**MAGIC MOUNTAIN PHYSICS LABS - HONORS**

This packet contains the labs that need to be completed and returned to your teacher the Tuesday after we return. You will only need to do FOUR of the labs in this packet. The labs are listed as Type A, Type B, Type C, and Type D labs; you must do one lab from each type. You may do the “You Choose the Ride Lab Report” on the last page for a few extra credit points. Preview the labs and determine ahead of time which ones you plan to complete as well as what information you will need to gather while at the park. Your group will need to check out an accelerometer and an angle-measuring device that you and your group will be responsible for returning, in working order, to your instructor. You will also need a stopwatch or a phone or digital watch that can double as a stopwatch (times to nearest .01 second) for timing. A $10 replacement fee will be assessed to any group that loses or breaks their school equipment. These labs must be completed in groups of 2-4 students *from the same teacher*.

A note on measurements: sometimes we find large errors in the data collected on or about the rides. If this dreaded event happens to your group, you have a chance to correct yourself. First, you must show me all data YOU collected and the calculations completed WITH YOUR DATA. Then you may get data from another source (another group, the Magic Mountain web site, a knowledgeable park employee), CREDIT THE SOURCE, and again complete the calculations with the new data.

**NAMES \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period \_\_\_\_\_\_\_\_**

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**MAGIC MOUNTAIN PHYSICS LABS - REGULAR**

This packet contains the labs that need to be completed and returned to your teacher the Tuesday after we return. You will only need to do THREE of the labs in this packet. The labs are listed as Type A, Type B, and Type C labs; you must do one lab from each type. You may do the “You Choose the Ride Lab Report” on the last page for a few extra credit points. Preview the labs and determine ahead of time which ones you plan to complete as well as what information you will need to gather while at the park. Your group will need to check out an accelerometer and an angle-measuring device that you and your group will be responsible for returning, in working order, to your instructor. You will also need a stopwatch or a phone or digital watch that can double as a stopwatch (times to nearest .01 second) for timing. A $10 replacement fee will be assessed to any group that loses or breaks their school equipment. These labs must be completed in groups of 2-4 students from the same teacher.

A note on measurements: sometimes we find large errors in the data collected on or about the rides. If this dreaded event happens to your group, you have a chance to correct yourself. First, you must show me all data YOU collected and the calculations completed WITH YOUR DATA. Then you may get data from another source (another group, the Magic Mountain web site, a knowledgeable park employee), CREDIT THE SOURCE, and again complete the calculations with the new data.

**NAMES \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period \_\_\_\_\_\_\_\_**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period \_\_\_\_\_\_\_\_**

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**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period \_\_\_\_\_\_\_\_**

**Magic Mountain Measurement Lab Entrance Exam**

The purpose of this exercise is to become familiar with the double triangulation method of estimating height and correct any errors in measuring techniques before entering Magic Mountain.

**You must show all of your measurements and calculations and obtain your instructor’s initials before entering Magic Mountain**

**Objective**: Determine the height *of* ***“X” - The Extreme*** from the parking lot using the double triangulation method.

**Apparatus**: Horizontal Accelerometer, 10 meter long string

### **Procedure:** Double Triangulation – From the parking lot of Magic Mountain, use triangulation to find the height to the top of the first hill of ***X-The Extreme***. Since the fence keeps you from easily and accurately pacing from directly beneath the structure, you will need to use the double triangulation method to find the height. Start from a location in the parking lot (watch our for cars and buses) far away from ***X-The Extreme*** and measure the angle 1, then move some distance D (the length of your string) closer to ***X-The Extreme*** and measure the angle 2. Show all your work below for determining the height to the top of ***X-The Extreme***.

**Data**

1\_\_\_\_\_\_\_\_\_\_\_ D\_\_\_\_\_\_\_\_

2\_\_\_\_\_\_\_\_\_\_\_ h0 (your height) \_\_\_\_\_\_\_\_\_

**Calculate h1 below**

h1 =\_\_\_\_\_\_\_\_\_\_\_m

Calculate total height H of X-The Extreme

H=\_\_\_\_\_\_\_\_\_\_m Instructor’s Initials\_\_\_\_\_\_\_\_\_

**Colossus – Type A**

**Note: If Colossus is closed, do these measurements for any ride that you are able to get data on during the first drop. I suggest Viper.**

**Purpose** Use the height of the first hill to describe the motion of the car as it drops.

**Data and Evaluation**

**Part 1:** Determine the velocity of the car at the bottom of the hill (vf), using ***each*** of the following methods (assume an initial velocity of zero.):

1. Measure directly: measure the length of the car and the time required for it to pass a point at the bottom of the hill. This is easiest to see from the parking lot, near where we meet the buses. Record in the table below.

|  |  |  |
| --- | --- | --- |
| Length of Train (m) – measured by pacing | Time to Pass Point at bottom of 1st hill (s) | colossus  There are two time measurements:  1. (Record to the left) Measure the time for the train to pass the single point shown with the star at the bottom of the hill.  2. (Record in Part 2) Measure the time for the train to go all the way down the hill as shown by the arrow. |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| Average Time= |  |

Calculate the velocity at the bottom of the first hill.

vf = \_\_\_\_\_\_\_\_\_\_\_\_ m/s

1. Calculate using the conservation of energy.

From the Magic Mountain website, record the height and convert to meters.

Height of first hill in feet: \_\_\_\_\_\_\_\_\_\_\_\_\_\_ ft

Conversion:

Height of the first hill in meters: \_\_\_\_\_\_\_\_\_\_\_\_\_\_ m

Use conservation of energy (gravitational at the top = kinetic at the bottom) to calculate the velocity at the bottom of the first hill

vf = \_\_\_\_\_\_\_\_\_\_\_\_ m/s

Average of the two vf calculations(your answers for A & B):

velocity of the car ***at the bottom of the hill***: vf = \_\_\_\_\_\_\_\_\_ m/s

**Part 2: Find your acceleration during the drop down the first hill.**

Measure the time from the top of the first hill to the bottom: \_\_\_\_\_\_\_\_\_\_\_\_\_ s

Use kinematics equations to CALCULATE your acceleration as you go down the first hill of Colossus. Assume vi (at the top of the hill) is zero and vf is your average from Part 1.

Calculated a = \_\_\_\_\_\_\_\_\_\_m/s2

*During the drop down the hill* (NOT at the bottom of the hill), use the accelerometer to measure your vertical acceleration. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ gs

Convert this to an acceleration in m/s2 by the formula (1 - # *measured gs*)\*9.81

Measured a = \_\_\_\_\_\_\_\_\_ m/s2

# Analysis / Conclusions

How did your calculated acceleration compare to your measured acceleration down the first hill? Describe possible reasons for any difference.

Find a percent difference using the equation

% difference = | calculated value – measured value| x 100%

average value

How close was your measured acceleration down the first hill to true free fall?

% error = | measured value – 9.81| x 100%

9.81

Describe how the ride felt from the top of the first hill to the top of the next hill – where do you feel heavier, lighter, etc.

**Tatsu, Ninja, Viper – Type A**

**Note:** Sometimes lines are long or rides are closed **– you must have at least two of these**

**rides available to do this lab.**

**Purpose:** Calculate the speed on different rides by different methods.

**Data and Evaluation**

**Part 1**

Six Flags lists the total length of the TASTU track as 3,602 feet (about 1,098 m), the total length of the NINJA track as 2,700 feet (about 820 m) and the total length of the VIPER track as 3,830 (about 1,167 m) . Calculate the average speed of the rides by measuring the total ride time (from dispatch to return). Convert your speeds to mph.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Tatsu** | **Ninja** | **Viper** |
| Total Ride Time (s) |  |  |  |
| Speed (m/s) |  |  |  |
| Speed (mph) |  |  |  |

Show work for at least one ride here:

**Part 2: Viper**

Measure the speed of the Viper train at the TOP of each of the first three vertical loops

Pace the length of VIPER train = \_\_\_\_\_\_\_\_\_\_\_\_

Times for train to pass the top of each loop

|  |  |  |  |
| --- | --- | --- | --- |
| **Trial** | **Loop 1** | **Loop 2** | **Loop 3** |
| **1** |  |  |  |
| **2** |  |  |  |
| **3** |  |  |  |
| **Average Time (s)** |  |  |  |

Calculate the speed of the train at the top of each loop. Show work.

Loop 1 v at top = \_\_\_\_\_\_\_\_\_\_\_

Loop 2 v at top = \_\_\_\_\_\_\_\_\_\_\_

Loop 3 v at top = \_\_\_\_\_\_\_\_\_\_\_

### **Part 3: Tatsu**

Compare the speed of Tatsu at the top and bottom of the vertical loop.

Pace the length of Tatsu train = \_\_\_\_\_\_\_\_\_\_\_\_

Times for train to pass the key point

|  |  |  |
| --- | --- | --- |
| **Trial** | **Bottom of Loop** | **Top of Loop** |
| **1** |  |  |
| **2** |  |  |
| **3** |  |  |
| **Average Time (s)** |  |  |

Calculate the speed of the train at each point. Show work.

V at bottom = \_\_\_\_\_\_\_\_\_\_\_

V at top = \_\_\_\_\_\_\_\_\_\_\_

## Analysis/Conclusions

# Part 1

1. Are these speed values what you expected? What factors lead to this speed?

2. Does the average speed calculated really represent the true speed of these rides? Suggest another method to find a better average speed.

**Parts 2 and 3**

3. How does the kinetic energy of the train relate to the speeds you have calculated in these parts of the lab? How is the kinetic energy related to the gravitational potential energy at each part of the loop?

**Superman: Escape from Krypton – Type B**

**Purpose:** Determine the velocity of the car and track efficiency using the conservation of energy.

**Data and Evaluation:**

Use triangulation to determine the full height of the ride (hmax), the *actual* height the cars reach at their highest point (note that the cars don’t reach the full height of the ride) (hactual). Also triangulate the height of the track at its lowest point (hmin). Make sure your triangulations are done from the same place – the pacing needs to be along level ground (head towards Batman if possible).

hmax



Δhcar

hmin

hactual

hmin

hactual

Δhcar

Record your measurements

|  |  |  |  |
| --- | --- | --- | --- |
|  | θ1 | θ2 | D |
| hmin |  |  |  |
| hactual |  |  |  |
| hmax |  |  |  |

Show your calculations for each height.

hmin = \_\_\_\_\_\_\_\_\_\_ hactual = ­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_ hmax = \_\_\_\_\_\_\_\_\_\_\_ Δhcar = \_\_\_\_\_\_\_\_\_\_\_\_\_

How did your estimates and your triangulated heights compare to the “real” heights? The published heights are hactual = 126.5 m and hmin­ = 26.5 m.

Discussion for hactual

Discussion for hmin

# Energy Conservation and Track Efficiency

The Magic Mountain website states that the car reaches 100 mi/hr (44 m/s) before going up the tower. Based on this speed, calculate the maximum height the car should reach using conservation of energy. Note – consider hmin to be your zero height to simplify the problem.

theoretical Δhcar = \_\_\_\_\_\_\_\_\_\_\_\_\_m

How does your theoretical Δhcar compare to your measured Δhcar? Explain why there is a difference.

Use your theoretical and real change in height to calculate the efficiency of the track.

(Eff = measured Δhcar / theoretical Δhcar, then multiply by 100%)

Eff = \_\_\_\_\_\_\_\_\_\_\_%

Using your measured Δhcar , determine the velocity of the car just as it reaches the bottom of the curved path using conservation of energy.

vbottom = \_\_\_\_\_\_\_\_\_ m/s

**Cost**

The mass of an unloaded car is 2300 kg. Count the number of people on a full car and assume that they each have a mass of about 70.0 kg.

**Data:** # People on a single car \_\_\_\_\_\_\_

Total mass of car + passengers

Mass \_\_\_\_\_\_\_\_\_\_\_kg

Calculate the change in kinetic energy of the car from when it’s launched to when it hits its maximum speed of 44 m/s

Change in Ek \_\_\_\_\_\_\_\_\_\_\_\_J

How much does it cost to accelerate a single car from rest to its maximum speed? Assume electricity costs $0.25 per kWh and there are 3.6 x 106 J in each kWh.

Cost $ \_\_\_\_\_\_\_\_

**Analysis/Conclusions**

Does it cost Magic Mountain more money to launch a loaded car or an empty car? Explain.

What did it feel like when you reached the highest point (hactual)?

What did it feel like when you are being launched?

Batman – Type B

h d

θ

**Apparatus**: stopwatch, triangulation device (horizontal accelerometer)

**Objective 1: To calculate the average speed of the Batman train as it travels up the first incline.**

Estimate (your best guess) the height (h) of the first incline.

h \_\_\_\_\_\_\_\_\_\_\_m

**Procedure**:

I - Determine the height of the first incline using the characteristics of the ride or double triangulation. It may help you to know that the height of one of the steps is 0.18 m, if you’re a VERY fast counter! Otherwise, use double triangulation.

II - Determine the angle of the incline by holding the horizontal accelerometer so that the straw is parallel to the surface of the incline and then reading off the angle.

III - Measure the time required for the train to reach the top of the first incline.

**Data**: data for height calculation:

Angle of incline \_\_\_\_\_\_\_\_\_\_degrees Time \_\_\_\_\_\_\_\_s

**Evaluation of Data:**

Calculate height: (describe how you did this and show your work)

Measured height \_\_\_\_\_\_\_\_\_m

Calculate d:

d \_\_\_\_\_\_\_\_ m

Calculate average speed along the hill:

Speed \_\_\_\_\_\_\_\_ m/s

According to Magic Mountain, the height of the hill is actually 32.0 m. How does your measured height compare to the given height of 32.0 m?

**Objective 2: Determine the increase in gravitational potential energy as the train moves from the bottom to the top of the first incline (use the given height of 32.0 m).**

**Procedure:**

The mass of the unloaded train is 9440 kg. Count the number of people on a full train and assume that they each have a mass of about 70 kg.

**Data**: # of people on a single full train \_\_\_\_\_\_\_\_\_

# Analysis / Conclusions

Total mass of train + passengers:

Mass \_\_\_\_\_\_\_\_ kg

Change in gravitational potential energy:

ΔEg \_\_\_\_\_\_\_\_\_\_ J

Determine the kinetic energy of the car (using the speed from above):

Ek = \_\_\_\_\_\_\_\_\_\_\_ J

Determine the total energy of the car at the top of the track by adding the potential energy you just found and the kinetic energy of the car (using the speed from above).

Etot = \_\_\_\_\_\_\_\_\_\_ J

How much does it cost to bring the car from rest at ground level to the top of the first incline at the speed you calculated if electricity costs $0.25 per kWh and there are 3.6 x 106 J in each kWh?

Cost $ \_\_\_\_\_\_\_\_

Estimate (your best guess right after riding) how fast you are moving at the bottom of the first hill.

Estimated speed \_\_\_\_\_\_\_\_\_\_\_\_m/s

Assuming all of the potential energy is converted to kinetic energy how fast would you be moving at the bottom of the first hill?

Calculated speed \_\_\_\_\_\_\_\_\_\_\_\_m/s

According to Magic Mountain the top speed of Batman is 22 m/s. How does this speed compare with your calculated speed and your estimated speed? Was your estimate fairly accurate? Use the calculation below in your discussion.

% error = |calculated speed – given speed| x 100%

given speed

**Dive Devil – Type B**

**Purpose:** Determine the velocity of the diver using the conservation of energy.

**Data and Evaluation:**

Use triangulation to determine the full height of the tower (hmax), the *actual* height the “flyers” reach at their highest point (note that the people don’t reach the full height of the ride) (hactual). Also estimate the height the riders reach at their lowest point (hmin). Make sure your triangulations are done from the same place – the pacing needs to be along level ground.

hmax

Release Point

hmin

hactual

Δhrider

Record your measurements

|  |  |  |  |
| --- | --- | --- | --- |
|  | θ1 | θ2 | D |
| hactual |  |  |  |
| hmax |  |  |  |

Describe how you estimated hmin

Show your calculations for hactual and hmax­.

hmin = \_\_\_\_\_\_\_\_\_\_ hactual = ­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_ hmax = \_\_\_\_\_\_\_\_\_\_\_ Δhrider = \_\_\_\_\_\_\_\_\_\_\_\_\_

How did your estimates and your triangulated heights compare to the “real” heights? The published heights are hactual = 46.6 m and hmin­ = 2 m.

Discussion for hactual

Discussion for hmin

# Energy Conservation and Efficiency

The Magic Mountain website states that the rider reaches 60 mi/hr (26.8 m/s) at the bottom of the swing. Based on this speed, calculate the height from which the rider was dropped using conservation of energy. Note – consider hmin to be your zero height to simplify the problem.

theoretical Δhrider = \_\_\_\_\_\_\_\_\_\_\_\_\_m

How does your theoretical Δhrider compare to your measured Δhrider? Explain why there is a difference.

Use your theoretical and real change in height to calculate the efficiency of the pendulum.

(Eff = measured Δhrider / theoretical Δhrider, then multiply by 100%)

Eff = \_\_\_\_\_\_\_\_\_\_\_%

Using *your measured* Δhrider, determine the speed of the rider just as he/she reaches the bottom of the curved path using conservation of energy.

vbottom = \_\_\_\_\_\_\_\_\_ m/s

**Cost**

The mass of the harness is 25.0 kg. Assume that three people are riding and that they each have a mass of about 70.0 kg.

**Data:**

Calculate the total mass of harness + passengers

Mass \_\_\_\_\_\_\_\_\_\_\_kg

Calculate the change in gravitational potential energy of the pendulum bob (the passengers plus harness) from the ground to its maximum height.

Change in Eg \_\_\_\_\_\_\_\_\_\_\_\_J

How much does it cost to lift a single pendulum bob from the ground to its maximum height? Assume electricity costs $0.25 per kWh and there are 3.6 x 106 J in each kWh.

Cost $ \_\_\_\_\_\_\_\_

**Analysis/Conclusions**

Does it cost Magic Mountain more money to lift one flyer or three? Explain

**Grand Carousel – Type C**

Good physics in a classic gentle ride.

Objective: Examine the centripetal accelerations on the riders of carousel horses.

**Data collected before or after you ride:**

Measure the diameter of the carousel. Describe how you did this.

Measure the radius of the circle made by an outer horse: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_m

Measure the radius of the circle made by an inner horse: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_m

Measure the time for the carousel to complete one rotation: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_s

**Data collected during the ride:**

While riding on an *outer* horse, hold the *horizontal* accelerometer so that the straw is parallel to the ground and points toward the center of the circle. Record the angle. \_\_\_\_\_\_\_\_\_\_\_\_

Convert this to a centripetal acceleration using ac = g tanθ Note that the angle is measured from 0° straight down.

Outer horse ac = \_\_\_\_\_\_\_\_\_\_\_\_\_\_

How does the centripetal acceleration vary with the distance from the center of the ride? Repeat the measurement and conversion for an *inner* horse:

Record the angle: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Inner horse ac = \_\_\_\_\_\_\_\_\_\_\_\_\_

**Calculations:**

Calculate the circumference of the circle made by an *outer* horse: \_\_\_\_\_\_\_\_\_\_\_\_\_

Calculate the circumference of the circle made by an *inner* horse: \_\_\_\_\_\_\_\_\_\_\_\_\_

(show all of your work and any equations used)

Calculate the tangential speed of an *outer* horse: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Calculate the tangential speed of an *inner* horse: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(show all of your work and any equations used)

Calculate the centripetal acceleration of an *outer* horse: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Calculate the centripetal acceleration of an *inner* horse: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(show all of your work and any equations used)

**Conclusion**

Compare the calculated centripetal accelerations to the ones measured during the ride.

Does the outer horse or the inner horse experience a larger tangential speed? A larger centripetal acceleration? Explain using your data.

**The Buccaneer – Type C**

The Buccaneer rocks you back and forth experiencing changes in g-force.

**Problem**: Predict the maximum centripetal force and compare it to the measured g-force. Also compare g forces on different parts of the ride.

**Apparatus**: Stopwatch Vertical Accelerometer

**Procedure**:

I The maximum centripetal force occurs where the velocity is fastest. This is at the bottom of the swing during the part of the ride when The Buccaneer is swinging at full swing.

II The time for the boat to pass the bottom-most point can be measured using a stopwatch. Start timing when one end of the boat passes the bottom and stop timing when the other end of the boat passes the bottom.

III The radius is measured from the top pivot point (point of rotation) to the bottom of the boat. You can determine this by triangulation or by using uniformity in the structure.

IV The length of the boat can be approximated by pacing the length of the deck.

r

.

What acceleration value do you think (estimate) you will measure at the highest and lowest (bottom) points?

Estimated acceleration Top \_\_\_\_\_\_\_\_\_gs Bottom \_\_\_\_\_\_\_\_\_gs

**Data**:

Time for the boat ***to pass bottom*** (**not** the entire swing) \_\_\_\_\_\_\_\_\_\_\_\_ s

Length of boat \_\_\_\_\_\_\_\_\_\_ m

How was this determined?

Measured g-force at the highest point \_\_\_\_\_\_\_\_\_\_ gs

Measured g-force at the bottom \_\_\_\_\_\_\_\_\_ gs

Show how you determined the radius

Radius \_\_\_\_\_\_\_\_\_\_ m

**Evaluation of Data**:

Calculate the velocity at the bottom of the swing.

velocity \_\_\_\_\_\_\_\_\_\_\_\_m/s

Using your mass and the velocity and radius calculated above calculate the centripetal force at the bottom of the swing.

force \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_N

Calculate your weight in Newtons:

weight \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_N

Draw a force diagram showing the two major forces acting on you when you are at the bottom of the swing. Write the equation for Fc in terms of FN and Fg.

Calculate the seat force (normal force) acting on you in Newtons:

force \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_N

Calculate the seat force (normal force) acting on you in terms of g forces:

force \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ gs

# Analysis / Conclusions

What differences did you feel when you were at the top and bottom of the swing?

How does the calculated seat force (normal force) at the bottom of the swing compare with the g-force you measured while on the ride?

Are the maximum g-forces significantly different for riders in different parts of the boat? How do you know?

### **Goliath – Type C**

**Objective** – Determine the g forces on the horizontal loop (helix part) near the end of the Goliath ride and compare the measured and calculated values. The helix is just after the spot that they brake the train to slow it down – it is a full horizontal loop.

**Apparatus** – stopwatch, vertical accelerometer

# Procedure

Stand at the exit of the ride(the long ramp down) where you can clearly see the horizontal loop on the Goliath ride. You need to be near the far end of the bridge for a clear view. Measure the time for one of the trains to complete the first entire loop.

From the same position, measure the time for a train to pass a single point on that loop.

While riding Goliath, measure the g forces on you during the horizontal loop (point the accelerometer toward the center of the circle, and good luck!).

After riding Goliath, pace the length of the train.

# This is the helix loop you are looking for!

# Data

Record the g-force measured on the train during the curve \_\_\_\_\_\_\_\_\_\_\_\_\_ g’s

Record the time for the train to complete ONE loop: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ s

Record the time for the train to pass **one point** on the loop: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ s

Record the number of paces for the length of the train: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ paces

Record your mass in kilograms: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

# Calculations

Calculate the length of the train in meters:

Length \_\_\_\_\_\_\_\_ m

Calculate the speed of the train during the helix loop.

Speed \_\_\_\_\_\_\_\_\_ m/s

Use the speed of the train and the time for the train to complete the loop to calculate the circumference and radius of the loop.

Circumference = \_\_\_\_\_\_\_\_\_ m

Radius \_\_\_\_\_\_\_\_ m

Use your mass, the speed of the train and the radius of the loop to calculate the centripetal force in Newtons you experience on the ride.

Centripetal force \_\_\_\_\_\_\_\_ N

Convert the centripetal force to a g force by dividing by your weight in Newtons.

g force \_\_\_\_\_\_\_\_\_ gs

# Analysis / Conclusions

How did you feel as went through the loop (helix)?

Why do some people lose vision (close to blacking out) at this portion of the ride?

Compare the g force you calculated to the one you measured on the ride. What is the percent difference between the two?

**Wonder Woman: Lasso of Truth – Type D**

Once the Lasso gets spinning, it tips up giving the rider an experience of uniform circular motion in a nearly vertical plane.

**Problem**: To calculate the centripetal acceleration and centripetal force on a rider and compare the calculated values to measured g-force.

**Apparatus**: Stopwatch (Vertical) accelerometer

**Procedure**:

Determine your mass. (You can approximate this by taking your weight in pounds and dividing by 2.2)

The time will be measured with a stopwatch for more than one revolution. Calculate the time for one revolution.

Measure the g-forces when you are on the ride and it is in its most vertical orientation. Note the readings when you are at the top and bottom of the circle. Use the vertical accelerometer and hold it perpendicular to your body, pointing toward the center of the circle.

Determine the diameter of the circle (by pacing from OFF the ride or by circumference on the ride).

**Data**:

Number of rev. timed \_\_\_\_\_\_\_ Total time \_\_\_\_\_\_\_\_s Time for one revolution \_\_\_\_\_\_\_\_\_ s

Accelerometer readings/apparent "g-force" at bottom \_\_\_\_\_\_ at top \_\_\_\_\_\_\_

Data for computation of radius:

**Evaluation of data**

Radius of ride:

Radius \_\_\_\_\_\_\_\_ m

Circumference of circle:

Circumference \_\_\_\_\_\_\_\_ m

Tangential speed of rider (remember v = d/t):

Speed \_\_\_\_\_\_\_\_ m/s

Centripetal acceleration:

Centripetal acceleration \_\_\_\_\_\_\_\_ m/s2

Centripetal force on you:

Centripetal force \_\_\_\_\_\_\_\_ N

Centripetal force in terms of “g”: (divide it by mg)

Centripetal force \_\_\_\_\_\_\_\_ gs

# Analysis / Conclusions

Note that there are two forces always acting on you – gravity and the normal force. We’ll neglect friction and air resistance.

At the top of the ride, gravity acts on you in the same direction as the normal force. Draw a force diagram for you when you're at the top of the ride.

Write the equation for Fc in terms of FN

and Fg. Use the centripetal force (in g)

from above to calculate the normal force

on you for this situation.

Note that the force of gravity is 1.0 g.

At the bottom of the ride, gravity acts on you in the opposite direction from the normal force. Draw a force diagram for you when you're at the bottom of the ride.

Write the equation for Fc in terms of FN

and Fg. Use the centripetal force (in g)

from above to calculate the normal force

on you for this situation.

Note that the force of gravity is 1.0 g.

Compare your calculated values for the normal forces to what you measured on the ride (your G forces).

**The Revolution – Type D**

The Revolution was the first vertical loop ride at Magic Mountain - ride it and enjoy the history…

**Objective 1** : Determine the speed of the train from distance and time measurements.

**Procedure**:

Determine the length of the train and time the passage of the train at indicated points along the path in order to calculate speed. Point A is as you are entering the loop, not leaving it.

B

**Apparatus**: Stopwatch A

**Data**: Describe how you determined the length:

Length of the train: \_\_\_\_\_\_\_\_\_\_\_ m

Time **for the train to pass** points A and B (Note - this is not the time down the hill).

point A: \_\_\_\_\_\_\_\_\_ s

point B: \_\_\_\_\_\_\_\_\_ s

**Calculations**: Speeds at point A and B (show your work)

Speed at point A: \_\_\_\_\_\_\_\_\_\_\_\_ m/s

point B: \_\_\_\_\_\_\_\_\_\_\_\_ m/s

**Objective 2**: Use circular motion to find the forces acting on the rider during the vertical loop.

**Procedure**:

Use the speeds determined in part 1 for the train on the vertical loop.

Measure the g force you experience at the bottom and top of the loop using the vertical accelerometer, held vertically upward (perpendicular to the seat, toward the center of the circle).

Estimate the radius of the loop at the top and bottom.

**Apparatus**: Vertical accelerometer; horizontal accelerometer for triangulation

**Data**:

G forces: at point A \_\_\_\_\_\_\_\_\_\_\_\_\_\_ gs at point B \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ gs

Radius of loop : at point A \_\_\_\_\_\_\_\_\_\_\_\_\_\_ m at point B \_\_\_\_\_\_\_\_\_\_\_\_\_\_ m

How did you determine the radius of the loop?

Even though the actual radius is larger at the bottom than at the top of the loop, the average radius of the loop is 7m - use this value for your calculations.

Your mass (your weight in pounds/2.2) \_\_\_\_\_\_\_\_\_\_\_ kg

Show your work:

# Calculations

Calculate the centripetal force acting on you at the bottom of the loop (point A) and the top of the loop (point B). Use your speed data from the first page.

Show your work:

Fc for point A \_\_\_\_\_\_\_\_\_\_\_\_\_\_ N Fc for point B \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N

Take the values of Fc you’ve just calculated and express them in terms of g. To do this, divide the centripetal force by mg.

Show your work:

Fc for point A (in g) \_\_\_\_\_\_\_\_\_\_\_ Fc for point B (in g) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Analysis / Conclusions

Note that there are two forces always acting on you – gravity and the normal force from the seat. We’ll neglect friction and air resistance.

At the bottom of the loop, gravity acts on you in the opposite direction from the normal force. Draw a force diagram for you when you are at the bottom of the ride.

Write the equation for Fc in terms of FN

and Fg. Use the centripetal force (in g)

from above to calculate the normal force

on you for this situation.

Note that the force of gravity is 1.0 g.

At the top of the loop, gravity acts on you in the same direction as the normal force. Draw a force diagram for you when you're at the top of the ride.

Write the equation for Fc in terms of FN

and Fg. Use the centripetal force (in g)

from above to calculate the normal force

on you for this situation.

Note that the force of gravity is 1.0 g.

Compare your calculated values for the normal forces to what you measured on the ride (the G forces).

**You Choose the Ride Lab Report**

(A.K.A. the lab on the last page)

Name of ride \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Rank (1-10, ten being best) \_\_\_\_\_\_

Favorite part of the ride \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Physics of your favorite part\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Least favorite part of the ride \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Physics of your least favorite part \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Acceleration measurement**

Where is the measurement being made? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

How did you feel at the point where the measurement is to be made? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Measurement value \_\_\_\_\_\_\_\_\_ g’s Value in meters per second per second \_\_\_\_\_\_\_\_m/s/s

Work for conversion

Time of ride \_\_\_\_\_\_\_\_\_\_\_s Time in line \_\_\_\_\_\_\_\_\_\_\_s

Divide the amount of time of ride by the amount of time in line. Report the number with units.

Use a complete sentence to describe what the ratio found in the previous question means.

One word to describe ride \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Recommend to a friend? \_\_\_\_\_\_\_\_\_

METHODS OF TAKINGS MEASUREMENTS

MEASURING ACCELERATIONS

Use the vertical accelerometer to measure the g-forces

experienced on different rides. Accelerometers measure

accelerations by measuring forces. The accelerometer is

calibrated in units of “g”. The unit “g” is related to the 0 g

local acceleration due to gravity. When a person is

standing still on the surface of the earth the accelerometer

should read **1 g**. This means that you are experiencing the 1 g

force of gravity. A reading of 2 g on an accelerometer

does not mean that the gravitational field has increased.

It means that the rider feels a force which is twice the 2 g

magnitude of the rider’s weight, 3 gs equals three times

a person’s weight and so on. The accelerometer reads how

many g-forces you are experiencing at any one time. 3 g

Remember that on a ride you are experiencing both the

force of gravity and the ride forces. When you and the

accelerometer are upside-down, the force of gravity is 4 g

pulling the bob toward the top of the accelerometer, not

down. When the bob rises to the **0 g** mark then you are

in free fall. 5 g

MEASURING DISTANCES

There are several good ways to determine a distance measurement. The best way, may depend on what distance you are trying to measure.

**Pacing** – Pacing is a good way to measure long straight distances. You should determine your pace length before you go to Magic Mountain. You can then pace off lengths at Magic Mountain and determine the total length. For example, if you need to know the length of a train of cars on a roller coaster, you can pace the length of the train on the deck just before you get on or after you get off the ride. Pacing inherently has errors. To help reduce these random errors it is a good idea for each member of your group to pace the length separately and then average the distances.

**Uniformity in Structure -** Another way to estimate distances is to use uniformity in the structure to guide your estimate. It is difficult to accurately estimate large distances; however, small distances (like 1 – 2 meters) can be easily and reasonably estimated. If a structure has a repeating small pattern then you can estimate the length of the small pattern and count how many times the pattern repeats itself throughout the structure.

**Triangulation –** You can use the horizontal accelerometer as a sextant (an angle-measuring device) to aid in measuring the heights of objects that are too tall to measure directly, such as the height of a tall building. You can measure heights with reasonable accuracy with a little trigonometry. The process is outlined below.

**h1**

## H



**h0 h0**

**S**

1. Measure the distance S by pacing it off or using your string. Because of security fences, sometimes is will be difficult to get right up against the ride you are trying to measure the height of. You will need to get as close as possible and then estimate the remaining distance or choose to double triangulate (explained below).
2. Sight through the straw on the top of the sextant to the top of the object you are trying to determine the height of. Measure the angle on the sextant from the middle BB.
3. Measure h0, which represents the height from the ground to your eye level.
4. Calculate h1 using the following equation. h1 = S tan .
5. The total height you are trying to measure, H, is equal to **h0 + h1**.

**Double Triangulation –** Most of the time you will be unable to stand right up against the object whose height you are trying to measure. This will make measuring the distance S very difficult. If you cannot reasonably estimate the distance from the fence to the base of the ride, then you may want to use double triangulation. The method is outlined below.

**h1**

## H

 

**h0**

**D**

Fence blocking your access to the ride

1. Stand as close as you can to the object and measure the angle with your sextant.
2. Pace or measure some distance, D, away from the ride.
3. Measure the shallower angle  with your sextant again.
4. With a little trigonometry, it can be shown that the distance h1 can be found from the following equation.

h1 = D sinsin

sin()

1. The total height you are trying to measure, H, is equal to h0 + h1.

# MEASURING TIMES

Several of the lab activities require you to measure a time, for example, the time it takes the roller coaster to travel from the top of the hill to the bottom. Most of the time, this is best done while you are **not** on the ride. Instead, if you have a good vantage point to view the ride from, measure the time while you are on the ground. This can be done best while you are waiting in line for a ride, or along the exit to the ride after you get off. There are a few circumstances, where you will not be able to view the part of the ride you must time unless you are physically on the ride. In that case, you will have to take the time while you are riding. Use a stopwatch or phone or the stopwatch function on a digital watch.

# OTHER WAYS TO OBTAIN DATA

Some physical data about particular rides can be obtained from other sources as well. One place to check for information about each ride is on the Magic Mountain website. Some of the rides do list specific information, like heights, weights, etc. Be sure the information listed is in fact what you are looking for to complete the lab. Sometimes you may not need the *maximum* height of a ride (such as Superman), but the actual height that the roller coaster car is at. I encourage all of you to visit the website, but be sure you are on the website for the Six Flags in California. Another place you may be able to obtain information about a ride is from the people that work at the park. Let me caution you about this information. Sometimes, a ride technician may know what he/she is talking about, other times, they may flat out be lying to you or giving you false information to sound knowledgeable or to make the ride seem more spectacular than it actually is. Finally, never completely rely on these alternative forms of obtaining measurements. Use them as a backup to check your own measurements or only rely on them when they verify that your measurements are way off. **Remember, it always helps to get as much data as possible to get the most accurate results.**