PHYSICS DAY

Six Flags
DARIEN LAKE

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Physics Day
At
Darien Lake

Introduction

Welcome to physics day at DARIEN LAKE. We hope that you will have a great day EXPERIENCING PHYSICS.

This booklet has been prepared for you to measure and determine quantities that underlie the physics of amusement parks. Your teacher should have discussed the methods of measurements that you will be making.

The booklet is arranged with the opening section of a ride containing space for measurements and observations that you should take before, during, or after the ride. These measurements will be referred to in the calculation sections for each ride.

The rides are arranged in the book according to their general location in the park. The first are located near the entrance and picnic pavilions and the last are located near the Viper and Mind Eraser. A map/brochure is available at the front gate if needed.

Page numbers have been included at the bottom of each page, and an index to the rides included in this booklet is given on the next page for your convenience. You will find the formulas used in the calculations in the FORMULA SHEET found at the back.

This year we have provided an ANSWER KEY which should be used as a reference as answers may vary. Different answers should be discussed and any feedback to help improve the workbook is welcomed. Please contact your sales representative with this feedback.

We hope that you will have a good time EXPERIENCING the PHYSICS that you have learned in class. The amusement park is a great place to learn as well as have fun.

Enjoy your day.

PHYSICS DAY

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BASIC FACTS YOU WILL NEED OFTEN:

YOUR MASS (m): _______________ kg

YOUR WEIGHT (w = mg): __________________ N

THE LENGTH OF YOUR FOOT: ___________ m

PHYSICS CONCEPTS

To the student:

Your physics teacher will discuss with you the expectations for your class on Physics Day.
While the rides are designed for you to experience physics in a safe way, not everyone can participate in these experiences directly. Nevertheless, there are plenty of readings and measurements that can be made from a distance, and so you can still learn many things by careful observation. All measurements should be made in MKS notation: distance measurements are made in meters, mass measurements in kilograms, and time measurements in seconds. The key that accompanies this booklet uses this notation system as well.

As you have studied physics this year, you have covered a number of topics, ideas, and concepts that have to do with motion, forces, and circular motion. Below is a list of physics ideas or concepts that you probably have studied that are demonstrated by rides in the park.

1. **Kinematics:** The study of motion. (Velocity, acceleration, relative motion)
2. **Vectors:** Addition and Resolution of forces, velocities, displacements.
3. **Momentum/Force:** Impulse, F = ma, conservation of momentum.
4. **Power:** Time rate of doing work. (Rate of using energy)
5. **Friction:** An extension of the electromagnetic force. It usually is thought of as resisting motion, but is often necessary for accelerated motion (*e.g.* sitting on a bench on the Carousel as it is moving)
6. **Energy:** Potential, Kinetic, Conservation of mechanical energy.
7. **Circular motion:** Centripetal force, horizontal circles, periodic motion.
8. **Vertical Circles:** Circular motion in a vertical plane.

As you work your way through the park and go on the rides, keep these ideas in mind. You should cover as many of the concepts as you can or are instructed to. The chart on the next page will help you to figure out what rides will cover what concepts. Most of the rides duplicate some of the concepts. As you get information on a ride, check off the concept boxes at the top of the concept chart for that ride.

When you have all of the boxes checked, you will know that you have experienced all of the concepts listed above.

CONCEPT TABLE

Fill in the chart below as directed.

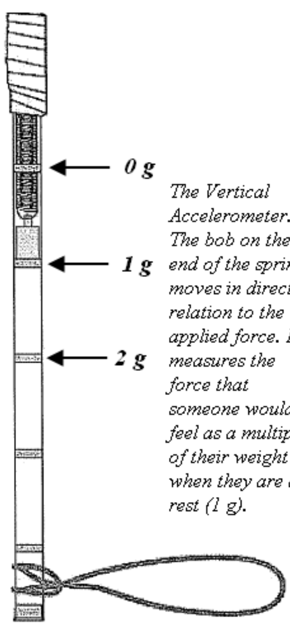
Concept Covered Ride Name	Kinematics	Vectors	Momentum	Power	Friction	Energy	Circular	Vertical Circles	Harmonic Motion
The Slingshot				√		√			
Predator	√			√		√			
Ride of Steel	√				√	√			
Lasso		√					√		
Carousel		√			√		√		
Sky-Coaster					√	√	√	√	√
Boomerang	√	√				√			
Silver Bullet		√					√	√	
Bumper Cars	√		√				√		
Pirate						√	√	√	
Motocoaster	√			√		√			
UFO					√		√	√	
Viper	√					√	√	√	
Mind Eraser				√		√			

SENSING SENSATIONS

We do not sense velocity as well as we sense acceleration. We use a variety of our own senses to determine if we are in motion, but motion itself is a very relative thing. We can be in motion in a bus or car moving at constant speed, yet if we close our eyes, the only sense of motion may come from the sound of an engine or of the tires against the road. Even the observation of being "at rest" is deceptive because none of us is ever truly at rest. We are always moving with the earth which always turns on its axis at a speed of 258 m/s at the latitude of Darien Lake (43º). We don't notice this at all, but we certainly would if the earth suddenly changed its speed!

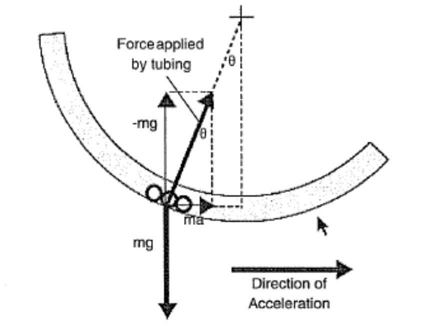
Our bodies have sensors that can detect changes in motion in the absence of visual cues. Chief among these are the semi-circular canals, which help us to distinguish up from down, to determine when we are falling, and even when we are moving in circular motion. These built-in accelerometers are important to maintain our balance and to protect us in the event of a change in motion such as a sudden fall or a slip that causes unbalanced forces to act on our mass.

Throughout the year, you've studied motion by observing carts on tracks, or by solving problems in which you might imagine that you are in a car, or some object moving through space. At Darien Lake you get to be a part of the experiment and experience firsthand the forces and sensations that accompany changes in motion that can be disorienting at times. For example, you feel heavier in an elevator that is accelerating upward, not because gravity is acting differently, but because the sum of the forces in your reference frame are playing tricks on your senses. On an amusement ride your eyes may tell you that you are upside down, but you may feel as if you are sitting normally in a seat. A handy way to gauge this feeling is to measure your acceleration with the use of a vertical accelerometer.



The Vertical Accelerometer. The bob on the end of the spring moves in direct relation to the applied force. It measures the force that someone would feel as a multiple of their weight when they are at rest (1 g).

The vertical accelerometer that you may be carrying can be calibrated to a number of scales, but the most straightforward is to use a scale that measures your acceleration as a multiple of the acceleration due to gravity (g). If you hold the accelerometer when you are "at rest" in the vertical direction, the mass should be hanging at a mark that essentially reads $1g$. If you are in "freefall," then the mass moves close to the zero mark and you feel weightless. On the other hand, if you are being accelerated upward at values higher than g, the mass will move to the marks below where the mass hung when you were "at rest." Each successive mark represents a multiple of the acceleration due to gravity. These can come under various names like "g's" or force factors, but the idea is essentially the same. Finally, it's important to note that the vertical accelerometer can only obtain useful readings when the length of the tube points toward the center of the earth and the mass can move freely through the tube without sliding. This limits its effectiveness to just two directions: "up" and "down."



The Horizontal Accelerometer. The beads in the tube move in direct proportion to the acceleration. The acceleration is determined by observing the angle the beads make with the vertical

The horizontal accelerometer is used for the other directions, and is particularly useful for studies in circular motion. If the horizontal accelerometer is used correctly, the acceleration can be determined my measuring the angle that the small beads make inside the tube with respect to the vertical. The acceleration can be determined by the formula:

$$a = g\tan\theta.$$

The vertical and horizontal accelerometers give us useful measurements, but all devices have their limitations and we must be always mindful of whether or not the data we record from them is obtained properly.

RIGHT NOW you feel a force on your bottom exactly equal to your weight as the seat supports you. With an accelerometer reading GREATER than 1, you FEEL HEAVIER than normal and feel pressed into the chair. When the reading is LESS than 1, you FEEL LIGHTER than usual and can feel as if you are almost floating out of the chair.

At a given point on a ride, everyone, regardless of mass, experiences the acceleration.

On a certain ride a 50-kg girl is being pushed with a vertical force of 1500 Newtons.

(a) What is her accelerometer reading?

If we round *g* (Acceleration of Gravity) off to 10 m/s^2; she weighs 50-kg x 10 m/s^2 = 500 Newtons.

$$\text{Accelerometer reading} = \frac{\text{Force being applied}}{\text{Weight}} = \frac{1500\ \text{N}}{500\ \text{N}} = 3$$

(b) If her friend weighs 120 pounds, what force in pounds is her friend feeling?

They will feel the same acceleration. This time, the number we were given is the person's weight. Her normal weight is 120 pounds, but she is experiencing an acceleration that is three times g, and is therefore feeling a force of 3 times her normal weight.

The force on her must be 3 x 120 pounds = 360 pounds.

<u>YOUR TURN, SHOW YOUR WORK</u>

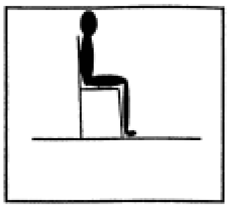
An 80-kg boy is on a ride where he is feeling a force of 2000 Newtons.

What is his accelerometer reading?

reading = __________

What force will his 500 N friend experience?

Force = _______ Newtons



The figure to the left represents you in a chair. Identifying forces that act on you can be complicated and confusing. Newton's Laws can make predictions on the motion of objects provided that the forces on the object can be isolated. The free-body-diagram is a device that allows you to reduce a complex object down to a simple dot that has the same mass as the object under study (*i.e.* you in a chair). Ideally, the position of the dot is at the center of mass, which would be near the back of the seat. From the dot, we can show the magnitude and direction of all forces acting on the object with vector arrows.

1. Show the magnitude and direction of the force the chair is exerting on you.

2. Now, assuming that you are standing up, show the size and direction of the force the ground is exerting on you.

   On what part of your body is the force exerted?

3. If you are lying on the ground. Show the size and direction of the force that the ground is exerting on you.

   On what part of your body is the force exerted? Is the force exerted in just one place?

4. If you are upside down and strapped into a chair, show the size and direction of the force that keeps you from falling out.

What is exerting this force and on what part of your body is it exerted?

CONSCIOUS COMMUTING

As you ride to Darien Lake, be conscious of some of the PHYSICS on the way.

A. STARTING UP

<u>THINGS TO MEASURE:</u>
As the bus pulls away from a tollbooth or stop sign, find the time (*t*) it takes to go from rest to 40.0 miles per hour. You will have to put someone up front to help.

t = __________s

<u>THINGS TO CALCULATE:</u> always show equations used and substitutions

1. Convert 40.0 miles per hour to meters per second (1.00 mph = 0.447 meters/second).

v =_________________

2. Find the acceleration (*a*) of the bus from rest. ***a*** = __________

3. Using your mass in kilograms and Newton's Second Law, find the average forward force (*F*) on you as the bus accelerates from rest.

F = __________

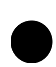
4. Is this force greater or less than the force gravity exerts on you (*i.e.* your weight).

5. Calculate the force that you felt as a multiple of *g*. (NOTE: the number has no units)

multiple = _________________

<u>THINGS TO NOTICE AS YOU RIDE:</u>

1. As you start up, use the free-body-diagram to identify the forces acting on you as you accelerate forward.



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

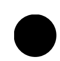
3. How can you explain the difference between what you feel as the bus starts up and what a stationary observer sees? (You may want to use FRAMES OF REFERENCE)

B. GOING AT A CONSTANT SPEED

<u>THINGS TO NOTICE:</u>

1. Describe the sensation of going at a constant speed on a straight road. Do you feel as if you are moving?

   Use the free-body-diagram to illustrate the forces acting on you when you travel on a bus at constant speed.



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

C. ROUNDING CURVES

<u>THINGS TO NOTICE:</u>

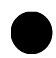
1. If your eyes are closed:

   a. How can you tell when the bus is rounding a curve?

   b. What do you feel when you are seated facing forward when the bus is rounding a curve?

c. What do you feel when you are seated with your back against the side of the bus when the bus is rounding a curve?

2. Before the bus starts around a curve, concentrate on a tree or a building that is directly in front of you. From the law of inertia, you know that your body should continue straight ahead unless an unbalanced force acts on it. See if you can sense the force that causes you to go around the curve.
   a. Use the free-body-diagram to illustrate the forces acting on you when you are rounding a curve.



   b. If the turn was tighter (smaller radius), how would the force be different?

   c. How is this force applied to your body? Consider:

      (*i*) the friction of the seat

      (*ii*) your seat mate

      (*iii*) the wall

      (*iv*) the arm of the seat

      (*v*) a combination of these? Explain:

THE SLINGSHOT

DATA:

Maximum height on first launch: 80.1 m

MEASUREMENTS AND OBSERVATIONS TO MAKE:

1. Average time for slingshot to reach the top after launch = ________ t_1

________ t_2

________ t_{ave} ________ t_3

2. Count the number of springs inside the box behind the riders.____________________

CALCULATIONS and OBSERVATIONS:

1. Calculate your potential energy at the maximum height.

PE = ________________

2. Calculate the average power required for you to reach this height.

P = ________________

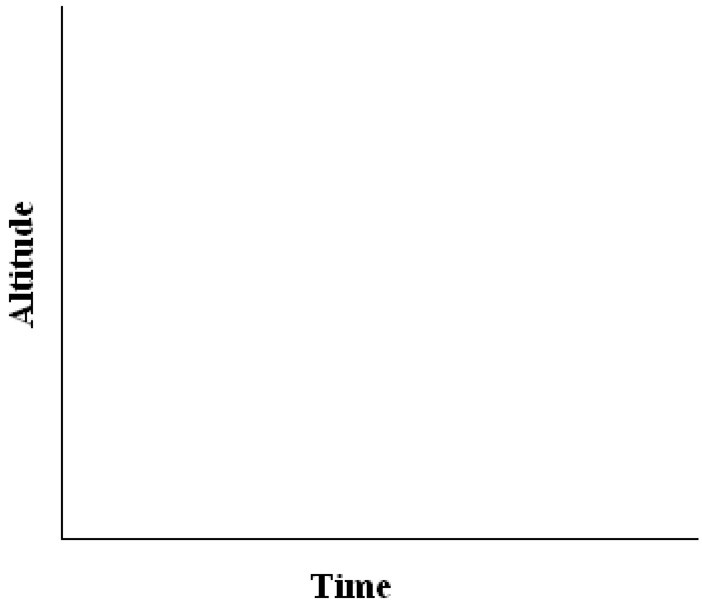
3. How many 100 watt light bulbs could be powered during this launch?

\# = ________________

4. What is the purpose of the springs behind the riders?

5. Are the springs arranged in series or in parallel? What is the advantage of this arrangement?

5. In the space below sketch a graph of altitude as a function of time. Is there a period of time during the ride when the acceleration can be described as constant or not constant? Identify these on your graph and explain why.



6. Observe several launches of the Slingshot and watch what happens to the springs and the support towers as the cage with the riders is prepared for launch. Are the springs the only place where energy is stored? Explain.

THE PREDATOR

MEASUREMENTS:

Height of first hill = 21.3 meters

Angle of first hill, θ = ____________°

Time up first incline = ___________s

Length of train = __________m

Measure the following times as you watch the train pass a support tower:

Gate at top: t = _______s

first hill at the bottom: t = ______s

OBSERVATIONS:

1. If the work necessary to get to any height is independent of the path taken, 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?

CALCULATIONS:

1. What is your gravitational potential energy (PE) at the top of the first hill?

(PE_{top}) = _________________

2. How much power (P) is used to get you up the first hill? P = _______________

3. What is your speed at the top of the first hill?

$\boldsymbol{v}_{top}$ ________________

4. What is your kinetic energy (KE) at the top of the first hill?

KE_{top} ______________

5. Calculate the speed at the bottom. $\boldsymbol{v}_b$ = ________

6. What your kinetic energy at the bottom of the first hill?

(KE_b) _______

7. How much energy was "lost" to friction? Energy "lost" = $(PE_{top}+KE_{top})-KE_b$ ____________

8. Was energy conserved (within errors)? Explain.

THE RIDE OF STEEL

DATA:

Height of tallest hill = 63.1 m

MEASUREMENTS TO MAKE:

Length of train = ________________m

Time for train to pass a fixed support near the top of the first hill = ________s

Angle of descent for tallest hill = _____________

Time for train to pass a fixed support at the bottom of the first hill = ________s

CALCULATIONS

1. Determine your gravitational potential energy at the top of the first hill.

PE_T = ________________

2. Determine your velocity near the top of the first hill (before you accelerate downward).

$\boldsymbol{v}$ = __________________

3. Determine your kinetic energy at the top of the first hill.

KE_T = ________________

4. Determine your total mechanical energy at the top of the first hill ($KE_T + PE_T$).

E_T = _________________

6. Determine the normal force acting on you as you descend the first hill.

$\boldsymbol{F}_N$ = ________________

7. Determine the velocity at the bottom of the first hill.

$\boldsymbol{v}$ = __________________

8. Determine your kinetic energy at the bottom of the first hill.

KE_B = ______________

9. Assuming that the total mechanical energy at the bottom consists entirely of kinetic energy, what percentage of the total mechanical energy was lost?

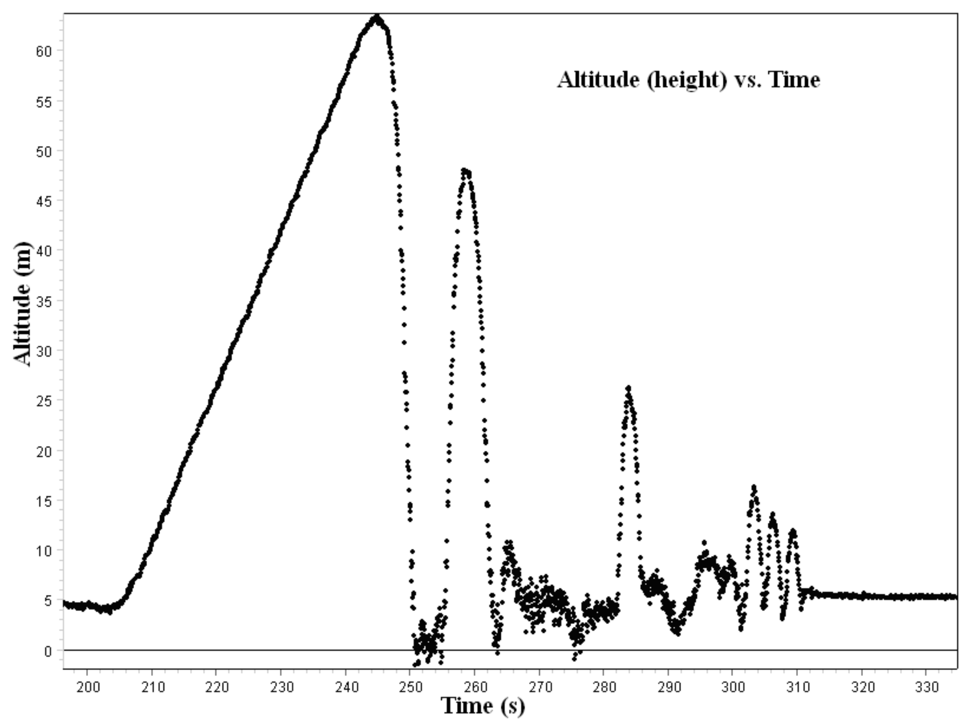
Use: $\frac{E_T - KE_b}{E_T} \times 100$

% = ________________

OBSERVATIONS

1. When a person is in a gravity field, what circumstances might produce a sensation of weightlessness?

Below is a graph of the height (altitude) of the Ride of Steel as a function of time.



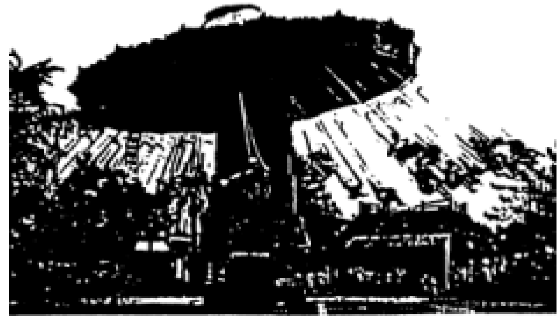
2. Identify at least three locations on the ride where you would likely feel weightless.

3. Why are remaining hills lower than the first hill?

4. From the figure above can you speculate how weightlessness is produced inside an aircraft?

LASSO

In this ride the vertical and horizontal force meters are used. To get both readings safely, you can share the data collection responsibilities with a partner, or ride the Lasso twice, holding a different force meter each time. Make sure that you hold the vertical force meter perpendicular to the ground. Hold the horizontal accelerometer with the long axis of the card pointing toward the center of the ride.



DATA:

Radius of ride at top speed: 5.41 m.

MEASUREMENTS TO MAKE:

Time for 5 revolutions at top speed t = ___________

PERIOD T = _____________

Maximum angle chain makes with the vertical. θ = _____________ °

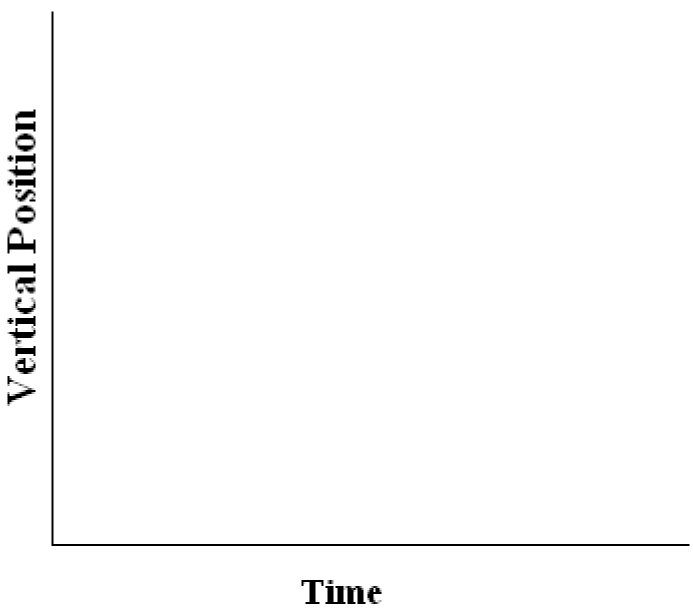
Maximum vertical force meter reading (F_{max}) _________________

Minimum vertical force meter reading _________________

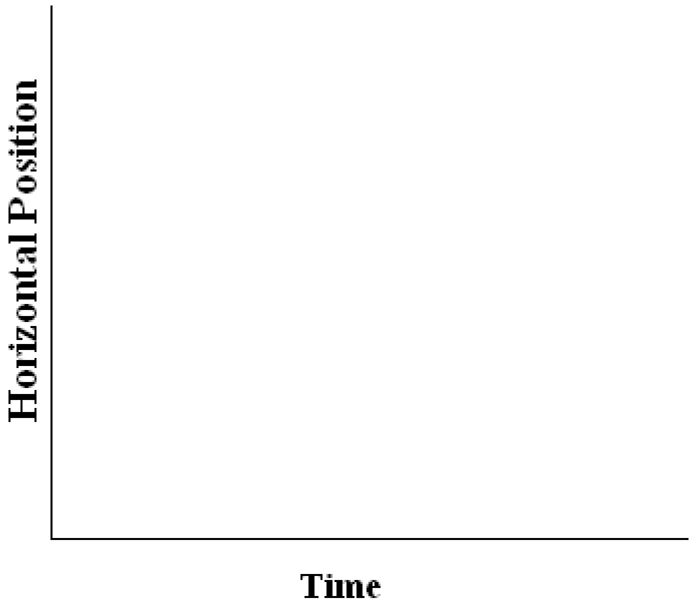
Maximum horizontal force meter reading: θ =_________________ °

OBSERVATIONS:

1. In the space below, sketch a graph of your vertical position with time. Label on the graph where the vertical force meter reading is highest and lowest.



2. In the space below, sketch a graph of your horizontal position (*x* or *y*) with time.



3. Are the readings of the horizontal force meter consistent with your diagram above? Explain.

4. How do the force meter readings relate to how you feel on the ride?

<u>CALCULATIONS:</u>

1. Calculate the maximum speed of the swings: $\boldsymbol{v}$ = _______________

2. Calculate the centripetal force acting on you: $\boldsymbol{F_c}$ = _______________

3. Calculate the vertical component of the tension (T_v) in the chains by multiplying your weight by the maximum reading on the vertical force meter ($T_v = F_{\max} \times W$):

   $\boldsymbol{T_v}$ = ____________

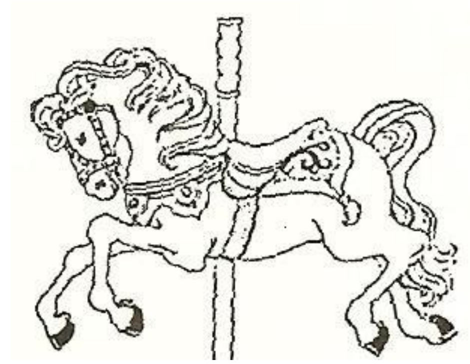
4. In the space below, draw a free body diagram identifying the forces acting on you when the vertical force meter has its highest reading.

5. Calculate the minimum required tension (T_m) in the chains at this point.

$T_m = \sqrt{F_c^2 + T_v^2}$ **T_m** = ______________

CAROUSEL

The Carousel can be thought of as a spinning disk that is divided into equal parts or sectors. If you know the distance of the outer edge of one sector, you can determine the circumference of the carousel by multiplying the length of a sector edge by the number of sectors.



DATA:

Distance of inner horses from center = 3.08 m

Distance of outer horses from center = 4.62 m

MEASUREMENTS AND READINGS TO MAKE:

Number of sectors________________

Distance of the outer edge of one sector ________________

Period of the carousel at top speed. ______________

As the ride is in operation, spend a few moments and observe qualitatively the readings of your **vertical** and **lateral** **force meters**. Note specifically how the readings change with time.

CALCULATIONS AND OBSERVATIONS:

1. Compute the circumference of the Carousel using the gathered sector data.

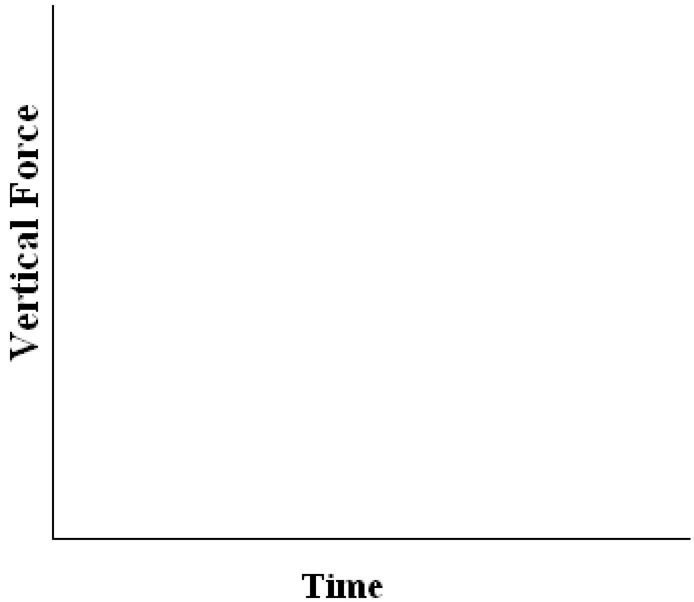
   C = _______________

2. Compute the radius of the Carousel from the computed circumference.

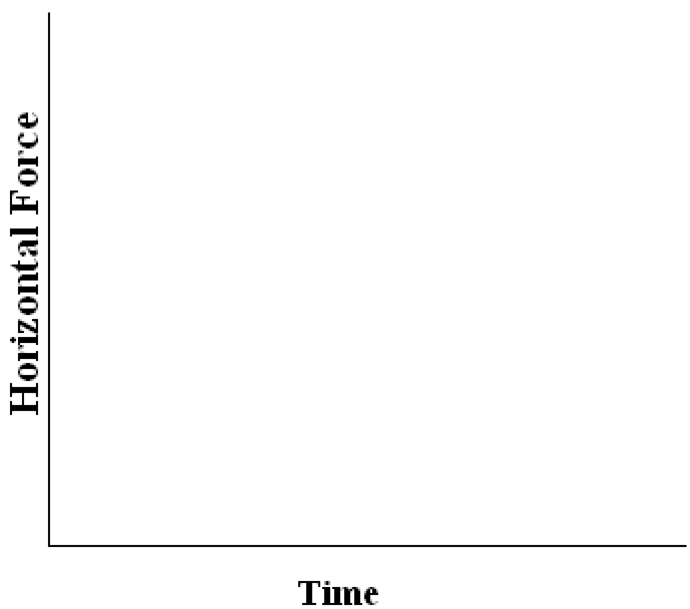
   r = ________________

3. From your measurements, compare the radius of the carousel with the distance of the outer horse from the center. Are these numbers in agreement? Explain.

4. Below is a graph of **<u>vertical force</u>** vs. **<u>time</u>**. From your vertical force meter observations, draw a graph showing qualitatively how your readings changed with time. Label on the graph where the horse is at its lowest and highest positions.



5. Below is a graph of **<u>horizontal force</u>** vs. **<u>time</u>**. From your horizontal force meter observations, draw a graph showing qualitatively how your readings changed with time if any change was noted.



6. As the ride is in motion, how would the horizontal force meter reading on an inner horse compare with that on an outer horse?

7. Calculate the average maximum speed of an outer horse.

$\boldsymbol{v_c}o$ = _______________

8. What is the average maximum speed of an inner horse?

$\boldsymbol{v_c}i$ = ________________

9. Calculate the centripetal force acting on you when you ride an outer horse.

$\boldsymbol{F_c}o$ = _______________

10. Calculate the centripetal force acting on you when you ride the inner horse.

$\boldsymbol{F_c}i$ = _______________

11. If a quarter was placed on the outer edge of the carousel, what would be the minimum coefficient of friction (μ_s) necessary to keep the quarter in its place without slipping?

$$\mu_s = \frac{v_c o^2}{gr}$$

μ_s = ________________

12. If the same quarter is placed at the radius of the inner ring of horses, what would be the minimum coefficient of friction (μ_s) necessary to keep the quarter in its place without slipping?

$$\mu_s = \frac{v_c i^2}{gr}$$

μ_s = ________________

13. Would the coefficients that you calculated in #11 and #12 be different for a greater mass? Explain.

THE SKY COASTER

DATA:

Height of riders before the first drop: 52.1m

MEASUREMENTS TO MAKE:

Period of swing near end of ride: T_o = ____________

CALCULATIONS and OBSERVATIONS:

1. Calculate your potential energy (PE) at the top of the Sky Coaster just before the first drop.

PE = ___________________________

2. Assuming no air resistance, or any other non-conservative force, what will be your kinetic energy at the bottom of the first drop.

KE = ____________________

3. From your kinetic energy calculation, determine your ideal speed at the bottom of the first drop.

v = ______________________

4. Use the free body diagram below to identify the forces acting on you just before the cable is released.

5. Use the free body diagram below to identify the forces acting on you at the instant the cable is released.

6. Use the free body diagram below to identify the forces acting on you at the bottom of the first swing.

7. Compare the free body diagrams in #4 and #5 and explain why you might feel weightless at the instant the cable is released.

8. From #6, write a Newton's 2nd Law formula that accounts for all of the vertical forces acting on you at the bottom of the first swing.

9. Assuming that the motion at the bottom of the swing is uniform circular motion, calculate the net force acting on you by the upward force of the cables (T_b)

$\boldsymbol{T}_b$ = _______________

10. Assume that you are riding with two friends who have the same weight as yourself. Calculate the upward force of the cables (T_c) on the three of you at the bottom of the first drop.

$\boldsymbol{T}_c$ = _______________

11. The two cables on the Skycoaster are capable of withstanding a force up to 80,000 N 40,000 N each) before they fail. What multiple of your like-weighted trio could safely ride on the Skycoaster at once (assume a minimal horizontal component to the tensions in the cable).

multiple = ______________

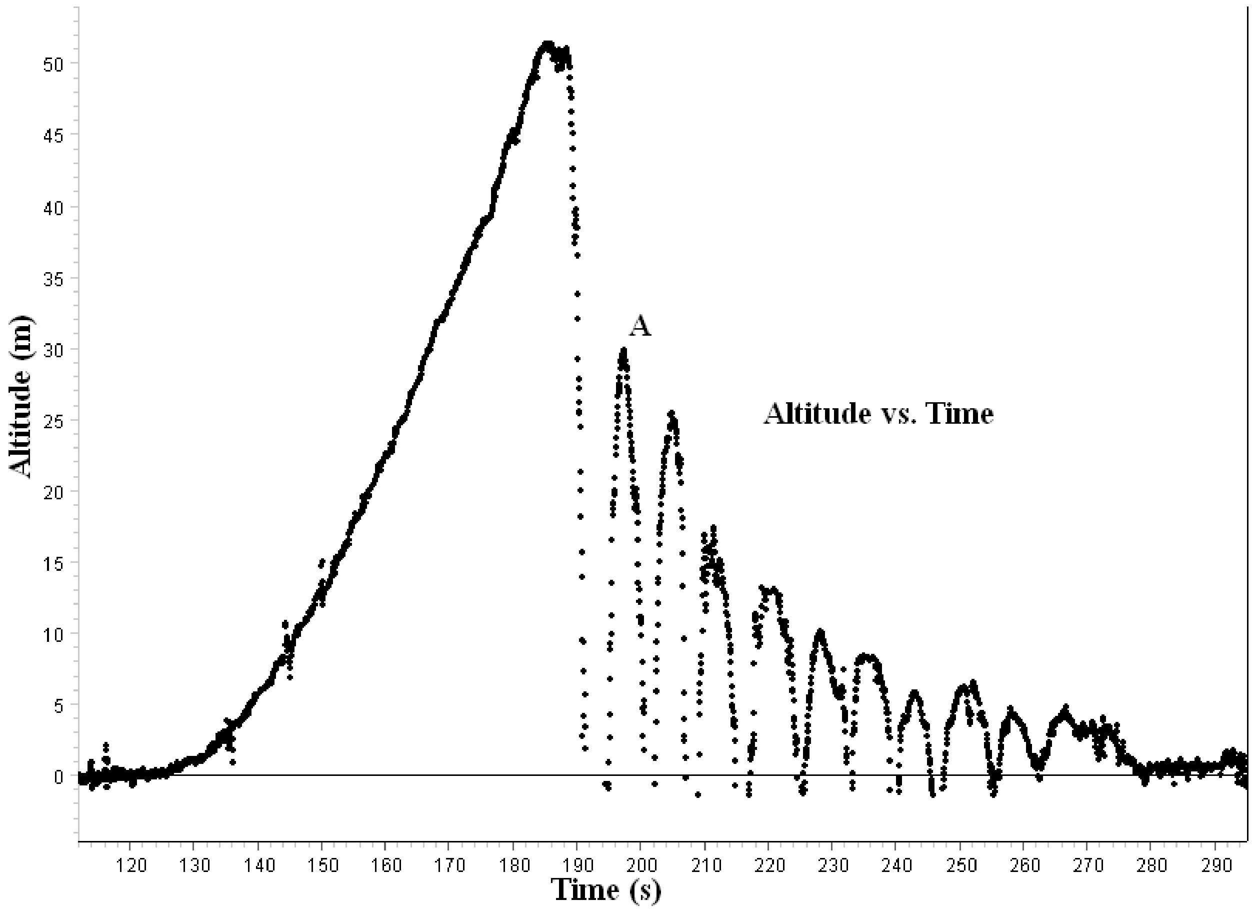
12. Near the end of its swings, the Sky Coaster appears to behave as a simple pendulum. Given the length of the cables, calculate the period (T_s) of the Sky Coaster near the end of its swings.

T_s = ____________________

13. Calculate the percent difference from your observed value: $\frac{T_s - T_o}{T_s} \times 100$

Percent difference = ___________________

13. The figure below shows a graph of altitude vs. time during a ride on the Sky Coaster. Use the graph to determine whether your calculated value of the period agrees with the value of the period determined from the graph.



Is there reasonable agreement? Explain.

14. From the figure above, determine your kinetic energy at the bottom of the 1st swing assuming all of the kinetic energy that you have is converted into potential energy when you reach the next highest altitude (labeled **A** on graph).

v = ______________________

15. How much of the total mechanical energy is lost between the top and the bottom of the first swing?

THE BOOMERANG

DATA:

Radius (R) of first loop = 8.4 m

MEASUREMENTS TO MAKE:

Length (L) of train = _______________m

Number of cars in train = _______________

Angle (θ) of primary incline ______________°

Estimate the length of the ramp (to the nearest tenth) from the bottom to the center of the train just before it is released (C) in terms of a multiple of one train length (this number has no units).

____

Time for train to pass a fixed support at the bottom of the first hill = __________________s

Time for train to pass a fixed support at the top of the first loop = ______________s

Vertical force meter reading just as you enter the first loop (F_b). _______________

Vertical force meter reading at the top of the first loop (F_t). _____________

CALCULATIONS:

1. Determine the distance (D) that the train climbs up the ramp (= CL)

D = _______________

2. Determine the height (h) of the center of mass of the train (use $h = D\sin\theta$)

h = ________________

3. Determine your potential energy (PE) at the top of the first hill.

PE = ______________

4. Calculate the normal force acting on you as you descend the first ramp. (Use $Mg\cos\theta$)

$\boldsymbol{F}_N$ = _______________

5. Calculate the normal force acting on you as you enter the first loop (= $F_b \cdot mg$).

$\boldsymbol{F}_N$ = _______________

6. Determine your speed at the top of the first loop.

v = ________________

7. Determine your kinetic energy at the top of the first loop.

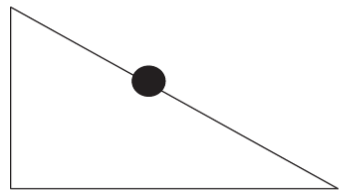
KE = _______________

8. Determine the normal force acting on you at the top of the first loop (= $F_t \cdot mg$).

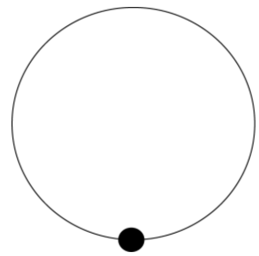
$\boldsymbol{F}_N$ = _______________

OBSERVATIONS:

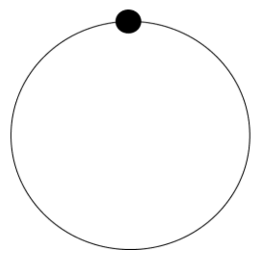
1. Using the free body diagram below, label the forces acting on you as you descend on the first ramp.



2. Using the free body diagram below, label the forces acting on you at the bottom of the first loop (ignore friction).



3. Using the free body diagram below, label the forces acting on you at the top of the first loop(ignore friction).



4. Write a Newton's Second Law equation that describes your acceleration at the top of the loop.

5. According to the equation, can you be "weightless" and still make it around the top of the loop? Explain.

6. Explain why the force meter readings are not zero at the top of the first loop.

7. After you finish the first series of loops, you ascend the ramp and you are "assisted" to the top of the incline before you make the return trip. Why is this necessary?

8. Would any of the free body diagrams that you completed above be any different for the return trip? Explain.

SILVER BULLET

DATA:

RADIUS OF RIDER’S SEAT AT TOP SPEED $r = 6.15$ m

MEASUREMENTS TO MAKE:

Time for 5 rotations at top speed $t =$ ________________

PERIOD AT TOP SPEED $T =$ ________________

OBSERVATIONS:

1. Use the free-body diagram to identify the magnitude and direction of the forces acting on the rider when the ride is at rest.

2. Use the free-body diagram to identify the magnitude and direction of the forces acting on the rider when the ride is rotating horizontally.

3. Use the free-body diagram to identify the magnitude and direction of the forces acting on the rider when the ride is rotating vertically and the rider is at the **top** of the loop.

4. Use the free-body diagram to identify the magnitude and direction of the forces, acting on the rider when the ride is rotating vertically and the rider is at the **bottom** of the loop.

CALCULATIONS:

1. Calculate the top speed of the car. v = ________________

2. Calculate the force that the seat exerts on YOU (F_T) when you are at the **top** of the vertical loop.

   $\boldsymbol{F}_T$ = _______________

3. Calculate this force as a multiple of your weight. multiple = ________________

4. Calculate the force that the seat exerts on YOU (F_B) when you are at the **bottom** of the vertical loop.

   $\boldsymbol{F}_B$ = _______________

5. Calculate this force as a multiple of your weight. multiple = _______________

6. From the value calculated in #2 at the top of the ride, explain why riders do not FEEL as if they are falling out of their seat.

BUMPER CARS

This is your chance to take your frustrations out on other people. Apply Newton's Laws to your fellow students!

<u>MEASUREMENTS TO MAKE:</u>

You will need to determine the top speed of the cars. Use the length of your foot to get a rough estimate of the length of one car. As you stand next to a car walk off one car-length by touching the heel of one foot to the toe of the next. If you know the length of your foot, you can estimate the length of a car. Use a stopwatch to measure the time it takes for the length of one car to pass a fixed point. Be sure to make your velocity measurements on cars that are not colliding. Then time several cars to determine the average velocity.

Length used for speed determination 1 = _________

Times used for speed determination t_1 = _______ t_2 = _______ t_3 = _________

<u>OBSERVATIONS:</u>

1. When a person hits a car at rest, describe the motion of the car doing the hitting.

2. Describe how Newton's Third Law applies to cars?

3. Of the following three measurements, which one is closest to the length of a bumper car? *The correct answer **<u>is</u>** the actual length of a bumper car* (Compare to your estimate and circle your choice).

a.) 1.85 m b. 1.17 m c.1.46 m

<u>CALCULATIONS:</u>

1. Calculate the top speed (v) of an average car. Use an average of your times.

v = _______________

2. Calculate your momentum if you were in that car.

$\boldsymbol{p}_{\text{initial}}$ = __________

3. If you hit another car such that your final speed was 0.100 m/s, what would be your final momentum?

$\boldsymbol{p}_{\text{final}} =$ ______________

4. How much of your momentum was transferred to the other car?

$\boldsymbol{p}_{\text{transferred}} =$ ______________

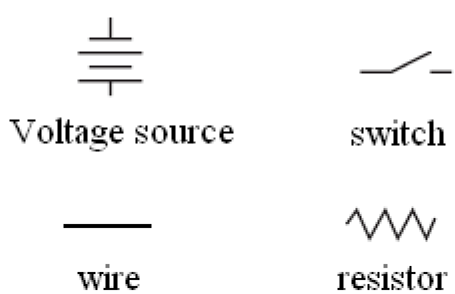
5. Assume that the collision takes place in a time of 0.1 second. Determine the magnitude of the force on you.

$F =$ _________________

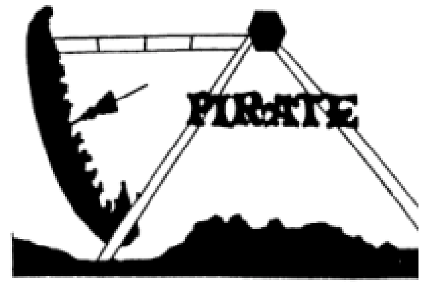
6. If there was no rubber bumper on either car, how would that affect the time of collision and the force on you?

7. Why are you more likely to break a bone falling on concrete than on soft grass even though you hit the ground at the same speed?

8. The bumper cars are powered by electricity. If each car is represented as one resistor, use the symbols below to draw an equivalent circuit representing the operation of four cars.



THE PIRATE



DATA:

Radius of swing = 13.1 m

Maximum vertical rise during a swing = 6.04 m

MEASUREMENTS TO MAKE:

Vertical force meter reading at the top of a swing __________

Vertical force meter reading at the bottom of a swing __________

OBSERVATIONS:

1. The Pirate appears to behave as a simple pendulum. Why is this assumption incorrect?

2. Where in the swing is the normal force on you the greatest?

3. Where in the swing is the normal force on you the least?

4. Do you ever feel weightless? Do your force meter readings support this observation?

5. A common experiment is to hold a penny in your hand to see if it floats upward. Based on your response to the previous question, explain why the penny is likely to stay in your hand or float upward?

6. Use the free body diagram below to identify the forces acting on you at the top of the swing.

7. Use the free body diagram below to identify the forces acting on you at the bottom of the swing.

CALCUATIONS:

1. Your force meter measures acceleration as a multiple of g (= 9.81 m/s^2). Convert your reading for the bottom of the swing to acceleration in m/s^2.

$\boldsymbol{a}$ = ______________________

2. In a separate experiment on this ride using a digital accelerometer, the value of the acceleration of an observer was found to be 16.1 m/s^2. What is the percent difference of your value in #1 from this reading?

% difference = _______________

3. Despite the differences in values from 1 and 2, both values are measures of the normal force acting on you at the bottom of the swing. Now consider the free body diagram above in Observation diagram 7. Write a Second Law equation to describe the forces acting on you at the bottom of the swing.

4. From this equation, and assuming uniform circular motion, calculate the speed (v_t) of the Pirate at the bottom of its swing. Draw an arrow representing the direction of the velocity in Observation diagram 7.

$\boldsymbol{v}_t$ = ______________________

THE MOTOCOASTER

DATA:

The Motocoaster goes from rest to 14.4 m/s (v_b) in 3.06 seconds.

MEASUREMENTS:

Length of train ___________

Time for Motocoaster to pass a fixed point on the highest portion of the track. t = _____________

CALCULATIONS:

1. What is the average acceleration of the Motocoaster from rest?

$\boldsymbol{a}$ = _______________

2. What is the average force on you during this time?

$\boldsymbol{F}$ = _______________

3. How far (d) does the Motocoaster travel during this time?

d = _______________

4. What is your kinetic energy when you reach maximum speed at the start of the ride (calculate from v_b)?

KE_b = _____________

5. What is your velocity at the highest portion of the track?

$\boldsymbol{v}_t$ = _______________

5. What is your kinetic energy at the highest portion of the track?

KE_t = _____________

6. If all of your kinetic energy can be converted into potential energy, what is the maximum height to which you can ascend if your speed is 15 m/s?

h = _______________

7. From your answers to questions 4 and 5, estimate the height of the highest portion of the track (assume minimal loss of energy due to friction). ($KE_b - KE_t = mgh$)

h = _______________

<u>QUESTION:</u>

The Motocoaster seats 6 rows of 2 people and can perform 20 runs per hour. If there are 150 people waiting in line in front of you, how long will you have to wait for your ride?

t = _______________

THE VIPER

<u>Note:</u> The Viper begins its run with a descent to the base of the first hill. The place where the Viper begins to climb is considered as the point at which the Viper has zero potential energy. In other words, from the rider's perspective, this is the ground level. All height measurements are given relative to this point.

<u>DATA:</u>

Height of plateau just before the first drop = 29.3 m

Height at bottom of first drop = 6.9 m

Maximum height of first loop = 23.7 m

<u>MEASUREMENT:</u>

Length of train (determine while waiting) Length = ________________m

Measure the following times as you watch the train pass a reference point:

Along the plateau before the first drop: t = ______________s Bottom of hill: t = ________s

Top of first loop: t = ______s

<u>FORCE-METER READINGS</u>

Bottom of first hill (Point A in figure on p. 48) _________

Top of loop (Point B in figure on p. 48) ________

<u>OBSERVATIONS</u>

1. Where does your meter read closest to zero? Do you feel weightless at this point?

2. Where does the meter give a maximum reading? Why is it a maximum here?

<u>CALCULATIONS</u>

1. What is your potential energy along the plateau? PE = ______________

2. Calculate the speed at the top of the first hill. v_t = ______________

3. What is your kinetic energy along the plateau? KE_t = ______________

4. What is your total mechanical energy at the top of the plateau? E_Tt = ______________

5. Calculate the speed at the bottom of the first hill. v_b = ______________

6. What is your kinetic energy at the bottom of the first hill? KE_b = ______________

6. Calculate the speed at the top of the first loop. v_l = ______________

7. What is your kinetic energy at the top of the first loop? KE_l = ______________

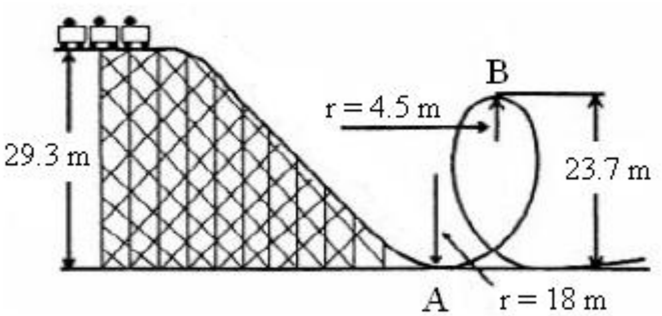
8. What is your total mechanical energy at the top of the loop? E_Tl = ______________

9. Find the percent difference between the total energy at the top (E_Tt) and the total energy at the top of the loop (E_Tl). Within experimental error, was energy conserved? Explain your answer.

% difference = ___________________

THE VIPER PART 2

THE LOOP



CALCULATIONS:

USE YOUR INFORMATION FROM PART 1 OF THE VIPER TO ANSWER THE FOLLOWING QUESTIONS.

1. From your vertical force meter readings, calculate the normal force the track exerts on you at the bottom of the hill at point **A**

$\boldsymbol{F}_{NA}$ = ___________

2. From your vertical force meter readings, calculate the normal force the track exerts on you at the top of the hill at point **B**.

$\boldsymbol{F}_{NB}$ = ______________

3. From your velocity calculations in **Part 1**, calculate the normal force acting on you at the bottom of the loop (Point A). Use $F_b = \dfrac{mv_b^2}{r_b} + mg$

$\boldsymbol{F}_b$ = _______________

4. From your velocity calculations in **Part 1**, calculate the normal force acting on you at the top of the loop (Point B). Use $F_t = \dfrac{mv_b^2}{r_b} - mg$

$\boldsymbol{F}_t$ = _______________

5. Calculate the percent difference between the calculated value of the normal force at the top of the loop (F_t) and the value obtained from the vertical force meter reading (F_{NB}).

$$\% \text{ difference} = \frac{F_t - F_{NB}}{F_t} \times 100 \ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

5. Calculate the percent difference between the calculated value of the normal force at the bottom of the loop (F_b) and the value obtained from the vertical force meter reading (F_{NA}).

$$\% \text{ difference} = \frac{F_b - F_{NA}}{F_b} \times 100 \ = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

6. As you ascend the loop between points A and B, what happens to the magnitude and direction of the centripetal acceleration? Do either of these quantities remain constant during the ascent?

THE MIND ERASER

DATA:

Length of first hill = 54.7 m

Angle of incline of first hill = 29.3°

MEASUREMENTS:

Time to climb first hill: *t* = _______s

Length of train (determine while waiting) length = ______m

Measure the following times as you watch the train pass a support tower:

Support at bottom of first drop: *t* = ______s First loop at top: *t* = ______s

VERTICAL FORCE-METER READINGS:

Top of first hill ______ Bottom of first hill ______

OBSERVATIONS:

1. Where does the meter give a maximum reading? Why here?

2. Describe the motion of the hair of someone in front of you as you go through a roll.

3. Is the acceleration down the first hill uniform? Explain.

4. Where along the ride, if anywhere, might the acceleration be uniform?

CALCULATIONS:

1. To what height do you climb as you ascend the first hill?

h = ______________________

2. What is your average speed up the first hill? $\boldsymbol{v}_{ave}$ = ____________________

3. What is your kinetic energy at the top of the first hill?

KE_T = ___________________

4. What is your potential energy at the top of the first hill? PE = ____________________

5. What is your total mechanical energy at the top of the first hill?

E_T = _____________________

6. What power was used to lift you to this height? P = ______________________

7. What is the average force that was exerted on you to climb the first hill?

$\boldsymbol{F}$ = _____________________

8. Find the percent difference between the average force and the force component due to gravity (mg sinθ).

$$\% \text{ difference} = \frac{F - mg\sin\theta}{F} \times 100 \ = \text{ ____________}$$

9. The percent difference should be small. Why?

10. What is your speed at the bottom of the first hill? $v =$ ______________

11. Calculate your kinetic energy at the bottom of the first hill? $KE_b =$ ______________

12. Relative to where you started the ride, your potential energy at the bottom of the first hill is zero. Therefore the value that you calculated in #11 is also equivalent to the total mechanical energy. Calculate the percent difference between the energy calculated in #5 and #11.

$$\%\ \text{difference} = \frac{E_T - KE_b}{E_T} \times 100 \ = \text{______________}$$

12. Was energy conserved? Explain.

FORMULA SHEET

USE THESE FORMULAS FOR YOUR CALCULATIONS

ACCELERATION	$a = \frac{v_f - v_i}{t}$
AVERAGE VELOCITY	$V_{ave} = \frac{\text{distance}}{\text{time}}$
CENTRIPETAL FORCE	$F_c = \frac{mv^2}{r}$
CIRCUMFERENCE	$2\pi r$
CIRCULAR VELOCITY (or tangential speed)	$v_c = \frac{2\pi r}{T}$
CONSERVATION OF ENERGY	$KE + PE =$ **constant**
IMPULSE	$J = \Delta p = F\Delta t = m\Delta v$
KINETIC ENERGY	$KE = \frac{1}{2}mv^2$
MOMENTUM	$P = mv$
NORMAL FORCE AT BOTTOM OF A VERTICAL LOOP	$F_b = F_c + mg$
NORMAL FORCE AT TOP OF A VERTICAL LOOP	$F_t = F_c - mg$
NORMAL FORCE (CALCULATED FROM ACCELEROMETER READING)	$F_N = \text{reading} \cdot mg$
POTENTIAL ENERGY	$PE = mgh$
POWER	$P = \frac{W}{t} = \frac{F \cdot d}{t} = Fv_{ave}$
PERIOD OF PENDULUM	$T = 2\pi\sqrt{\frac{l}{g}}$
WEIGHT	$F_{\text{g}} = mg$

THANK YOU FOR

ATTENDING

PHYSICS DAY

AT DARIEN LAKE!