _____

Maximum angle chain makes
with the vertical $\beta =$ _____

Force meter reading along the chains
at top speed = _____



Observations

1. Sketch what happens to the swing as the ride gains speed:
Start Slow Fast

2. How do you feel as the ride gains speed?

3. Compare the angle of the chain with respect to the vertical on an empty swing with that of an occupied one at the same radius:

More Less The Same

4. Describe the change in the motion that occurs as the ride gains full speed:

5. Describe the path of the top of the ride:

6. How does the force meter reading relate to how you feel on the ride?

Rotating Swings #6 2 of 4

Calculations (Show all substitutions)

$$\text{Speed} = \frac{2\pi r}{T}$$

$$F_c = \frac{mv^2}{r}$$

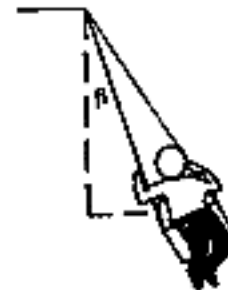
$$F_g = mg$$

1. Calculate the maximum speed of the swings.
2. Calculate the centripetal force acting on you.
3. If you have not already done so, calculate your weight in newtons.
4. Sketch all the forces acting on this rider.

Speed = _____

Centripetal force = _____

Weight = _____



5. To find the tension in the chains:
 - (1) Draw to scale a horizontal vector representing the centripetal force pointed left.
 - (2) Add to it a vertical vector equal in magnitude to your weight but directed upwards. These are the components of the tension.
 - (3) Draw the resultant force vector (tension) and determine its magnitude using your scale.
6. How does angle θ in your drawing compare with angle measured while observing the ride?

Calculated tension = _____

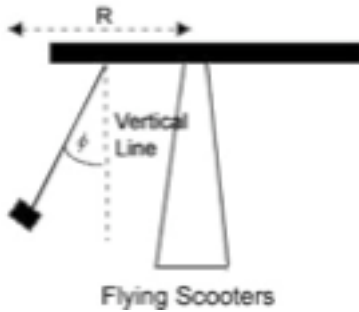
Diagram $\theta = \underline{\quad}^\circ$

7. Multiply the force meter reading by your weight. This gives the measured tension.

Measured tension = _____

8. How does the calculated tension compare with the measured tension?

Investigation #6B: The American Flyers



The American Flyers are similar to the Wave Swinger in that the cars swing out away from the axis of rotation during the ride. The American Flyers are different because the rider controls the amount of the swing by positioning the “sail” on the front of the vehicle.

1. Estimate the mass of the car and passenger.
2. Estimate or find the period of rotation.
3. Estimate the radius of the circle traveled by the “flying car” when the passengers do not touch or move the “sail.”
4. Estimate the amount of centripetal force needed to keep the vehicle flying in the circle described in Question #3. Explain.
5. Estimate the amount of centripetal force needed to make the vehicle fly as far as possible from the ride’s axis.
6. Estimate the amount of centripetal force needed to make the vehicle fly as close as possible to the ride’s axis.
7. What is the approximate outward force that can be provided by the “sail.” How did you get this answer?
8. What is the approximate inward force that can be provided by the “sail”? How did you get this answer?

Investigation #7: Saw Mill Plunge (A Water Roller Coaster)

Reminder: Use the information provided by your teacher concerning the bench marks for hard-to-measure locations.

Data and Measurement:

Length of boat: 9 ft = _____ meters Mass of boat: 350 lb = _____ kg

Vertical drop of hill: _____ meters Angle of down hill: _____

Time for whole boat to pass any given point before going up to top of hill: _____ seconds t1

Time for boat to come down hill: _____ seconds t2

Time duration of the splash at the bottom of the hill: _____ seconds t3

Time for whole boat to pass any given point after splashing at bottom of hill: _____ seconds t4

Observations:

1. Why is there water on the slide or hill and not just at the bottom of the slide?
2. If there is a great deal of mass in the front of the boat, is the splash larger or smaller than if there is a smaller mass in the front? If so, explain.
3. Is there an observable splash-time difference with greater mass in the front than if the greater mass is in the rear? If so, explain.
4. Is there any place on the ride where riders “lunge” forward involuntarily? Where does this occur? Explain why.

Calculations:

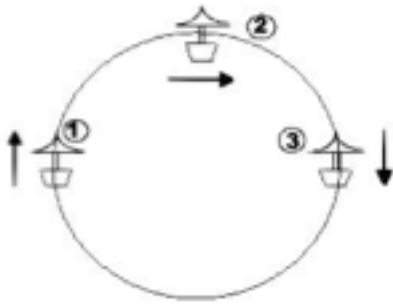
1. Determine the average velocity of the log before going up the hill.
2. Calculate the length of the hill.
3. Determine the average speed of the log down the hill.
4. Assuming the speed of the log at the top of the hill is the same as the speed before the hill, calculate the speed of the log at the bottom of the hill just prior to splashing.
5. Calculate the average acceleration of the log going down the hill.
6. Calculate your momentum at the bottom of the hill before splashing.
7. Calculate your momentum after splashing is complete.
8. Using the time of splash, calculate the average force you experience during the splash.
9. List several purposes of having water as part of this ride.
10. Compare this ride to a roller coaster. What are the similarities?

Investigation #8: Compounce Mt. Skyride



1. Determine the length of the Skyride in meters. Describe the method you used to determine the total distance (round trip) that a single chair travels during its circuit.
2. Observe the ride for one full circuit (or ride the ride yourself). How long does it take for the ride to reach the top of the mountain?
3. How many chairs are on the Skyride? Each chair can carry up to 4 adults. Using information from your answers to the above questions, what is the average number of people that can ride the chairlift in an 8 hour day if all chairs are used?
4. What is the distance between chairs? Explain how you arrived at your answer.
5. The Skyride is a continuously moving attraction. If you are on the chair at the base of the mountain heading upward, is this potential energy or kinetic energy?

Investigation #9: Ferris Wheel



1. If you were sitting on a bathroom scale, where on the above diagram would you see a greater weight than normal?
2. At which position in the above diagram would you see a smaller weight?
3. Estimate the maximum speed of the ride in rpms (revolutions per minute).
4. Does the size of the Wheel affect your perception of its speed? Why or why not?
5. How many gondolas are there on the Ferris Wheel?
6. What are the maximum numbers of passengers that the wheel can carry with a capacity of 6 adults or of 8 children per gondola?
_____ adults _____ children
7. Estimate / calculate the full height of the wheel from its base.
_____ meters
8. Estimate / calculate the radius of the wheel. _____ meters
9. Calculate the circumference of the wheel. _____ meters
10. If light bulbs are to be placed 6 centimeters apart around the front edge of the perimeter (circumference) of the wheel, give a close approximation of how many bulbs would be needed.

11. Compute the mechanical advantage if the radius of the Ferris Wheel is 12.2 meters and the diameter of the axle is 12.0 inches.
-

12. Time 1 complete period (use a particular chair as your starting point). Find the height for each angle (use triangulation). Make a data table of angles, times, and heights from starting point. Label time in seconds and height in meters. Plot 1 period of a time vs. height graph.

Angle	time	height
0		
$\pi/4$		
$\pi/2$		
$3\pi/4$		
π		
$5\pi/4$		
$6\pi/4$		
$7\pi/4$		
2π		

13. Write a sine equation for your graph.
14. At what height will the chair used as the starting point be after 15 seconds? Use your equation to answer.

Investigation #10: Enterprise



A road is banked to differing angles and curves based upon the speed that cars and trucks will use when traveling the road.

The suspended cars of the Enterprise will swing out at some angle when they travel in a circle. The angle depends upon the radius of the circular path and the speed of the wheel.

1. Measure the radius of the wheel.
2. Measure the angle each car makes with the vertical as the wheel approaches full speed while rotating horizontally. Is each car uniformly the same angle, regardless of the position around the wheel?
3. Record your spring accelerometer reading at the following points of the ride:
 - a. at rest
 - b. at full speed, but while horizontally oriented.
 - c. at full speed, but at maximum vertical orientation
 - i. at the top
 - ii. halfway down
 - iii. at the bottom
 - iv. halfway up
4. Record your apparent weight changes (sensations) and compare with the readings in Question #3.
5. Carefully observe the angle of each car relative to its suspension point as it goes around when the arm is at its maximum vertical elevation. Why is it different when approaching the very top from when it is approaching the very bottom?

6. At what point do you feel the lightest?

The heaviest?

Why is there a difference?

7. Determine the period of motion when the car is rotating at its maximum rate.

8. Calculate the accelerations and the number of g's experienced when:

a. at rest

b. at full speed, but while still horizontally oriented.

c. at full speed, but at maximum vertical orientation:

i. at the top.

ii. halfway down

iii. at the bottom

iv. halfway up

9. Calculate the force the seat exerts on you at the bottom when the ride is vertical.

10. Draw a force diagram showing all of the forces acting on your body in each of the following situations:

a. at rest

b. at full speed, but while tilt horizontally oriented

c. at full speed, but at maximum vertical orientation

i. at the top

ii. halfway down

iii. at the bottom

iv. halfway up

11. Knowing the force acting on a rider when the car is rotating at top speed in a horizontal circle (Question 10b), derive an expression for calculating the theoretical angle of tilt of the cars at this speed.

12. Using the results from Question 11, calculate the theoretical angle of tilt of the cars at top speed. Compare and contrast this theoretical value of tilt with the measured value.

13. Calculate the gravitational, centripetal, and tensional forces acting on you while you are on this ride. Do this for the following four cases:

a. at rest

b. moving, but not tilted

c. moving, tilted, and at the top of the orbit

d. moving, tilted, and at the bottom of the orbit

Investigation #11: The Bumper Cars

Participate in this investigation with a partner.

- What happens in a collision to each car when:
 - one bumper car is not moving?
 - a rear-end collision occurs?
 - a head-on collision occurs? (speculate)
 - there is a collision with a stationary object (the side rail)?
 - cars sideswipe?
- Describe how you feel when any type of collision occurs. Are you a well-packaged passenger? Please explain your answer.
- How is electrical energy supplied to the bumper cars? Describe the complete circuit for one of the cars.
- Why do the cars have rubber bumpers?
- Mass of the bumper car: 385 lbs _____ kg
Mass of rider (you) _____ lbs _____ kg
Mass of car and rider _____ lbs _____ kg
Total mass of your partner and his/her car _____ kg
- During collisions, is kinetic energy always conserved? Please explain your answer.
- Is the mechanical energy (kinetic + potential) of the bumper cars conserved? Please explain your answer.
- Estimate the average speed of a bumper car in motion.
- Estimate the stopping distance of a bumper car in an average collision. Try to observe the approximate amount of “give” of a bumper car in a number of different collisions where the car comes close to stopping after the collision.
- Find an average negative acceleration of a bumper car in an “average” collision. How many g’s is this? (Show your work)

11. Assume that you are traveling at 2 m/s. for momentum $mv=mv = \text{impulse } (f \cdot t)$

- a. Calculate the momentum of you and your car.
- b. You collide with a wall and rebound at a speed of 1 m/s. Calculate the momentum of you and your car after the collision with the wall bumper. (Keep in mind that momentum is a vector quantity!)
- c. Calculate the change in momentum of you and your car.
- d. Assume that you are moving at 2 m/s. You strike a wall bumper and come to a rest in 0.5 seconds. Calculate the impulse acting on you and your car during the collision.
- e. Calculate the force that caused the change in momentum.

Investigation #12: Thunder Rapids Raft Ride

Data and Measurements:

Mass of raft: 681.8 kg

Radius of raft: _____ meters

Vertical length of lift conveyor: _____ meters

Time for whole raft to pass any given point before going up to top of hill: _____ seconds

Time for raft to cycle the route: _____ seconds

Time duration of the raft in the load / unload station: _____ seconds

Time for whole raft to pass any given point after entering the station until it drops off the conveyor _____ seconds

Observations:

1. Why is there water on the slide or hill and not just at the bottom of the slide?
2. If there is a great deal of mass on one side of the raft, is the splash larger or smaller than if there is a smaller mass on a side?
If so, explain.
3. Is there an observable splash-time difference with the greater mass of a fully loaded raft than if the greater mass is on one side?
If so, explain.
4. Is there any place on the ride where the riders “lunge” forward involuntarily? Where does this occur? Explain why.

Calculations:

1. Determine the average velocity of the raft before going up hill.
2. Calculate the length of the conveyor hill.
3. Determine the average speed of the raft up the hill.
4. Assuming the speed of the raft at the top of the hill is the same as the speed before the hill, calculate the speed of the raft at the end of the trough just prior to entering the load / unload station.
5. Calculate the average acceleration of the raft as it leaves the conveyor.
6. Calculate your momentum at the bottom of the trough before entering the load / unload station.
7. What happens to your momentum as water splashes down on you at Lover's Rock.
8. List several purposes of having water as part of this ride.
9. Compare this ride to a roller coaster. What are the similarities?
10. What would happen to the time length of the ride if the inflatable tubes were to be over inflated? Under inflated?

13. _____ ((((. . . = = = *Boulder Dash*

This mountain coaster, new in 2000, is marvel of engineering. It is the longest wooden roller coaster on the east coast and the only one of its kind, built on a 750 ft. mountain, which forms the western boundary of Lake Compounce Park. The course is determined by the mountain topography and designed to disturb as little of the natural setting as possible, including the trees, bushes, ledges, and boulders.

The coaster ride begins in the north end of the Park near the Ferris Wheel (located in Bristol) travels to the south end of the Park near the Skyride (located in Southington) and back again over 4500 plus ft. of track. For a breathtaking two minutes, guests race through dense woods, past rugged rock facing, and between large boulders at up to 60 miles per hour.

The unusual design tries to keep the coaster a hill hugger and very fast. The speed doesn't change greatly during the ride as with most roller coasters. Heavily dependent on gravity from the top of the first initial drop on, it maintains a high range speed throughout the ride. For true coaster lovers (as well as everyone who dares to ride), a deluxe assortment of other specialties complete the unparalleled ride. In amusement park lingo, your experience might include sideways jogs, bunny hops, ejector or floater airtime, laterals, and a feisty 180-degree turnaround.

In short, Boulder Dash may be one of the coolest psychologically thrilling rides in the world. Because you are actually riding on a real intact mountain, many unexpected "blind" surprises may have your hair standing on end.

Now, that you know the scoop, give it a try!

Data:

One train: Mass of each car: 1134 kg
Number of cars: 6
Capacity of one train: _____

Your Mass: _____ kg
Total distance traveled: 4672 ft. = _____ meters
Total time of ride: _____ seconds
Time from loading to unloading: _____ seconds

Estimate height of first hill: _____ ft = _____ meters
Estimate angle of first hill: _____
Time to climb first hill: _____ seconds

Estimate height of largest drop hill: _____ ft = _____ meters
Time to descend largest drop hill: _____ seconds

1. Calculate the distance up the first hill.
2. Calculate your average speed going up the first hill.
3. What is your potential energy at the top of the first hill?

(Show your work.)

4. How much work was needed to get you to the first hill?

5. What force was used to get you to the top of the hill?

6. From observation: Does relatively the same speed appear to be maintained throughout the ride ?
How about as the rider?
7. Did the speed appear to be faster because of the boulders and trees?
8. Were there any backward leaning zones?
Any forward leaning zones?
9. What percentage of your ride appeared to be airtime?
Compare your estimate with those of your classmates.

10. Compare your adventure on Boulder Dash to that of the Wildcat and/or the Zoomerang.
 - a. On which coaster did you experience less sideward g forces?
 - b. On which coaster did you have more airtime?
 - c. Did you experience differences in speed?

Congratulations! You are now officially a bold, brave, bona fide Boulder Dasher!

DOWNTIME!!!

14. A heart pumping, adrenaline flowing, white knuckled, and literally hair raising experience, DownTime is a vertical drop tower with attitude and turbo action.

After the guests are seated, the cart is raised slightly and weighed. Then it is steadily lifted to the top of the tower where it is locked in brakes. Stationary for a few seconds, the cart is then abruptly launched toward the ground with chilling negative g-force acceleration. The ride softens with a bungee like bounce before reaching the bottom of the tower and rebounds for a few soft bounces before descending slowly back to the ground. Air pressure, power cylinders, pistons, and air powered brakes work in harmony with each other to provide guests with some exciting ups and downs.

Whether you're a watcher or a rider, DownTime is an interesting phenomenon to investigate.

1. How many guests can the ride accommodate?
2. Why do you think the cart needs to be weighed?
3. Measure the overall cycle time of the ride from start to finish to gain perspective about the ride. You'll need a watch with a second hand or one with a stopwatch mode.
4. Measure the time it takes for the cart to be lifted to the top of the tower. Start measuring at the end of the weigh sequence.
5. Measure the time of the cart's turbo descent. Start immediately after release of the braking mechanism. Hint: Don't look away or you'll miss it! Stop just as the cart is ready to bounce.
6. Calculate the height of the DownTime tower (including the flagpole) using triangulation. The distance from the center DownTime tower panel to the right front corner of the retail building (facing building) is 83.79 feet = _____ meters. (Reminder: The height of the ride = height from sighting + height of your eye.)
7. Calculate the height of the DownTime tower (excluding the flagpole).

DownTime is **185 feet tall** (without the flagpole). The **dynamic distance is 165 feet** (the distance through which all the action occurs.) The **first bounce** occurs about **40 feet up** the tower (from height without flagpole). The empty cart weighs approximately 2000 lbs.

185 ft = _____ m 165 ft = _____ m 40 ft = _____ m 2000 lbs = _____ kg

8. Calculate the average speed of the cart moving up the tower (begin end of weigh sequence).

9. Calculate the average speed of the cart moving back down toward the ground (begin release to just as cart is entering first bounce).

10. Calculate the momentum of cart filled with riders (140 lb average), as it is entering first bounce.

11. Consider the following overview of the DownTime ride cycle, filling in the blanks as you proceed.
 - A. Load/unload passengers: Cart is at tower bottom. Air pressure in all components except the air supply tank is at ambient.

 - B. With the cart lifted slightly and held at constant height, the weight is established. The ride control system determines the _____ required to accomplish the desired ride action.

 - C. The cart is dispatched and moves from bottom to top of tower. The “up-valve” admits air into the power _____ to accomplish this. The air admitted into the cylinders acts on the top side of the _____ and drives them downward. The passenger cable system lifts the cart in proportion to _____ movement. Air is exhausted from the “dump-valve and exhaust” located on the bottom of each cylinder.

 - D. The cart is latched in the air-powered _____ at the top of the tower. As the cart is held, the air in the upper portion of the cylinders and main valve is vented to atmosphere through the port valve filters, and calculated _____ is introduced into the bottom side of power cylinders and the turbo tank.

 - E. Cart launch: The brakes release the cart and air pressure accelerates the cart downward with an initial acceleration of approximately _____ g. The power cylinders top side begins to build pressure. The power cylinders bottom side begins to dissipate pressure.

 - F. The cart reaches the bottom of the first bounce about 40 ft up the tower as air is compressed by the pistons. Passenger cart acceleration loading attains its _____ vertical acceleration of approximately _____ g. The air pressure in the upper portion of the power cylinders and the main valve reaches its _____. This pressure depends on the _____.

 - G. The cart bounces softly several times and descends slowly back to the ground.

14. If DownTime was a free fall drop tower rather than a turbo drop tower, what differences would you expect to find in the ascent and descent? Consider time, speed, and g forces.

You're done?! Had fun?! Then you've earned some Down Time!

To aid in triangulation measurements, 4 “bench marks” have been placed in the Park at carefully measured distances from hard-to-measure locations, as follows.

1. A yellow marker can be found on the rail of the fence in front of the Zoomerang, facing the loop. It is exactly 107' 7" from a point directly under the center of the Loop. It is also 185' from a point under the starting end of the Track (Lift 1).
2. A nail has been driven into the asphalt directly in front of, and 100' from the Pirate. It is at the intersection of perpendicular lines from the lamp post in front of the Pirate and a nearby lamp post in front of the Twister.
3. To gauge the drop height at the Saw Mill Plunge, a stone marker is in the grass lawn with trees in front of the water pumps at the lift slope, outside the fence, and up the stone-walled terrace. The marker is 75 meters horizontally from a point under the top of the drop hill. The ground at the marker is 1 m below the water level at the bottom of the drop hill.
4. Another nail has been placed into the asphalt in front of the raised garden with Carousel horse) in the entrance Plaza. It is aligned with the highest point of the first hill of the Wildcat roller coaster and is 7' 4" from the garden wall when facing and aligned with the flag atop the Wildcat. The nail head is 186' from a point below the highest elevation of the Wildcat.